From: Georgia Acevedo
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F. 1 Testimony
Date: Tuesday, October 5, 2021 10:01:06 AM

Testimony to the Board of Land & Natural Resources

REJECT Oahu Aquarium FEIS Item F.1

October 5, 2021

I am writing to urge the Board to **reject** the EIS for failing to adequately address the environmental, cultural, and socio-economic impacts as required by HEPA. I am a resident of Windward Oahu who unfortunately has witnessed the toll to our fish populations by commercial aquarium fish collectors in the past. The Final EIS is flawed in so many ways, that if accepted will not only allow this devastation to restart but will greatly increase the danger to our fragile environment. These are some of the reasons to reject the EIS:

--[if !supportLists]-->1.   <!--[endif]-->The EIS data on estimated fish populations is, according to NOAA, “marginal” to “terrible.”

--[if !supportLists]-->2.   <!--[endif]-->The EIS refers to fish populations as “possibly being underestimated” without discussing that they could be overestimated, (according to the NOAA team). This could result in the possibility of wiping out entire species in one area.

--[if !supportLists]-->3.   <!--[endif]-->The EIS proposes levels of take that far exceed historical reported data.

--[if !supportLists]-->4.   <!--[endif]-->The Cultural Impact Assessment stated substantial prohibited areas, yet NO prohibited areas are proposed in the EIS.

--[if !supportLists]-->5.   <!--[endif]-->The EIS proposes no enforcement or compliance measures even though DLNR requested that, and numerous collectors have been charged with poaching.

I could list many more facts and issues that show how inadequate, improper, and damaging acceptance of this EIS would be to our state, our fish populations, and therefore our citizens not only now but into the future. Please REJECT the EIS.

With Aloha,

GA

Windward Oahu

Please Accept Aquarium EIS

My name is Kimo Adams and I am a kanaka maoli with deep roots in Kāneʻohe. I have followed the aquarium fish controversy for years because I have two good friends that used to make a modest living selling aquarium fish that they caught. I consider them both lawaiʻa and kilo iʻa (fish watchers) because they were in the Bay every day paying attention to what's going on. They caught some small fish that we don't eat, and when I went with them we always went back to the same few places, which made me think it is sustainable. Baby fish were constantly coming into the reefs.

We have a lot of threats to our Bay, but I believe aquarium fishing has a relatively tiny impact compared to food fishing, runoff of mud and chemicals from land, and impacts from boats of locals and high numbers of tourists.

Diversified fishing keeps alive Hawaiian traditions. Thanks for considering our Hawaiian values and not bowing to mainland people promoting their own agenda with a problem that scientists agree doesn't exist.

Mahalo for your time,

Kimo Adams
45-245 William Henry Road
Kaneohe HI 96744
808-232-8534

Department of Land and Natural Resources
Aha Moku Advisory Committee
State of Hawaii
Post Office Box 621
Honolulu, Hawaii 96809

Hawaii State Aha Moku Response
To the Board of Land and Natural Resources (Land Board)

For the meeting of the Land Board

October 8, 2021
Honolulu, Hawaii

Agenda Item F-1: Determination of whether the Final Environmental Impact Statement (FEIS) complies with applicable law and adequately discloses the Environmental Impacts of Proposed Issuance of Commercial Aquarium Permits and Commercial Marine Licenses for the Island of O'ahu, for the purpose of accepting the FEIS; dated August 20, 2021, Applicant Pet Industry Joint Advisory Council (PIJAC); Island of O'ahu, State of Hawaii.

Aloha Chairperson Case and Honorable Members of the Land Board,

On behalf of the Aha Moku participants, members of Native Hawaiian generational families of the ahupua'a that encompass Kakuhihewa (O'ahu), we ask the Board to **Reject** the O'ahu Aquarium Collection FEIS for the issuance of 15 aquarium permits and commercial marine licenses for failing to meet the legal requirements of HEPA and the corresponding Cultural Impact Analysis (CIA).

The FEIS proposes take of 461,190 fish from 31 fish species and 1,002,975 invertebrates from 4 invertebrate species by 15 collectors over 5 years on O'ahu. This amounts to nearly 1.5 million species being removed from our island's reefs and oceans. This cannot be allowed!

While the sheer number of specific instances of noncompliance of applicable laws within the FEIS are shown in other testimonies such as the Earth Justice, we focus on one critical law. The FEIS clearly does not comply with the applicable Kapa'akai O Ka'Aina Hawaii Supreme Court Law (Kapa'akai). For any Cultural Impact Analysis to be completed, the petitioner – in this case, the PIJAC, must complete the Kapa'akai O Ka Aina[1] Analysis.

The Kapa'akai Analysis is used in determining whether traditional and customary practices would be impacted by petitioners

Findings of Fact and Conclusions of Law of the Kapa'akai Case

- Identification and scope of "valued cultural, historical, or natural resources" in petition or impacted area, including the extent to which traditional and customary native Hawaiian rights are exercised in the petition area;
- The extent to which those resources, including traditional and customary native Hawaiian rights, will be affected or impaired by the proposed actions;

[1] Ka Pa'akai O Ka'Aina v. Land Use Commission, State of Hawai'i, 2000, Supreme Court of Hawai'i

- The feasible action, if any, to be taken to reasonably protect native Hawaiian rights if they are found to exist.

The petition area in this case are all the marine coastal and ocean areas of the entire Island of O'ahu. These ocean and coastal areas have traditionally and continue to be used for cultural practices that would be seriously and critically impacted by this flawed Environmental Impact Statement with a Cultural Impact Analysis that is fundamentally wrong.

In order to comply with Kapa'akai, the petitioner (PIJAC) should have consulted with the generational families of each of the 88 ahupua'a that comprise O'ahu. Each one is distinct in its cultural practices in coastal areas, deeper ocean, land, wetlands and mauka summits. No generational practitioner from any specific ahupua'a was consulted. Even within the public notice that was put into the Ho'olaha Lehulehu article in July 2019, no practitioner from any specific ahupua'a was notified. In the table below, the 88 traditional ahupua'a listed are attached to the ocean and have coastal traditional practices. Not one was consulted who is a lawai'a or cultural generational practitioner.

Mokupuni O Kakuhihewa (Island of O'ahu)

Mokupuni	Moku	Ahupua'a
Moku O Kakuhihewa (O'ahu)	Kona	*Moanalua, Kahauiki, Kalihi, Kapalama, Honolulu, Waikiki, Waialae, Wailupe, Niu, and Kuliouou.* (10)
	Ewa	*Honouliuli (Puuloa and Kapolei), Hoaeae, Waikele, Waiawa, Waipio, Waimanao, Manana, Waiau, Waimalu, Kalauao, Aiea, Halawa*(12)
	Waianae	*Nanakuli, Lualualei, Waianae, Makaha, Keaau, Hikilolo, Makua, Kahanahaiki, and Keawaula.*(9)
	Waialua	*Kapaeloa, Punanue, Kuikuiloloa, Lauhulu, Kawailoa, Paalaa, Kamananui, Mokuleia, Aukuu, Kihahi, Kawaihapai, Kealia, and Kaena.*(13)
	Koolauloa	*Waimea, Pupukea, Paumalu, Kaunala, Wailelea, Pahipahialua, Opana, Kawela, Hanaka'oe, Oio, Ulupehupehu, Punaluu, Kahuku, Keana, Malaekahana, Laiewai, Laiemaloo, Kaipapau, Hauula, Makao, Kapeke, Papaakoko, Haieaha, Kaiaha, Puheemiki, Waioho, Punaluu, Kahana, Makaua, Kaawa (30)*
	Koolaupoko	*Maunalua, Koko, Waimanalo, Kailua, Mokapu, Kaneohe, Heeia, Kahaluu, Waihee, Kaalea, Waihole, Waikane, Kakipuu, and Kualoa.*(14)

<u>Summary</u>

Mokupuni (Island)	Moku (District)	Ahupua'a
Moku O Kakuhihewa (O'ahu)	6	88

Aha Moku Foundation

The Hawaii State Aha Moku (Aha Moku), via Act 288, SLH 2012 brings the voices of the native Hawaiian generational and lineal descendants forward to the Hawaii State government in issues that impact their traditional and customary practices within natural and cultural resources. Working within a traditional resource sustainability process restored from the 9th century through translations of ancient chants and mo'olelo, the Aha Moku focuses on three main principles:

- Malama Ke Akua (Honor God)
- Malama I Ka'Aina (Honor the Land)
- Malama Na Iwi Hanau O Ka 'Aina (Honor the people of the land)

These three principles are critical to the testimonies and generational knowledge of the native Hawaiians who continue to practice customary beliefs within their ahupua'a, and in this case, the entire coastal area and marine waters of the island of O'ahu.

The people are comprised of their beliefs and are themselves an integral part of the natural resources and cannot be separated from them because the Akua, the land and the people are one. They are the whole entity and not separate compartments. In this traditional protocol, the Kupuna of the 'Ohana, with their life experience, generational knowledge and wisdom are the guardians of their family knowledge and customs. This belief system is often not comprehended within the western thought process, yet it is the core of Hawaii State constitutional protection of the traditional and customary practices (TCP) of Hawaii.

We do not believe that the FEIS complies with the Kapa'akai Hawaii Supreme Court Law. Its CIA is an insult to the native Hawaiian culture and its practices – all of which are protected by the Hawaii State Constitution. But most importantly, this petitioner, as shown by this faulty FEIS does not understand the core of the people of Hawaii. There is no mention of how they will give back to the people of Hawaii – the Public Trust through which native Hawaiians are included. We believe PIJAC only sees opportunities for monetary profit in this endeavor.

For these reasons, we ask that the Land Board **REJECT** the FEIS!

Respectfully yours,

Kawaikapuokalani Hewett, Ka Mea Ho'okumu
Hawaii State Aha Moku
808-382-6043
kahalelehua@outlook.com

Rocky Kaluhiwa, Kahu Nui O Kakuhihewa
Hawaii State Aha Moku
808-286-7955
Rockykaluhiwa1122@gmail.com

Leimana DaMate, Luna Alaka'i/Executive Director
Hawaii State Aha Moku
808-640-1214
Leimana.k.damate@hawaii.gov

October 6, 2021

Members of BLNR

Testimony in support of Agenda Item F-1. Determination of whether the Final Environmental Impact Statement (FEIS) complies with applicable law and adequately discloses the Environmental Impacts of Proposed Issuance of Commercial Aquarium Permits and Commercial Marine Fishing Licenses for the Island of O'ahu, for the purpose accepting the FEIS; dated August 20, 2021. Applicant Pet Industry Joint Advisory Council (PIJAC); Island of O'ahu, State of Hawaii.

The testimony that follows is in my personal capacity as a Commercial fisherman with more than 30 years of experience both above the surface as well as below, including five years as a Commercial Aquarium Fisherman. As a Native Hawaiian fisherman I have more than 50 years of cultural fishing experience continuing the traditions of our Kupuna. My wife, Melva Aila who is a co-author of this testimony has an equal amount of Commercial and Cultural fishing experience.

Relative to the submittal title, we strongly agree with DAR Staff's recommendation to the Land Board that it does. The preferred alternative, inclusive of a very limited proposed white list of species of fish allowed to be collected, a limit of 15 permits, and the very conservative proposed daily individual catch limits, mitigate any impacts to sustaining these species populations.

In addition, the combination of large, closed areas such as Pearl Harbor, Kaneohe Marine Base Hawaii, several Marine life conservation Districts, many Fishery Management Areas around O'ahu. The many days of strong tradewinds, making fishing impossible on the windward side of the Island. A deep-water reserve beyond the 150 feet depth, which is out of the range of most of the 15 potential permitted fishermen, all make for an extremely conservative fishing situation and minimal take that provides an additional layer of confidence of sustainability.

We have read the Cultural Impact Assessment and the testimony of Native Hawaiians who oppose but, cannot understand how allowing 15 permitted aquarium fishermen with the restrictions of a limited species white list, conservative daily individual catch limits, weather imposed fishing restrictions, and a significant deep water reserve, will result in any over fishing of species that will result in harm to cultural practices.

A fish that is eaten, chopped up for palu (chum), used for bait, or is offered as ho'okupu (an offering), or placed in aquarium is no longer available for spawning. The FEIS provides analysis and indicates that the preferred alternative results in a sustainable fishing practice.

None of the proposed white listed species are commonly caught fish to be offered in ceremony. Having stated this, if a Kahu of a ceremony decides that a white listed species is required for a ceremony on O'ahu, then the preferred alternative is likely to result in it remaining available through a sustainable fishing practice.

Not all Native Hawaiian families willingly identify the species that is their family Aumakua and not all members of a species of fish are Aumakua. It would be impossible unless someone came forward and identified an individual of white listed species as Aumakua, to analyze cultural impacts and mitigation measures in that situation. To date no one has disclosed this concern.

In summary, the three criteria for acceptance pursuant to HAR 11-200-23(b) listed below has been met.

1) The procedures for assessment, consultation process, review and the preparation and submission of the statement, have all been completed satisfactorily as specified in this chapter.
2) The content requirements described in this chapter have been satisfied.
3) The comments submitted during the review process have received responses satisfactory to the accepting authority, or approving authority, and have been incorporated in the statement.

We strongly urge the Members of the Board of Land and Natural Resources to vote in acceptance of the Final Environmental Impact Statement.

Mahalo for the opportunity to provide testimony. Take care, be safe, and mahalo for your service!

William J. Aila Jr. and Melva N. Aila
Ailaw001@hawaii.rr.com
86-630 Lualualei Homestead Road
Wai'anae, Hawaii 96792
PH# 808-330-0376

From:	Crystal Alexander
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Re: Agenda item F.1
Date:	Wednesday, October 6, 2021 12:32:10 AM

Dear Hawai'i BLNR:
Re: Agenda item F.1

I oppose the Environmental Impact Statement as invalid, and illegitimate, and in disregard of the Hawai'ian culture as ruled by the Supreme Court of the State of Hawai'i. The Pet Industry Joint Advisory Council prepared the document seeking permits on behalf of 10 individuals. The Board of Land and Natural Resources has the discretion and authority to prevent the issuing of aquarium permits" through the Hawai‘i Constitution.

The claim of "sustainability" has been used for too long, at the expense of Hawai'i public trust, for the benefit of commercial interests. The aquarium trade only takes reef wildlife from Hawai'i and leaves nothing. People around the world have Hawai'i in their hearts and spend a billion dollars annually on reef activities that take nothing from the reef. Hawai'ian reef wildlife should remain in the waters of Hawai'i, not in glass tanks globally.

Sincerely,
Crystal Alexander
Scuba Instructor
Reef Wildlife Lover

From:	Geri Allison
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Item F1
Date:	Saturday, October 2, 2021 5:32:08 AM

Aloha decision makers,
Please reject the environmental impact statement regarding the collection of aquarium fish in Hawaii. I am a Hawaii resident who values the fragile nature of our coral reeves and ocean ecosystems. It is up to us to protect what we have for future generations.
Mahalo Nui Loa,
Geri Allison
Kailua-Kona, HI

Sent from Yahoo Mail for iPhone

From: Javier Amores
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Re: Agenda item F.1
Date: Wednesday, October 6, 2021 3:16:42 AM

Dear Hawai'i BLNR:
Re: Agenda item F.1

I oppose the Environmental Impact Statement as invalid, and illegitimate, and in disregard of the Hawai'ian culture as ruled by the Supreme Court of the State of Hawai'i. The Pet Industry Joint Advisory Council prepared the document seeking permits on behalf of 10 individuals. The Board of Land and Natural Resources has the discretion and authority to prevent the issuing of aquarium permits" through the Hawai'i Constitution.

The claim of "sustainability" has been used for too long, at the expense of Hawai'i public trust, for the benefit of commercial interests. The aquarium trade only takes reef wildlife from Hawai'i and leaves nothing. People around the world have Hawai'i in their hearts and spend a billion dollars annually on reef activities that take nothing from the reef. Hawai'ian reef wildlife should remain in the waters of Hawai'i, not in glass tanks globally.

Sincerely,
Javier
Reef Wildlife Lover

From:	cathyg@animalrightshawaii.org
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda item F. 1 testimony
Date:	Wednesday, October 6, 2021 6:06:12 PM

On behalf of our many supporters throughout Hawai'i, I ask that the BLNR reject to latest version of the EIS submitted by PIJAC. Coral bleaching and the disappearance of herbivorous fishes pose an existential threat to the health of our oceans and our island home. Keep Hawaiian fishes in Hawaiian waters where they belong!

ARH has been advocating for Hawai'i's animals and environment since 1977. As a fifty year resident of Hawai'i, I have noticed the degradation of our shorelines, increased water pollution and diminution of marine life. You have the opportunity to end the destructive aquarium trade and allow our reefs to rebuild. Please reject the EIS proposed by PIJAC.

With aloha,

Cathy Goeggel

President
Animal Rights Hawai'i
1511 Nu'uanu Ave. Unit 173
Honolulu, HI 96817
808.721.4211

From: lance arakaki
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Oahu tropical fish EIS
Date: Monday, October 4, 2021 7:19:45 PM

ALCON,
I, Lance A. Arakaki, support the Oahu Tropical Fish EIS, Environment Impact Statement. We are a sustainable and model fishery. NOA AND DLNR supports the EIS. Aloha

Sent from my iPhone
V/R,
Lance A Arakaki

From:	Sofia Arreguin
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] protect Oahu"s reefs
Date:	Tuesday, October 5, 2021 3:45:52 PM

To whom it may concern,
PLEASE REJECT the fatally flawed environment impact statement proposing to reopen Oahu's reefs to the destructive aquarium pet trade! Hawaii and it's natural heritage need to be protected. It should be illegal to remove wildlife to sell as pets.
Thank you
Sofia Arreguin

From:	Leslie Awana
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] EIS
Date:	Tuesday, October 5, 2021 10:12:44 AM

Aloha,
My name is Leslie Ac Awana Jr I am Hawaiian and Was born and raised on the Leeward coast of Oahu.
I am writing this Email because I am in full support of this EIS, as a Local Born Hawaiian I learned to fish and grow my food, I also learned the importance of Malama not only for the land but for the ocean as they both provide food, medicines, and other necessities necessary to sustain life.
I firmly believe that both fishing and farming play essential part in our culture and that balance and sustainability can be achieved with the help of DLNR.

Mahalo,
Leslie Ac Awana Jr.

From:	Emily Bagley
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] AGENDA ITEM F.1 - I appose the EIS for Aquarium extraction
Date:	Monday, October 4, 2021 7:12:35 PM

Hello!

I am a resident of Kaimuki and oppose the EIS you are reviewing on 10/8. Please protect our endemic marine life and deny aquarium extraction on Oahu.

Thank you,

Emily Bagley
651 11th Ave, Honolulu, HI 96816
808-306-1591

From:	Leanne Baker
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL]
Date:	Thursday, October 7, 2021 8:30:52 AM

Please do not allow the capture of exotic fish from Hawaii. The survival rate is abysmal and fish are intelligent, complex creatures who do not deserve a life trapped in an Aquarium, which is boring and unstimulating. I would far rather enjoy the opportunity of seeing them in their natural habitat in the beautiful waters of Hawaii.

From: Bonnie Bee
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Chris Yuen & et al addendum ~ "NO" ~ AGENDA Item F.1
Date: Wednesday, October 6, 2021 6:30:15 AM

Please vote "No" on Proposed (EIS) Environmental Impact Statement
AGENDA ITEM F.1 Proposal for allowing
Aquarium Trade on O'ahu

ALOHA 'Aina

Ua Mau Ke 'Ea O Ka 'Aina I Ka Pono

MAHALO Loa ! ! !

P.S. See Below Testimony of 'Ohana

From: Bonnie Bee <recallbherenow@hotmail.com>
Sent: Wednesday, October 6, 2021, 6:10 AM
To: blnr.testimony@hawaii.gov
Subject: Chris Yuen & ALL ~ "NO" ~ AGENDA Item F.1

PO Box 30848
Anahola HAWAI'I 96703-0848

RE. AGENDA Item F.1

Dear BLNR Members,

ALOHA ! ! !

Please vote against passage of
AGENDA ITEM F.1
The collecting of REEF FISH on O'ahu.

I'm GRATEFUL to have been blessed to live in Hawai'i Nei for near fifty (50) years; like many of You BLNR Members who were born and raised here in Hawai'i Nei.

Don't Y'all recall when Hawaii's reefs were ABSOLUTELY Teeming with Reef Fish ? !

Virginia Isabel, attempted to pass a bill THREE decades ago in Kailua-Kona prohibiting The Aquarium Trade.

THAT attempt only recently became law.

The glorious beauty and integral eco-system of Reef Health with Reef Fish is well documented.

Climate Crisis is in Full Swing...

O'ahu has Millions of residents and tourists

Let's PROTECT the small amount of surviving REEF FISH, PLEASE Boardmembers of BLNR.

Please keep me abreast of the outcome of the vote, Thursday, 7 October 2021.

MAHALO Plenty ALL BLNR Members and Staff.

Malama Pono ! ! !

Sincerely With ALOHA,

Bonnie & 'Ohana

From:	The B
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Testimony regarding Oahu EIS being heard on Oct 8th
Date:	Monday, October 4, 2021 3:25:29 PM

Aloha,

My name is Bradley Bishop and I am a resident of Hawaii (on Oahu). I want to express my support for the Aquarium EIS. I truly believe that the people in Hawaii should be able to live off the land and the sea, as long as it is done in a sustainable way and managed by the Department of Land and Natural Resources (DLNR).

Mahalo,

Brad Bishop

From:	Lisa Bishop
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Written testimony, and request to provide oral testimony via zoom link, on Agenda Item F.1 at the 8 October 2021 BLNR Meeting
Date:	Thursday, October 7, 2021 7:46:36 AM

7 October 2021

Aloha Chair Case and Members of the Board of Land and Natural Resources,

My name is Lisa Bishop. I am an Oahu resident and homeowner. I also serve as President of the NGO Friends of Hanauma Bay.

lisa.fohb@gmail.com
(808) 748-1819

Mahalo for the opportunity to testify in **STRONG OPPOSITION OF AGENDA ITEM F.1.**

The Final Environmental Impact Statement (FEIS) proposing to reopen deadly commercial aquarium fishing on O'ahu is inadequate and must be rejected by the Board for the following reasons:

The FEIS DOES NOT COMPLY WITH HEPA.

The FEIS is flawed, relying on insufficient, faulty, inadequate and improper data and assumptions.

The FEIS does not disclose, analyze or discuss the impacts of aquarium collection on targeted species.

The Main Hawaiian Islands have been major exporters of ornamental reef fish. However, **there is a lack of baseline data on natural ornamental species abundance, and only one study [Grabowsky & Thornhill (2020)] on the effects of ornamental**

collection on Oahu reef fish populations. This study finds that when compared to Hanauma Bay, designated Hawaii's first Marine Life Conservation District in 1967 and best baseline representing natural abundance on Oahu, **the impacts of collection are extreme. Compared to Hanauma Bay:**

- Yellow tangs are **93% LESS abundant** in areas open to collection
- Kole are **90% less abundant** in areas open to collection
- Orangespine unicornfish are **89% less abundant** in areas open to collection
- Moorish idols are **80% less abundant** in areas open to collection

These results are **even more remarkable** when Hanauma Bay visitor traffic is factored. Prior to 2021, the bay received over 1 million visitors annually. The fact that these species are so much more abundant in the bay, given this tremendous human pressure, should put to rest any/all claims that the fish in areas open to collection haven't been over-harvested, they've just been scared away by tourists.

There is no population trend data for the fish species analyzed in the FEIS for the island of O'ahu, so there is no way to determine which, if any, species are experiencing population declines (FEIS Page 26). Yet the FEIS is proposing levels of take that far exceed reported historical catch for most species.

There is no research on the effects of commercial aquarium fishing on herbivores for the island of O'ahu (FEIS page 25). Yet the FEIS downplays the importance of the herbivores taken by aquarium collectors.

The required Cultural Impact Assessment claimed the EIS proposal would close 21% of Windward coast to collection. YET the FEIS proposes no such closures.

The FEIS does not describe how communities of reef species are disrupted by aquarium collecting.

The FEIS does not have a plan to restore depleted abundance and ensure future generations may encounter and enjoy these species in their natural habitat.

The FEIS does not explain why people with personal aquariums outside the state deserve these fish more than Hawaii does.

The FEIS does not provide a cost/benefit analysis that showed an aquarium collecting benefit to Oahu residents that outweighs the costs.

The Board must reject this inadequate FEIS!

Mahalo for the opportunity to testify.

Lisa Bishop
President
Friends of Hanauma Bay

From:	ted bohlen
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Written testimony and request for oral testimony for 10/8 Board meeting 9 a.m., Agenda item F1, Aquarium fishing FEIS
Date:	Monday, October 4, 2021 11:01:19 AM

Attached is my written testimony for the 10/8 Board meeting at 9 a.m., Agenda item F1, Aquarium fishing FEIS. I also hereby ask to testify orally at the hearing. Mahalo!

I am Ted Bohlen, a full-time resident of Oahu. I have substantial experience with environmental reviews under the Hawaii Environmental Policy Act (HEPA), Hawaii Revised Statutes (HRS) chapter 343, and rules in Hawaii Administrative Rules (HAR) chapter 11-200.1, since I served as legal counsel for the Hawaii Office of Environmental Quality Control (OEQC) and the Environmental Counsel as Deputy Attorney General from 2006-2020.

The Final Environmental Impact Statement (FEIS) for commercial aquarium fishing is inadequate and must be rejected by the Board for the following broad reasons:

IT DOES NOT COMPLY WITH HEPA

IT FAILS TO ADEQUATELY DISCLOSE ENVIRONMENTAL IMPACTS.

IT HAS NOT CURED THE NUMEROUS DEFECTS IDENTIFIED IN THE DRAFT EIS (DEIS).

IT IS WHOLLY DEFICIENT IN ITS DISCUSSION OF IMPACTS OF REMOVING OVER 92,000 FISH AND 200,000 INVERTEBRATES EACH YEAR, THE BENEFITS OF ALTERNATIVES, PARTICULARLY THE NO ACTION AND NO HERBIVORES TAKE ALTERNATIVES, AND MITIGATION, AS REQUIRED UNDER HAR SECTION 11-200.1-24.

I have the following specific concerns regarding the FEIS:

The FEIS does not describe how abundance is diminished by aquarium collecting, and ignores the science and other evidence that does.

The FEIS does not adequately address the importance of the herbivores taken by aquarium collectors. Hawaii reefs need more herbivores and aquarium collectors should not take them. Hawaii needs these fish more than ever before, given the stresses on reefs, including especially ocean warming and acidification.

The FEIS does not describe how communities of reef species are disrupted by aquarium collecting.

The FEIS minimizes the impacts of aquarium collecting on reef species.

The FEIS does not describe the increases in some or all of these species that would occur under the No Action alternative.

The FEIS does not have a plan to restore depleted abundance and ensure future generations may encounter these species.

The FEIS does not explain why people with personal aquariums outside the state deserve these fish more than Hawaii does.

The FEIS does not provide a cost/benefit analysis that showed an aquarium collecting benefit to Oahu residents that outweighs the costs.

The FEIS does not accurately describe how taking the fish reduces the beauty of coral reefs.

The FEIS does not adequately address the fact that aquarium collecting is contrary to native Hawaiian cultural practices and beliefs.

The FEIS does not adequately address the animal welfare issues and unacceptably high mortality rates linked to their practices.

The FEIS fails to accurately describe the undeniable and significant environmental, socioeconomic, and cultural impacts of what it proposed.

An additional comment: I am also the co-founder of the Hawaii Reef and Ocean Coalition (HIROC), an organization that includes coral reef scientists and was formed in 2017 to address the crisis on our coral reefs. HIROC is deeply concerned about the impact of aquarium fishing on our coral reefs, especially from taking of herbivores that clean the reefs and improve reef resiliency that is so needed given the stresses of climate change. Maintaining the current level of fish abundance is insufficiently “sustainable” when reefs are in crisis. Dismissing the moratorium on herbivores alternative alone renders this FEIS inadequate.

The Board must reject this inadequate FEIS!

I can be reached at Tbohl8@yahoo.com

From:	Leslie Briggs
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1 Testimony
Date:	Saturday, October 2, 2021 7:36:58 PM

Aloha,

I am a resident at 556 Pauku Street Kailua, Hawaii and I am asking BLNR to reject the EIS. The Final Environmental Impact Statement FEIS is deeply flawed. It will allow mainland pet trade- unidentified aquarium collectors to annually take hundreds of thousands of reef animals from Oahu reefs. Please do not allow the reopening of Oahu's deadly aquarium trade.

The very survival of Oahu's dwindling marine species is at stake. Decades of unlimited aquarium collection on Oahu have led to a 90% reduction of the most heavily targeted species. The FEIS totally ignores this fact and is proposing levels of take that far exceed reported historical catch for most species.

As a Windward resident, I object to the fact that the required Cultural Impact Assessment claimed the EIS proposal would close 21% of Windward coast to collection.

Leslie Briggs
556 Pauku Street
Kailua, Hawaii 96734

From: Karen Brittain
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Oahu"s FEIS should be passed
Date: Sunday, October 3, 2021 9:36:56 PM

Dear BLNR,

My name is Karen Brittain and I'm submitting written testimony for Oahu's FEIS. I think Oahu's FEIS should be passed and here's why.

I am the owner operator of a small marine aquarium fish hatchery on Oahu. The reason I started this business in 1997 was because I did not like the idea of fish being taken from the reef and wanted to provide a captive raised alternative. This idea came from my heart and was based on emotion. When managing natural resources we have to think rationally and follow scientific data. The aquarium fishery has been deemed sustainable and I think a sustainable fishery should be managed as such and not completely shut down.

Most marine ornamental fish hatcheries like mine have benefitted from the temporary closure of the aquarium fishery as prices for Hawaiian aquarium fish rise. This is great for my business but in spite of that I truly believe that the Oahu Aquarium fishery is sustainable and should be managed as such. Oahu's FEIS should be passed.

Thank you,
Karen Brittain
Reef Friendly Fishes

From:	Max Broad
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda item F.1
Date:	Wednesday, October 6, 2021 2:46:08 AM

Hawai'i BLNR -

I'm writing to express my concern for reef wildlife--that's why I oppose the Environmental Impact Statement. The BLNR should stop the issuing of permits to aquariums. If we allow institutions and private individuals to overharvest Hawai'i's natural biodiversity, it will (and has) come at a great cost.

Sincerely,
Max

From:	nedebrown@gmail.com
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Aquarium fisheries Oahu FEIS
Date:	Saturday, October 2, 2021 6:54:30 AM

To whom it may concern,

As a past long term resident of Oahu and a now frequent visitor; as an avid snorkler and diver; as a strong supporter of the protection of our environment and a past employee of The Nature Conservancy; as one who has many friends in and has worked closely with researchers in the marine science field, I would like to express my very strong support for the aquarium fishery Oahu FEIS and strongly encourage its approval.

The Oahu aquarium fishery is managed incredibly well and has minimal impact on its environment, much less so than Hawaii's commercial fishery or tourism industry activities such as snorkeling and diving. This fact has been recognized by many of Hawaii's leading marine scientists. The members of Hawaii's aquarium fishery have worked hand in hand with DAR over the years to ensure that their impact is minimal and to constantly improve the mitigation of this impact.

The aquarium fish business is local and small scale, providing jobs and income for Oahu's families, and providing a window into the marine world for those who keep aquariums, introducing them to an appreciation of the ocean environment which can then feed into more conscientious behavior toward this environment.

In summary, there are a number of local benefits from the well regulated and run aquarium fishery, and the past and current willingness of fishery members to work with its government and scientific partners to constantly monitor and improve its activities has ensured, and will continue to ensure, that its negative impacts are minimal.

Please support the approval of the Oahu FEIS.

Thank you,

Edward Brown
nedebrown@gmail.com

From: Ross Bronzan
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] REJECT THE EIS
Date: Wednesday, October 6, 2021 10:59:01 AM

Dear Sir or Madam,

As a resident of Hawaii, and a professional in the dive tourism and education industry, I hope you will REJECT the EIS.

The fragile marine ecosystem of Hawaii is stressed enough as it is. From the impact of tourism, toxic suncreen, sewage runoff, and our warming climate that is killing our coral, the last thing our ocean needs is to continue to be stripped of its precious resources.

The aquarium trade is an inhumane industry that exploits Hawaii's natural resources with no real benefit to its people or economy, no connection to traditional Hawaiian harvest and resource management practices, and significant detriment to its environment. A fish is worth so much more on the reef! Please don't let this wasteful, cruel, and exploitative practice continue.

You have an obligation to malama 'aina and malama kai. Understand that if you choose to allow this to continue, the demise of our marine ecosystem is on your hands. Do the right thing. Listen to those of us who have been watching the slow death of Hawai'i's reef for the sake of profit.

Mahalo for your attention to this matter.

Sincerely,
Ross Bronzan

From:	E Bryant
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] BLNR Testimony Re: Agenda Item F.1
Date:	Thursday, October 7, 2021 8:55:22 AM

Aloha,

I am writing to strongly urge the Board to REJECT PIJAC's FEIS for its failures to meet the basic requirements of HEPA, specifically with regard to its analysis of cultural impacts. I am speaking on behalf of my Bryant ʻOhana. We are cultural practitioners and come from a long line of lawaiʻa from the Island of Oʻahu – both subsistence-based fisherman as well as commercial fishermen. We are appalled by the FEIS's broad statement that the proposed action would impact cultural practices, but the extent of the impact is unknown. Outreach to cultural practitioners from the Ko`olaupoko and Ko`olauloa communities was virtually non-existent. The taking of our cultural and natural resources for ornamental purposes is an affront to our culture, our traditional and customary practices, and our cultural perspectives on resource management. The FEIS acknowledges that the proposed action would impact cultural practices, but it does not quantify or discuss these impacts and proposes no feasible actions to be taken to protect Native Hawaiian rights. As such, the Board must REJECT the FEIS.

I am also writing to request the opportunity to provide live oral/video testimony on Agenda Item F.1 regarding PIJAC's FEIS, which is pending before the Board of Land and Natural Resources at their October 8, 2021 meeting. My contact information is as follows:

Elena Bryant (testifying on behalf of the Bryant ʻOhana)
(808) 386-0254
bryant.elena@gmail.com

Please do not hesitate to contact me if you need any additional information regarding my request to provide testimony.

Mahalo nui,
Elena Bryant

From: CHRISTINE BUENO
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Oahu Tropical Fishing Testimony
Date: Monday, October 4, 2021 6:10:39 PM

Aloha,

Please bring back tropical fishing so that our small business local fisherman can continue to earn a living with dignity. They have had a very hard time trying to adjust to a new job especially the older fisherman.   They are unable to make the transition. It difficult for them to have been banned from a profession they have done and loved all their lives.

Mahalo,
Christine Bueno
Waipahu HI 96797

bcexpress8@yahoo.com
808-676-7238

Sent from my iPhone

From: Patricia Cadiz
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1 Testimony
Date: Sunday, October 3, 2021 12:12:44 PM

Aloha Board Members;
As a Hawaii resident that cares deeply about the Heath of our ocean, reef and beaches I urge to the reject the flawed and one-sided EIS.

Fundamentally, Hawaii's eco-system and citizens derive zero benefit for the aquarium trade and suffer all of the costs. These fish are an integral part of the reef eco system. The reef eco system is the source of sand for Hawaii's beaches. With sea level rise and climate change, we need the natural protection of healthy reefs and beaches. The aquarium trade is counter productive to the preservation of healthy reefs and beaches.
You are charged with protecting the lands of Hawaii - including our submerged lands. You have a fiduciary responsibility to reject this flawed and one-sided EIS to protect or fish, reefs and beaches. It's all one ecosystem.
Thank you,
Patricia Cadiz
Maui,HI

Patti Cadiz
Sent from my iPhone

From: Mal Chan
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Reject EIS
Date: Sunday, October 3, 2021 11:56:01 AM

Please reject EIS!!! We need to keep our marine ecosystem protected for all our future generations!

A Hawaii resident,
Mal Chan

October 7, 2021

Board of Land and Natural Resources

P.O Box 621

Honolulu, Hawai‘i 96809

Submitted via e-mail: blnr.testimony@hawaii.gov

Re: Testimony Regarding Item F1 Final Environmental Impact Statement for Issuance of 15 Commercial Aquarium Permits on O‘ahu

Aloha Chairperson Case and BLNR Board Members,

My name is Palakiko. I am writing in regards to the FEIS for Issuances of 15 Commercial Aquarium Permits on O‘ahu.

The prostitiution of Hawa‘i‘s people, culture, and natural resources has been a problem ever since settlers and colonizers first stepped foot on our white sands. The exportation and exploitation of Hawaiian goods have been a problem in Hawai‘i, and most of Hawai‘i‘s governing entities have largely ignored the Kanaka population‘s cry to cease and desist the selling of our resources..

Hawai‘i‘s i‘a belongs to Hawai‘i alone.

The Cultural Impact Assessment (CIA) stated substantial prohibited areas yet NO prohibited areas proposed in the EIS**.** The CIA was based on an alternative that was never proposed in the EIS, where collection would be prohibited in four zones (representing 21% of windward O'ahu’s coastline). Therefore, consultation was requested with those having knowledge or those involved in cultural practices occurring anywhere **except** those excluded areas. There is simply not enough information available for the BLNR to make an informed decision.

Furthermore, The EIS fails to accurately analyze the cultural and socioeconomic consequences of aquarium collection on O'ahu and ignores the research showing that Hawai'i residents receive **zero** benefits from the trade, but suffer **all** the costs.

I highly encourage and suggest the BLNR to reject this project proposal, to continue to protect Hawai‘i resources for Hawai‘i‘s own.

Me ka ha‘aha‘a,

Palakiko Chandler

From: danielle chomel
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Reject the EIS
Date: Saturday, October 2, 2021 3:05:58 PM

Aloha, I am a long-term Hawaii resident and have been swimming and snorkeling in the islands since 1975. I vote that you leave the fish on the reef where they belong. Our reefs CAN remain healthy as long as the fish are there. Thank you for your consideration, Danielle

Sent from my iPad

From: Keith Christie
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Testify on Agenda Item F.1 - Aquarium Collection NO!!
Date: Sunday, October 3, 2021 2:29:49 PM

My name is Keith Christie, and I am a Hawaii Resident. I OPPOSE the E.I.S. that could allow Aquarium Collection being allowed to resume or continue in any way. NO, I do NOT want that happening to our Hawaii reefs and fish. Our reefs are in peril and extracting these fish is not sustainable PERIOD.

Thank you,
Keith Christie
Hawaii Resident

From:	L. A.
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1 Testimony
Date:	Tuesday, October 5, 2021 9:35:48 AM

As a Hawaii resident that respects and wants to preserve our unique marine ecosystems for future generations I would like to encourage and ask BLNR to **REJECT the EIS!**

Taking fish from our oceans to pad the pockets of a few is wrong at every level, it goes against the culture of the islands and its people. Stop bleeding our world for pure greed. Our keiki deserve better. Mālama 'Āina!

With aloha,
Lilly Condrey

Board of Land and Natural Resources
October 8, 2021, 9:00am
Online Via Zoom
Agenda Item F.1: Determination of whether the Final Environmental Impact Statement (FEIS) complies with applicable law and adequately discloses the Environmental Impacts of Proposed Issuance of Commercial Aquarium Permits and Commercial Marine Licenses for the Island of Oʻahu, for the purpose of accepting the FEIS; dated August 20, 2021, Applicant Pet Industry Joint Advisory Council (PIJAC); Island of Oʻahu, State of Hawaiʻi.

Conservation Council For Hawaii (CCH) asks the members of BLNR to reject the FEIS that has been submitted for the proposed issuance of commercial aquarium permits and commercial marine licenses.

The FEIS provided ignores data and research documenting the impacts of their actions, such as:

- research documenting the 90% reduction of key species described above
- a paper describing the collapse of the aquarium fishery on Oʻahu's southwest reefs 35 years ago -- which have yet to recover
- research documenting that Hawai'i residents receive ZERO benefits from the trade, but suffer ALL the costs.

Additionally, the required Cultural Impact Assessment claimed the EIS proposal would close 21% of Windward coast to collection, YET the FEIS proposes no such closures.

The entire FEIS is designed to facilitate their foregone conclusion that taking large numbers of marine animals and selling them to the aquarium pet trade outside Hawaiʻi has no significant impact on cultural, biological, and socioeconomic resources. They do so by claiming that aquarium trade operations would take a small percentage of the entire island-wide populations of the species they target, yet nothing would prevent the collecting of species to the point of collapse in specific places, such as occurred in the past.

Our marine ecosystems are fragile, all species play a vital role in the balance that is necessary for the survival of marine life, it is imperative that we protect our marine resources, rejecting this FEIS and therefore issuance of commercial aquarium permits is essential to our island home's oceans.

Thank you for the opportunity to provide our testimony OPPOSING the FEIS provided for this agenda item.

Moana Bjur
Executive Director

From: Jeanne Cooper
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1 / vote no on the Aquarium Trade EIS
Date: Monday, October 4, 2021 3:09:08 PM

Aloha,
I am a resident of Hawai'i who writes about the culture, environment and unique beauty of Hawai'i for national and regional magazines, newspapers and websites. I have also coauthored the annually updated Frommer's guidebooks to our islands since the 2015 edition.

Sadly, in most cases, every year I have to temper my praise for snorkeling and diving areas once abundant with colorful reef fish, vibrant coral and other marine life. While global warming, sunscreen use and other environmental factors are contributing to the degradation of reefs I have witnessed, there is at least one threat that can easily be prevented, if BLNR will take appropriate action. That action is to reject the defective environmental impact statement (EIS) prepared by the Pet Industry Joint Advisory Council regarding extraction of marine life by the aquarium trade.

This trade is visibly *not* sustainable, it is certainly not humane -- nearly all reef creatures die within one year of extraction -- and it is not pono, as I have come to understand the term. I have learned that Native Hawaiians traditionally stewarded their resources, serving the land and sea so that in return the land and sea would sustain them. This EIS instead serves primarily off-island commercial interests and temporarily "benefits" collectors at the expense of local and visiting snorkelers, divers and others who appreciate Hawaiian marine life in its native environment. How is that pono?

Please vote in the interest of the people of O'ahu and Hawai'i, as well as our marine life, and do not approve the EIS.

Sincerely,
Jeanne Cooper
--
Cell +1 808.348.4012 / Twitter: @Hawaii_Insider / Facebook: Hawaii Insider / Instagram: @hulajeanne
Freelance travel and features writer for national and regional magazines | Former San Francisco Chronicle Travel Editor
Guidebook author (upcoming Frommer's Hawaii 2022; currently in print Frommer's Hawaii 2020, Frommer's Easy Guide to Maui 2020, Frommer's Maui Day by Day 2020)

To: Land Board Members

I, Elise Fernley, am a co-owner of Coral Fish Hawaii. I support the passing of the Oahu FEIS. A lot of work and thought has been invested in this FEIS by the applicants, data analysts and counselors.
The applicants have shown that they are willing to work with the state and listen to the concerns voiced by members of the public. They have met with DAR to find out what the department's concerns were. They have substantially reduced the number of catchable species on their white list and have suggested setting up FRAs.
Many of those who have applied have been fishing for a very long time, and understand the need to rotate their collection spots and to care for that location especially when they are fishing there.
Even though the number of fish being collected by the applicants is a small percentage of total fish caught, it does generate income for the fisher, employees (if they have them), suppliers, the State of Hawaii and the United States. This fishery also provides fish and resources for those in the research field. In the past there have been many times that the Waikiki Aquarium and UH have been given or purchased fish from Coral Fish Hawaii. However, since the ban, they have not been able to acquire fish from Coral Fish.
Passing the FEIS would mean that people can get back to work, make an income, possibly pay bills without having to decide which one takes precedence and put people/companies back in business.
I beseech you to look at the data and science of this fishery. It has been studied and found to be sustainable. There has been a lot of misinformation spread about the fishery. Please base your decision on facts not fiction, and pass this FEIS.

Thank you for your time and consideration on this matter.

Sincerely,

Elise Fernley

From:	carla cottrell
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Tropical fish EIS
Date:	Monday, October 4, 2021 1:35:51 PM

I’m in support for the tropical fish divers. There is no evidence that catching tropical fish is harmful to the coral reef or depletion the the fish.
Carla Cottrell

Sent from my iPad

From:	donna cottrell
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Tropical Fish EIS
Date:	Monday, October 4, 2021 3:31:52 PM

I, Donna Cottrell, support the Oahu Fish EIS, Environmental Impact Statement. As a Native Hawaiian born and raised on the Islands, I know for a fact that Tropical Fish Diving is done sustainably like how our Native Ancestors have done for generations. There is so much evidence that shows diving does not affect Hawaii's ecosystem. Hawaii has such a small community of divers and in this community everyone holds each other accountable with Kuleana (Responsibility) and Pono (Righteousness) in order to ensure that diving is done with respect to the 'Aina (Land) as well as the creatures in it.

As a daughter of one of these divers, I can see how much his love for the ocean is reflected in his work. My father has worked very hard in his line of business and his compassion for the ocean as well as his knowledge of the creatures in it is nothing short of amazing. I have learned so much from my father and have also gained so much knowledge and respect for the ocean and all of its animals. My father dives for Tropical Fish, yes, but he also spreads awareness of the importance of the ecosystem and to only take from the ocean what you need. He has always been a big advocate for the ocean and sustainability and so have all the divers i've had the pleasure of meeting through him. I'm very proud to call him my father because of his hard work as well as his love for the ocean and his job.

From:	Shannon Cruz
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL]
Date:	Monday, October 4, 2021 1:28:56 PM

- My name is Shannon Cruz and I am writing In support of the Aquarium Fishery FEIS passage

I am in favor of the Saltwater tropical fishing and hope the Fisherman's licenses can be reinstated. Halting these fishing licenses have affected a few of my family members drastically in their way of supporting themselves and their families. If you truly knew these fishermen you would know that they have only the utmost respect for the entire ocean. They see firsthand that what they take from the ocean is not depleting those species as some testify. I am disheartened by the halting of these Fishermen's livelihoods, especially during COVID when the whole world is suffering! Please let our fishermen do their jobs respectfully even if limitations as to amounts etc please let them continue to feed their Ohana.

Shannon Cruz
Shancruz74@gmail.com
808-861-4115

From: Judith Cucco"s gmail
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Aquarium Collecting
Date: Tuesday, October 5, 2021 2:52:29 PM

To Whom It May Concern:

Please reject the EIS aimed at re-opening Oahu's deadly aquarium trade. As a frequent snorkeler on Oahu, I have seen a serious decline in both the number and species of fish destined for the aquarium trade based on species and abundance fish surveys I have done for the Reef Environmental Education Foundation.

The FEIS ignores data and research documenting the impacts of their actions, such as:

- research documenting the 90% reduction of key species they intend to take,
- a paper describing the collapse of the aquarium fishery on O‘ahu’s southwest reefs 35 years ago -- which have yet to recover,
- research documenting that Hawai'i residents receive ZERO benefits from the trade, but suffer ALL the costs.

Additionally, the required Cultural Impact Assessment claimed the EIS proposal would close 21% of Windward coast to collection, YET the FEIS proposes no such closures.

The entire FEIS is designed to facilitate their foregone conclusion that taking large numbers of marine animals and selling them to the aquarium pet trade outside Hawai‘i has no significant impact on cultural, biological, and socioeconomic resources. They do so by claiming that aquarium trade operations would take a small percentage of the entire island-wide populations of the species they target, yet nothing would prevent the collecting of species to the point of collapse in specific places, such as occurred in the past!

Please reject re-opening Oahu for the aquarium trade.

Sincerely,

Judith Cucco

From:	Mendy Dant
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1 Testimony - Strongly Oppose!
Date:	Tuesday, October 5, 2021 4:55:14 PM

Aloha Honorable Chair Case and Land Board Members,

I am a 46 year resident of Hawaii nei and a family snorkel business owner. Please vote to reject this EIS written and paid for by a biased Pet Industry. I have seen a decline in tropical fish even while we have restrictions on Hawaii Island. A school of a rare Pyramid Butterflyfish has recently decreased by 50% from an area seldom gone to by any commercial tours, but tropical fish collectors can sneak in and take because the coastlines are not often patrolled. We need to outlaw all tropical fish collection and leave the marine life to live the life they are intended to live. The coral reefs need these fish to keep the environment in balance. We are causing a detrimental impact to the coral reef ecosystem and until we stop taking and causing harm, immediately, we will not turn this negative tide around in time. This is not only an Oahu issue but a Hawaii state problem. Your vote to reject this EIS can go a long way to help bring balance to our ocean environment.

Coral reefs are important in determining the amount of carbon dioxide in the atmosphere. The zooxanthellae algae, through photosynthesis, remove carbon dioxide from the air and make carbohydrates available as food for both the zooxanthellae and the coral polyps. The degradation of our coral reef ecosystem is causing an inability to clean the air of carbon dioxide, which is as degrading as cutting down trees in the Amazon Rainforest. We should be protecting our coral reefs and tropical fish as it is Hawaii's Amazon rainforest. As storms get stronger and stronger we rely on our reefs to protect our shorelines from devastation. We have so much of our critical food shipments, storage and power infrastructure built on the shoreline on Oahu, protecting its integrity should be of utmost importance. This should not even be up for discussion, we need to end all fish collection in our state as this is necessary to meet the Governors' 30x30 goals and to move in a positive direction for the health of the entire planet. Stopping industries that are stripping our natural resources of life need to be stopped not encouraged.

Please vote to reject the EIS and stop the Tropical Fish collection from Hawaii Nei!

Thank you for your time and consideration,
Mendy Dant

Mendy Dant
Executive Vice President
Fair Wind Cruises
Kona Sunrise Charters
78-6775 Box A Makenawai St
Kailua Kona, Hi 96740
O. 808-331-3119
C.808-345-6211

www.fair-wind.com

"We need to respect the oceans and take care of them as if our lives depend on it. Because they do." Dr. Sylvia Earle

https://www.youtube.com/watch?v=aGP9loQ0dqs

From: Hawaii Living
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1 Testimony
Date: Saturday, October 2, 2021 4:47:48 AM

To whom it may concern:

As a permanent resident of Hawai'i and someone who cares deeply about our environment I urge you to reject the Final Environmental Impact Statement regarding the harvesting of native fish in Hawai'i, specifically on O'ahu, for the pet trade or for any other purposes other than cultural. Native reef populations suffered major collapses decades ago and there have been no determinant studies that the current level populations have rebounded sufficiently to allow for such collecting for the pet trade. This harvesting only benefits mainland pet trade industries and has no benefit whatsoever for Hawai'ians and our local fish populations. It is extremely important that we protect the local reef fish populations from such harvesting in order to maintain a healthy balance in our oceans and fish populations. Thus, I urge you to reject any such proposals that would open up more areas on O'ahu or any of Hawai'i's other islands to the harvesting of our local fish populations for the aquarium pet industry.

Mahalo for your consideration,

Rene De La Paz-Magar
Honomu, HI

From: Alex Detrick
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1
Date: Saturday, October 2, 2021 5:19:07 PM

From Alex and Cathy Detrick
We are Hawaii residents and snorkel almost every day. We ask to REJECT the FEIS to reopen aquarium collection. Research has shown 90per cent reduction in key species. The detrimental effect 35 years ago has not been recovered to this day. And we the residents of Hawaii get no benefits!
Respectfully,
Cathy and Alex Detrick

Sent from my iPhone

From:	Keep ME Playing
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Please reject EIS proposing to open aquarium collecting on Oahu
Date:	Wednesday, October 6, 2021 7:10:13 AM

PLEASE end the destructive aquarium pet trade! As an avid swimmer and snorkeler all over the coasts of Oahu I can testify that our beautiful reef fish are NOT plentiful even in protected areas such as Shark's cove. Allowing individuals the right to legally take thousands and thousands of fish from our ecosystem will be a disaster. When was the last time you saw a huge school of yellow tang? I occasionally see a few individuals. How often do you dive and snorkel? How does allowing a few individuals to take our natural resources align with our values when it's simply a money making and unsustainable venture? Why is it wrong to take a piece of lava rock from Volcano national park, but someone can take every single fish off a reef on Oahu for purely financial gain, knowing that most of those fish will die once out of the ocean?

END Aquarium collecting for profit!

Mahalo for listening!

Jill Dietmeyer
Pearl City, HI

From:	Laurie Doerschlen
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Oahu"s FEIS Support Testimony
Date:	Wednesday, October 6, 2021 11:30:47 AM

To Whom It May Concern,

We are in support of reinstating aquarium permits to small, locally owned businesses. These small companies are well educated in the most sustainable collection methods for Hawaii's tropical fish. Since their livelihood depends on the health of Hawaii's fish populations, reefs and water; they should be given the opportunity to work, make a living and care for the State's waters and bounty. And, we understand that Hawaii's own scientific community supports "sustainable" collecting of tropical fish.

My husband's brother is one of the partners of Pisces Pacifica which has been in the aquarium fish business for 40 years with a DLNR issued aquarium permit (in good standing). They should be allowed to work and protect Hawaii's fish populations and ocean waters. His brother and business partner are responsible residents of Hawaii who are actively involved in their community. They volunteer at schools, churches, along with having their own learning center where they educate children and young adults about the importance of sustainable fishing and the ocean's role in relation to the health of the planet. They need their permit reinstated to continue contributing to Hawaii's economy!

We strongly support reinstating aquarium permits to small, local businesses. Thank you for your consideration of our written testimony.
Sincerely,

Laurie Doerschlen
Timothy Williams
3647 Kawelolani Place
Honolulu, HI 96816
808-737-4621

From: Martha Randolph
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1 Testimony
Date: Monday, October 4, 2021 4:12:59 PM

To the BLNR Members

I am writing on both my own behalf and on behalf of the Environmental Caucus of the Democratic Party of Hawaii to ask you to firmly reject the FEIS under review concerning reopening the Oahu Aquarium trade.
The seriously flawed FEIS does not consider proven scientific evidence of the decline of our living reefs and all the animal species that depend on them. We know that the University of Hawaii has shown that it is possible to raise reef fish to supply the aquarium industry but of course it would take time and money for the current industry to utilize that type of system. Well the time was years ago and if they had started then they would be up and running now. Instead many questionable decisions by people in power have brought us to a crisis point and there is no more time to prevaricate.

Global warming has increased the die off of reefs and reef life forms due to increased CO_2 in the ocean and increasing water temperatures. Simple common sense should tell you that under the current conditions any additional stress on reef fish, like overfishing by a poorly managed and poorly regulated industry can only result in a disatourious situation.

Once we have over fished our reefs to the point of no return it will be too late. So it will be up to you to do the right thing. Refuse to accept the current FEIS and find out who has been behind the questionable information it contains. Prevent ALL reef fishing at least for a short time, or at least put severe restrictions on who can collect such fish and the quantities they can collect. If you do not, you will know you were directly responsible for the ultimate end of living reefs around Oahu...because when you could act, you chose not to.

Most sincerely

Martha E Randolph
President of Democratic Precinct 4 District 25
DPH Kupuna Caucus Treasurer
DPH Environmental Caucus SCC Representative
808-284-0264

From:	Jeep Dunning
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] EIS
Date:	Saturday, October 2, 2021 7:15:55 AM

Reject the EIS! Save the fishes!

Jeanne Dunning,
Maui Resident

EARTHJUSTICE

October 4, 2021

Via Electronic Mail

Attn: Suzanne Case, Chair
Board of Land and Natural Resources
blnr.testimony@hawaii.gov

Re: **Agenda Item F.1: Determination of whether the Final Environmental Impact Statement (FEIS) complies with applicable law and adequately discloses the Environmental Impacts of Proposed Issuance of Commercial Aquarium Permits and Commercial Marine Licenses for the Island of Oʻahu, for the purpose of accepting the FEIS; dated August 20, 2021, Applicant Pet Industry Joint Advisory Council (PIJAC); Island of Oʻahu, State of Hawaiʻi.**

Dear Chair Case and Board Members:

Earthjustice submits this testimony on behalf of For the Fishes, Center for Biological Diversity, Kai Palaoa, Moana ʻOhana, and the Kaupiko ʻOhana of Miloliʻi regarding the Final Environmental Impact Statement ("FEIS") for Issuance of Commercial Aquarium Permits and Commercial Marine Licenses for the Island of Oahu, prepared on behalf of the Pet Industry Joint Advisory Council ("PIJAC"). We strongly urge the Board to **reject the FEIS** because it fails to fulfill the core purposes of the Hawaiʻi Environmental Policy Act ("HEPA"), Hawaiʻi Revised Statutes ("HRS") chapter 343, to inform agency decision-making by "alert[ing] decision makers to significant environmental effects which may result from the implementation of certain actions," and to provide for "public participation during the review process."[1]

The Board should reject the FEIS due to its numerous procedural and substantive flaws, including: (1) PIJAC's attempt to shoehorn an entirely new proposed action into a final EIS, sidestepping the HEPA review process altogether; (2) information flaws and gaps identified by the DLNR Division of Aquatic Resources ("DAR") that must be addressed now, instead of leaving assessment of impacts to the permitting stage; (3) use of flawed and unsupported methodology in assessing impacts; (4) failure to assess the trade's cumulative impacts; (5) use of flawed and misleading data for the proposed catch quotas; (6) failure to analyze economic impacts; (7) failure to disclose and minimize cultural impacts; and (8) failure to propose enforcement measures.

The FEIS is cut largely from the same cloth as the EISs for commercial aquarium collection in the West Hawaiʻi Regional Fishery Management Area ("WHRFMA"). Indeed, the

[1] HRS § 343-1.

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FEIS's substantive flaws repeat many of the same missteps the Board already cited as reasons for rejecting PIJAC's initial EIS for the WHRFMA. The Oʻahu FEIS, for example:

- Lacks localized estimates of future take (BLNR Reason for Non-Acceptance No. 1[2]), *see infra* Part V;

- Lacks any scientific basis for assuming that taking certain percentages of fish populations is "sustainable" (BLNR Reason for Non-Acceptance No. 8),[3] *see infra* Parts III & IV;

- Fails to assess cumulative impacts by comparing open and closed areas (BLNR Reason for Non-Acceptance No. 11),[4] *see infra* Part IV; and

- Fails to consider and minimize cultural impacts (BLNR Reason for Non-Acceptance No. 13),[5] *see infra* Part VII.

These long-standing and persisting defects in PIJAC's review documents, many of which the Board has already specifically rejected, again necessitate rejecting this FEIS.

I. BECAUSE THE PROPOSED ACTION DIFFERS SIGNIFICANTLY AND SUBSTANTIALLY FROM THE ALTERNATIVES CONSIDERED IN THE DRAFT EIS, PIJAC MUST SUBMIT A REVISED DRAFT EIS

At the outset, PIJAC's proffered document attempts to skirt HEPA's procedural requirements by proposing an entirely new action for approval in a "final" EIS. The proposed action in PIJAC's EIS differs materially and substantively from the action proposed in the draft EIS,[6] and thus, PIJAC's new preferred alternative has not been subject to *any* environmental

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[2] BLNR's Findings and Reasons for Non Acceptance of Final Environmental Impact Statement (FEIS) Regarding Proposed Issuance of Commercial Aquarium Permits, Commercial Marine Licenses, and West Hawaiʻi Aquarium Permits for the West Hawaiʻi Regional Fishery Management Area ("Findings & Reasons") (May 30, 2020) at 2.

[3] *Id.* at 3-4.

[4] *Id.* at 4.

[5] *Id.* at 4-5.

[6] *Compare* "Project Summary," Draft Environmental Impact Statement for Issuance of Commercial Aquarium Permits and Commercial Marine License for the Island of Oʻahu at portable document format page ("PDF") 7 ("The objective of the proposed action is for [DLNR] to issue 20 Aquarium Permits for the island of Oʻahu, along with required Commercial Marine Licenses") (published May 8, 2020), *with* "Project Summary," FEIS at PDF 7 ("The objective of

review or comment period. To ensure that the HEPA process is lawfully carried out, the Board should reject the FEIS and require the applicant to prepare a revised draft EIS, so that PIJAC's new proposal can be properly reviewed as required by chapter 343 and its administrative rules.[7]

Nothing in chapter 343 or the HEPA or its implementing rules allows for proposal of an entirely new action in an FEIS. As detailed in Part V, *infra*, PIJAC's proposed White Lists of aquarium species for Oʻahu and catch quotas present an entirely new and different proposition than what was considered in the draft EIS. Indeed, in the draft EIS, an alternative referred to as "creation of species-specific bag limits" was expressly "dismissed."[8] PIJAC presents no rationale for the species selected, which include 12 fish and 2 invertebrate species that were not analyzed or even mentioned in the draft EIS. The quotas proposed for the vast majority of White List species represent significant increases over historical take and would, more often than not, *double* the average annual take over the last two decades. Overall take under the proposed quotas would also be significantly greater than estimated take under the draft EIS. *See infra* Part V & Table 1.

One of HEPA's fundamental purposes is to establish and safeguard the public's procedural right to participate in the environmental review process.[9] The substantial changes to the proposed action raise significant environmental concerns, but the public—including the scientific community—has had no opportunity to review and critique the proposal. Thus, the Board must reject the FEIS and require revision of the draft EIS to allow for public review and comment on the new proposed action.[10]

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the proposed action is for [DLNR] to issue 15 Aquarium Permits and 15 corresponding Commercial Marine Licenses for the island of Oʻahu, *create a 'White List' of 31 species and 4 invertebrates that can be collected, and implement individual catch quotas for the 35 species on the proposed White List*") (emphasis added) (published Sept. 8, 2021); *see also* FEIS section 3.6 at 22-25 (detailing PIJAC's new preferred alternative, no form of which appeared in the DEIS.

[7] Although new rules implementing HEPA, HAR ch. 11-200.1, went into effect on August 9, 2019, the previous rules, HAR ch. 11-200, apply to PIJAC's FEIS because DLNR's August 8, 2018 Notice of Determination was published before the new rules were adopted. *See* HAR § 11-200.1-32(b)(2).

[8] DEIS at 18.

[9] *See* HRS § 343-1 ("The process of reviewing environmental effects is desirable because . . . public participation during the review process benefits all parties involved and society as a whole.").

[10] Interpreting the National Environmental Policy Act (HEPA's federal counterpart), the Ninth Circuit Court of Appeals has held that substantial changes to a proposed action require supplementation of a draft EIS. *Great Old Broads for Wilderness v. Kimbell*, 709 F.3d 836, 854 (9th Cir. 2013) (supplementation not required only if "(1) the new alternative is a *minor variation* of

II. THE TIME TO ASSESS THE TRADE'S IMPACTS IS NOW, RATHER THAN WAITING UNTIL THE PERMITTING PROCESS

DAR's staff submittal identifies major flaws with the FEIS, including a lack of population data for three popular fish species and four invertebrate species and a general lack of population trend data for O'ahu.[11] Yet, DAR recommends the Board punt these issues to the permitting phase,[12] despite the FEIS's proposed massive increases in take of most species. We agree that the Board has broad authority and duties to place restrictions on permits and licenses to fulfill its constitutional and statutory mandates.[13] However, for HEPA review to fulfill its purpose, PIJAC and the Board must *examine and disclose the impacts* of reopening the O'ahu aquarium trade *now*, before the permitting and licensing phase. HEPA is clear that such review is a "condition precedent" to implementing a proposed action.[14] Without completing this prerequisite step, the FEIS must be rejected.

III. FLAWED METHODOLOGY FOR ASSESSING IMPACTS

The FEIS frames and defines its assessment of impacts based on catch as a percentage of fish populations.[15] The FEIS repeatedly cites a Philippines-based, non-peer reviewed field manual (Ochavillo and Hodgson (2006)) for the proposition that catching 5% to 25% of fish populations is "sustainable."[16] Contrary to the Board's express directives in rejecting PIJAC's first EIS for the West Hawai'i commercial aquarium trade, the FEIS fails to conduct any statistical analyses of "sustainable" levels of take based on the species' life span, population size, reproductivity rates, and age at first reproduction.[17] Because the FEIS ignores the Board's clear instructions for determining take limits, the Board should reject the FEIS on that basis. Moreover, any definition or formula for determining "sustainable" levels of catch should be

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one of the alternatives discussed in the draft EIS, and (2) the new alternative is *qualitatively within the spectrum of alternatives* that were discussed in the draft") (emphases in original) (internal quotations and brackets omitted); *cf.* HAR § 11-200-26 (supplemental EIS required for actions that have "changed substantively in size, scope, intensity, use, location or timing, among other things").

[11] DAR Staff Submittal on Item F-1 (October 8, 2021), at 8.

[12] *Id*.

[13] *See, e.g.*, Haw. Const. art. XI, §§ 1, 6; Haw. Const. art. XII, § 7; HRS §§ 26-15, 171-3, 187A-2, 187A-5.

[14] HRS § 343-5(e).

[15] *See e.g.*, FEIS at 23-24, Tbl. 3-2 (31 White List species) & n.6.

[16] *See, e.g.*, *id.* at 102, 110.

[17] Findings and Reasons ¶ 8 at 3-4.

geared toward restoring populations and minimizing the adverse impacts of commercial extraction,[18] rather than merely "sustaining" and rationalizing already depleted populations.

PIJAC also admits there are ***zero population data*** available for:

- 3 of the proposed White List fish species, *i.e.*, the bandit angelfish (a species of greatest conservation need), the flame wrasse (a species of hīnālea), and the crosshatch (redtail) trigger fish (a species of humuhumu)[19]; or

- *Any* of the 4 proposed invertebrates, *i.e.*, the zebra hermit crab, the Halloween hermit crab, the cleaner shrimp, and the feather duster worm.[20]

Even if the Board were to except PIJAC's flawed percentage-based method for assessing impacts, there would be no basis for allowing collection of any of these seven species.

IV. FAILURE TO CONSIDER CUMULATIVE IMPACTS OVER TIME

Regardless of the FEIS's approach to analyzing sustainable levels of take, the FEIS must determine the cumulative impacts of the proposed action, defined as impacts that result from "the incremental impact of the action when added to other *past*, present, and reasonably foreseeable future actions *regardless of what agency or person undertakes such other actions*."[21] The FEIS falls far short of satisfying this requirement because it assesses impacts against a legally, scientifically, and logically faulty baseline of depleted fish populations that have been subject to decades of extraction, rather than assessing the trade's cumulative impacts over time. The FEIS states that commercial collection has been "part of the baseline condition of these resources since the late 1940s" and, therefore, concludes that PIJAC "does not anticipate a significant change in the current baseline condition of these resources."[22] Thus, the FEIS fails to consider or acknowledge how further collection will perpetuate an already degraded state and foreclose any return to momona for O'ahu.

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[18] *See In re Waiāhole Ditch Combined Contested Case Hr'g*, 94 Hawai'i 97, 150, 9 P.3d 409, 462 (2000) (maintaining that the constitutional public trust doctrine does "not differentiate . . . between preventing and undoing 'harm'" to public trust resources).

[19] *See* FEIS at 47 ("To facilitate analysis in this FEIS, PIFSC-ESD provided the updated estimated population size for 2019 for each fish species for the island of O'ahu with the exception of Bandit Angelfish, Flame Wrasse, and Crosshatch Trigger for which *no population estimate was available*.") (emphasis added).

[20] FEIS at 82 ("No population estimates are available for Halloween Hermit Crabs," "Cleaner Shrimp, or "Feather Duster Worms.").

[21] HAR § 11-200-2 (emphases added).

[22] FEIS at 17.

The FEIS should analyze cumulative impacts by comparing collected areas to protected environmental conditions without extraction activities. The FEIS could easily accomplish this by using readily available, scientifically sound data that compare population densities and other ecosystem health indicators in open areas to areas unaffected by the activity.[23] Without comparison between open and closed areas, the FEIS lacks a full and accurate assessment of environmental impacts, as well as alternatives and mitigation measures geared toward addressing cumulative effects.

V. FLAWED AND MISLEADING FOUNDATIONAL DATA FOR CATCH QUOTAS

Even beyond these fundamental flaws, the FEIS is riddled with faulty data that hides and skews impacts, which renders the FEIS inadequate and misleading for informing the Board's decision-making. The FEIS is built on the premise that any prior flaws in the draft EIS have been resolved by instituting catch quotas for the 31 fish species and 4 invertebrate species now slated for collection. The Board should reject this proposition for several reasons:

- **<u>Nothing in the FEIS prevents collectors from concentrating their catch in targeted areas on Oʻahu.</u>** Under an analogous hypothetical also involving public trust resources, the state could not grant a permit to divert water from an entire watershed, while allowing the diverter to selectively destroy individual streams by draining the maximum authorized amount wherever it wishes. To remedy this defect, the FEIS must analyze maximum catch in individual subzones on Oʻahu,[24] or establish subzone-specific quotas. This could be accomplished using the various catch zones that span Oʻahu and that collectors already use to report their take. Without considering potential localized impacts or setting place-based quotas, the FEIS lacks an honest assessment of significant effects on communities or adequate mitigation measures.[25]

- **<u>The proposed White Lists for fish and invertebrates lack any basis.</u>** The FEIS's new and unvetted proposal to limit collection to 31 fish species and 4 invertebrate species lacks *any* stated rationale for why these species were selected. Decisions on which species will be subject to collection should be rooted in science and data, rather than

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[23] *See, e.g.*, Brian N. Tissot & Leon E. Hallacher, *Effects of Aquarium Collectors on Coral Reef Fishes in Kona, Hawaiʻi*, 17 Conservation Biology 1759 (Dec. 2003); Brian N. Tissot, *et al.*, *Evaluating Effectiveness of Marine Protected Area Network in West Hawaiʻi to Increase Productivity of an Aquarium Fishery*, 58 Pacific Science 175 (2004).

[24] *Umberger v. Dep't of Land & Natural Res.*, 140 Hawaiʻi, 500, 517, 403 P.3d 277, 294 (2017) ("[T]he properly defined activity for the purposes of the HEPA analysis must encompass the *outer limits of what the permits allow* and not only the most restrictive hypothetical manner in which the permits may be used.") (emphasis added).

[25] *See* HAR § 11-200-17(b).

haphazardly selected based on market demand. The proposed White Lists were not included in the draft EIS and, therefore, have undergone no public and agency vetting, contrary to law, as discussed in Part I, *supra*. Moreover, 12 of the proposed White List fish **(Table 1)** and 2 of the proposed White List invertebrates (the Halloween hermit and cleaner shrimp) were not analyzed or even mentioned in the draft EIS.

- **<u>The proposed quotas lack any scientific basis.</u>** As discussed in Part III, *supra*, the Board previously instructed PIJAC, with respect to the commercial aquarium trade in West Hawai‘i, to determine "sustainable" levels of take based on each species' life span, population size, reproductivity rate, and age at first reproduction. The FEIS lacks any such analyses and instead bases its quotas for the 31 fish species on historical catch levels, *i.e.*, economic demand, without any regard for impact to the species.[26] Moreover, the FEIS states no rationale for the proposed catch quotas for the 4 invertebrate species. The proposed quotas are central to PIJAC's faulty assessment of environmental impacts and utterly fail to comply with HEPA because they are market-based, not science-based. The proposed catch quotas were not included in the draft EIS and, therefore, must be disclosed and publicly examined in a revised draft EIS, as discussed in Part I, *supra*.

- **<u>The proposed quotas would allow significantly greater levels of catch.</u>**

  Fish. The FEIS's preferred alternative proposes take of 461,190 fish by 15 collectors over 5 years.[27] This amount is significantly greater than the take estimate in the draft EIS's preferred alternative (between 265,041 and 426,633 fish over 5 years).[28] Assuming an even amount of fish take each year (92,238) under the FEIS's preferred alternative, this amount is more than double the annual average fish take (38,602) for 20 collectors from 2000-2017, and significantly greater than the annual average fish take (71,983) for *all* collectors from 2000-2017.[29] Under the preferred alternative, the FEIS proposes to increase annual take above historical average levels for 28 of the 31 proposed White List species **(Table 1)**.[30]

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[26] FEIS at 23 ("Individual catch quotas for the 31 fish species were set based on either the historic maximum annual catch by all fishers from 2000-2017 (Table 5-6), with the maximum catch capped at 4.5% of the population.").

[27] FEIS at 138, Tbl. 5-11.

[28] Draft EIS at 95.

[29] FEIS at 50, Tbl. 4-5.

[30] The only species for which the FEIS proposes to *decrease* annual take below historical averages are: Potter's angel, orange-spine unicornfish (umaumalei, kala umaumalei), and Moorish idol (kihikihi). *Compare* FEIS at 51-52, Tbl. 4-6 *with* FEIS at 23-24, Tbl. 3-2.

Common Name	Hawaiian Name[31]	Average Annual Catch From 2000-2017 (all collectors)[32]	Proposed Annual Catch Quotas (all 15 collectors)[33]
Yellow tang	lāʻī pala, lauʻī pala	15,186	23,524
Kole	kole, kole makaonaona	9,746	11,983
Ornate wrasse (pinkface)	lāʻō	2,562	4,066
Flame wrasse	species of hīnālea	1,605	3,480
Fourline wrasse	species of hīnālea	1,604	2,722
Hawaiian whitespotted toby (puffer)	unknown	1,590	3,382
*Forcepfish	lauwiliwili nukunuku ʻoiʻoi	1,583	2,817
Milletseed butterflyfish (lemon)	kīkākapu	1,405	3,154
Shortnose wrasse (Geoffroy's)	species of hīnālea	1,355	2,592
Bicolor anthias	unknown	1,343	3,140
Orangeband surgeonfish (orange shoulder)	naʻenaʻe	1,343	3,875
Eightline wrasse	species of hīnālea	892	1,905
Crowned puffer (saddleback)	puʻu ʻōlaʻi	809	1,848
Saddle wrasse	hīnālea lauwili	804	1,597
Fisher's angelfish	unknown	756	1,627
Bandit angelfish	unknown	286.2	638
Brown surgeonfish (lavender, forktail tang)	māʻiʻiʻi, māʻiʻi	454.1	969
*Crosshatch (redtail) trigger	species of humuhumu	388.9	759
*Dragon wrasse (rockmover)	unknown	154.5	470
*Gilded triggerfish (bluethroat)	species of humuhumu	496.5	1,483
*Golden dwarf moray	species of puhi	66	215
*Heniocus butterfly (pennantfish)	unknown	630.6	1,061
*Raccoon butterfly	species of kīkākapu	309.6	626

[31] *See* FEIS at 44-46, Tbl. 4-4.
[32] *See* FEIS at 51-52, Tbl. 4-6; FEIS at 68-69, Tbl. 4-7.
[33] *See* FEIS at 23-24, Tbl. 3-2.

*Spotted boxfish	pahu, moa	575.6	1,178
*Threadfin butterfly	species of kīkākapu	238.7	366
*Whitemouth moray	species of puhi	48.1	140
*Yellowtail coris (clown wrasse)	hīnālea ʻakilolo	672.5	1,543
*Zebra moray	species of puhi	110.2	258

*Asterisks indicate species that were not analyzed or mentioned in the draft EIS.

Table 1. Average Annual Catch from 2000-2017 Compared With Proposed Annual Catch Quotas

Invertebrates. The FEIS's preferred alternative proposes take of 1,002,975 invertebrates by 15 collectors over 5 years.[34] This amount exceeds total invertebrate take (93,023) by 20 collectors over a 17-year period (2000-2017).[35] Assuming an even amount of invertebrate take each year (200,595) under the preferred alternative, this amount is astronomical compared to the annual invertebrate take for 20 collectors from 2010-2017, which never exceeded 12,643, and averaged 5,168.[36] The annual invertebrate take under the preferred alternative also exceeds the average annual invertebrate take (165,056) for *all* collectors from 2000-2017.[37]

PIJAC's proposed quota system is merely another vessel for sustaining and promoting the aquarium trade—rather than aquatic public trust resources and reefs on Oʻahu. This skewed proposal, and the FEIS that rests on it, should be rejected.

VI. FAILURE TO CONSIDER ECONOMIC IMPACTS

The FEIS fails to comply with HEPA's requirement to disclose the "effects of the proposed action on economic welfare . . . *of the community and state*."[38] Rather than assessing the trade's economic impacts to Hawaiʻi holistically, the FEIS instead focuses solely on economic impacts to individual collectors seeking coverage under the FEIS. For example, the FEIS characterizes the economic impacts of the "No Action Alternative," under which commercial aquarium collection on Oʻahu would not occur, as job loss and a loss of sales revenues.[39] Similarly, under the preferred alternative, under which 15 aquarium collectors would be permitted to resume collection (subject to a White List and catch quotas), the FEIS concludes

[34] FEIS at 138, Tbl. 5-11.
[35] FEIS at 80, Tbl. 4-8.
[36] FEIS at 80, Tbl. 4-8.
[37] FEIS at 80, Tbl. 4-8.
[38] HRS § 343-2.
[39] FEIS at 89-90.

there would be an economic benefit of $746,052 annually based on projected sales.[40] PIJAC's FEIS also implicitly acknowledges that the lion's share of financial benefits derived from Hawaiʻi-caught aquarium fish accrues to citizens and governments of other states.[41]

By contrast, when economic impacts to Hawaiʻi are assessed more broadly beyond the collectors, the negative economic impacts of the aquarium trade are undeniable. For example, a peer-reviewed cost-benefit analysis ("CBA") published by Schaar and Cox analyzes the relative costs and benefits of four aquarium fishery scenarios: (A) 2019 status quo collection (CML-only, no fine-mesh nets or collection in WHRFMA); (B) 2016 pre-*Umberger* permitting (including fine-mesh nets and the WHRFMA); (C) a statewide ban on collecting; and (D) collection only to support captive breeding of aquarium fish.[42] Taking into account a list of nine discrete economic factors—including management costs for the state, the value of the aquarium fish trade to individuals in Hawaiʻi and elsewhere, impacts to on-reef tourism where commercial collection occurs, environmental costs, and others—Schaar and Cox reported that the only scenario showing positive net economic benefits for Hawaiʻi is a statewide ban on commercial aquarium collecting.[43] By analyzing on-reef tourism values for aquarium trade epicenters on Oʻahu and Hawaiʻi Island, and recognizing the negative impacts to tourism caused by removing fish from reefs, the CBA projects net losses to our state economy of over *$400 million annually* if commercial collection is allowed to continue on those islands.[44] Comparing the annual on-reef tourism value for Oʻahu alone ($442,496,000[45]) to the Oʻahu coast's value to the aquarium trade ($746,052.72[46])—a nearly 600 to 1 ratio—it is clear that any benefits to the aquarium pet industry come nowhere close to the benefits of maintaining reef fish populations for just the tourism economy alone, much less the full range of monetary and non-monetary benefits and values of such protections.

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[40] FEIS at 93-94.

[41] *See* FEIS at 94 (noting a national retail value of aquarium fish in 1993 "nearly 6 times" higher than the value of aquarium catch in Hawaiʻi during the same time, based on DAR aquarium catch reports); *see also* Siena I. Schaar & Linda J. Cox, *The Future for Hawaiʻi's Marine Aquarium Fisher: A Cost Benefit Analysis Compared to an Environmental Impact Assessment*, Marine Policy 127 (2021) 104429, Feb. 17, 2021 ("Schaar & Cox") at 3 (reporting that retail prices for Hawaiʻi-caught aquarium fish on the continent can be over 5 times the price of the same species sold locally and noting the accrual of greater taxes and other economic benefits in areas outside Hawaiʻi).

[42] Schaar & Cox at 2.

[43] *Id.* at 3-5.

[44] *Id.* at 3, 4.

[45] *Id.* at 3.

[46] FEIS at 94.

The Board must reject the FEIS because it fails to openly analyze, disclose, and discuss the trade's economic costs and benefits to the people of Hawaiʻi, and Oʻahu in particular.

VII. FAILURE TO CONSIDER AND PROTECT CULTURAL RESOURCES

In reviewing an FEIS, the Board must "effectuate [its] obligation to protect native Hawaiian customary and traditional practices," and "fulfill its duty to preserve and protect" such rights "to the extent feasible."[47] The Board must, "*at a minimum*," make specific findings and conclusions regarding (1) the identity and scope of valued natural and cultural resources on Oʻahu, (2) the extent to which these resources, including traditional and customary native Hawaiian rights, will be affected by continued commercial aquarium collection, and (3) feasible actions to be taken by the Board to protect such rights.[48]

PIJAC's FEIS fails to provide the information needed for the Board to make such findings. The FEIS includes discussion (largely irrelevant to the resources at hand) of sacred mauka areas and some fishing traditions, and mentions the role of Hawaiian culture in resource management on Kahoʻolawe and at Wao Kele o Puna.[49] When it comes to assessing cultural impacts of the aquarium trade on cultural practices on Oʻahu, however, the FEIS merely classifies them as "unknown."[50] This is as patently absurd and untrue for Oʻahu as it was when PIJAC claimed the same for West Hawaiʻi. More importantly, it deprives the Board of the information it needs to fulfill its constitutional duties to identify and protect traditional and customary rights.

PIJAC's entirely new preferred alternative also fails to sufficiently consider and minimize impacts to Native Hawaiian traditional and customary practices. As discussed in Part V, *supra*, under the island-wide quotas proposed, all commercial aquarium take could be concentrated in specific subzones and, therefore, drastically deplete fish populations in areas of particular cultural significance or importance for subsistence purposes. The proposed quotas, would also allow for higher levels of catch than historical levels for many species, which would further exacerbate cultural impacts.

PIJAC's FEIS further attempts to minimize impacts to cultural resources by fixating on subsistence fishing instead of acknowledging the aquarium trade's broader cultural impacts. Comments on the draft EIS and PIJAC's Cultural Impact Assessment ("CIA") contain several examples of how reef fish and the ecosystems they inhabit are "cultural resources" above and

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[47] *Ka Paʻakai o ka ʻĀina v. LUC*, 94 Hawaiʻi 31, 47 (2000) ("*Ka Paʻakai*")
[48] *Id.* (emphasis in original).
[49] FEIS at 36.
[50] FEIS at 144.

beyond their value as a food source. Hawai'i law requires the state to protect "cultural and religious purposes" *in addition to* subsistence needs.

Moreover, PIJAC's CIA is wholly inadequate because it excludes nearly 80% of O'ahu's Windward coast from examination **(Fig. 1)**,[51] even though under the preferred alternative, commercial aquarium collection would be allowed *anywhere* on the island, including in and around Kāne'ohe Bay, which has become a collection hotspot in recent years. Because the CIA fails to assess impacts along the entire O'ahu coast, where collection could and would occur, the FEIS must be rejected.

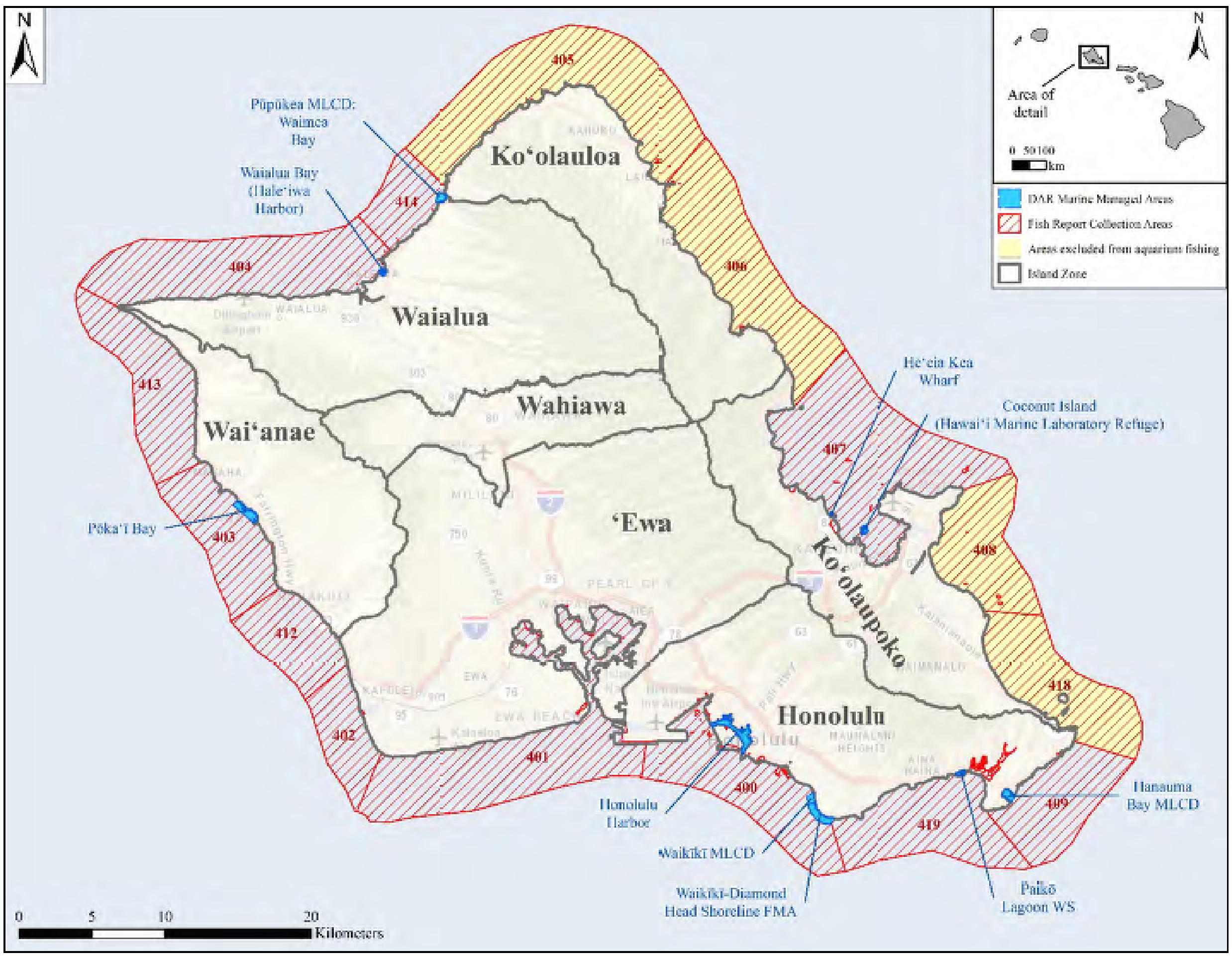

Figure 1. Study area location plotted on ESRI StreetMap World 2D map of O'ahu.

[51] *See, e.g.*, FEIS Appendix A, Cultural Impact Assessment, Figs. 1 & 2.

VIII. NO ENFORCEMENT MEASURES

PIJAC’s FEIS further fails to comply with DLNR’s specific instruction that “[e]nforcement and compliance needs and challenges . . . should be analyzed as part of the environmental impact statement.”[52] In both its initial draft EIS and in the FEIS currently before the Board, PIJAC lists some of the statutes and regulations providing for enforcement in state fisheries, but does not propose any additional enforcement, as DLNR requested. PIJAC provides no valid justification for its refusal to meet DLNR’s express requirements.

This failure to analyze enforcement “needs and challenges” raises serious concerns, particularly considering the quota system proposed in PIJAC’s all-new preferred alternative. DLNR has no mechanisms in place to enforce such quotas, and as discussed above, the quotas themselves are in most cases higher than historical take.

IX. CONCLUSION

In sum, the FEIS fails to comply with HEPA because it lacks critical information necessary for the Board to determine whether these 15 anonymous permit applicants deserve exclusive access to commercial aquarium collection on O‘ahu. The information it does provide is based on scientifically flawed and skewed analysis and is blatantly dismissive of many concerns previously raised by the Board, DLNR, and the public. Viewed in light of current science, the FEIS is little more than a self-serving recitation of the alleged benefits of the all-new proposed action—benefits that will accrue only to a limited circle of individuals, most of whom reside outside of Hawai‘i. Because the FEIS fails entirely in providing the information that HEPA requires for the Board to render a legally sound decision in the interest of all Hawai‘i citizens, the Board must reject it. Thank you for the opportunity to submit testimony on this matter.

He ali‘i ka ‘āina,

Mahesh Cleveland
Kylie Wager Cruz
EARTHJUSTICE

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[52] Final Environmental Assessment for Issuance of Aquarium Permits for the Island of O‘ahu, DLNR Notice of Determination at 3 (August 8, 2018).

From: rita elido
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] TESTIMONY OAHU EIS BEING HEARD ON OCTOBER 8, 2021
Date: Monday, October 4, 2021 12:45:26 PM

TO WHOM IT MAY CONCERNED:

ALOHA, MY NAME IS RITA ELIDO AND I SUPPORT THE AQUARIUM EIS ! I BELIEVE IT IS THE RIGHT OF THE PEOPLE OF HAWAII TO LIVE OFF THE LAND AND THE SEA WHERE THEY HAVE LIVED ALL THEIR LIVES AND THEIR FAMILIES, AS LONG AS IT IS DONE IN A SUSTAINABLE MANNER AND MANAGED BY THE DEPARTMENT OF LAND AND NATURAL RESOURCES.

PLEASE HELP AND SUPPORT THEM.

MAHALO

RITA ELIDO
CALIFORNIA

From: MICHAEL FEELEY
To: DLNR.BLNR.Testimony
Cc: Anke Roberts; lisa.fohb@gmail.com
Subject: [EXTERNAL] aquarium trade
Date: Monday, October 4, 2021 9:42:02 AM

My name is Michael Feeley, I am a Hawai'i resident living at 7007 Hawaii Kai Drive, Honolulu.

Please reject the EIS from the aquarium trade.

At a lecture given by the late Dr. Ruth Gates several years ago, someone asked her if she could have one wish, what would it be. Without hesitation, she said, "Hawaii would ban taking ANYTHING from our reefs and near shore waters for 10 years."

The aquarium trade needs to end and we need to stop catering to the greed of a few at the expense of our beautiful ocean environment. Sadly, Dr. Ruth Gates wish will probably never be granted, but as stewards of our 'aina, BLNR needs to do a more rigorous job in protecting our reefs and near shore waters.

This EIS is woefully inadequate in many areas including:

1. Claims taking small numbers of species does not cause damage
2. Inadequate monitoring to ensure the above is true.
3. No guarantees for closure of areas that are already under stress due to existing impacts

Although I wish the entire aquarium trade would be shut down permanently in Hawaii, at a minimum, BLNR has a moral and bureaucratic duty to ensure the best and most honest EIS. This EIS, like many EISs, decides on a conclusion first (they want the aquarium trade to continue), and then creates arguments that they think can influence the BLNR in their favor.

BLNR should start from the point of view that the aquarium trade is harmful and force the industry to present a complete EIS that proves to all of us there is a safe way to collect marine life from our reefs. I don't think they can do it. but this EIS doesn't come close to that goal.

Please respect the wishes of the vast majority of Hawaii residents who want the aquarium trade to stop. **REJECT THE EIS.**

E kupa'a ma ke aloha i ka 'aina

Michael Feeley
7007 Hawaii Kai Drive
Honolulu, 96825

From:	Chris Feleppa
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Reject aquarium trade
Date:	Monday, October 4, 2021 2:41:52 PM

Aloha,

I would like to oppose the notion to let the aquarium trade harvest any of Hawai'i's marine life! I am the owner of a kayak snorkeling company and I am in the water every single day. I see the lack of fish on the reef and the destruction of the reef due to overgrowth of alage due to lack of fish. The reefs need to be protected, if people want to enjoy these fish they should get in the ocean! During covid shut down I watched the reefs rejuvenate with lack of people, now that the reef is finally starting to heal we are going to let people come in and rape our ocean?!?! Tourist come here to experience the beauty of Hawai'i if we keep letting companies decimate our oceans we will be left with nothing! Please do not allow any company or personal entity, to take any fish off of our reefs for aquarium trade! Please feel free to give me a call I am happy to lend any more information you might like.

Mahalo Nui Loa
Chris Feleppa
808-638-4874
chris@tropicalguides.com

From:	cindy.ferg
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Do not allow Hawaii"s fish to be stripped from the reefs
Date:	Monday, October 4, 2021 8:12:12 PM

Having snorkeled in several locations around the western hemisphere, our observation of how depleted the reefs in Hawaii have become since our last visit to the islands, the senseless stripping of fish from these delicate reef biospheres must be stopped.

Ideas for Oral or Written Testimony

#1)

The fishery has had numerous in depth meetings with DAR and have made advances to **mitigate our impact** by reducing our total allowable catch to lower levels and by reducing the allowable catchable species by creating a much reduced "white list".

This "white list" has been reduced from **504** collectable species to **34 fish and 4 Invertebrates.**

#2)

It must be noted that due to the physical nature of Oahu, **the total area where collection occurs is much greater** than areas on other islands. For instance, the Ewa plain, where fishing occurs goes out 3 miles before depth reaches 100'. Likewise on the Waianae coast the collection areas typically go out 1 mi before it reaches the 100' level.

#3)

All aquarium fishing is done sustainably with 100% of all moneys received from outside sources **kept in our community** to feed our families and support our local businesses.

#4)

Oahu has taken on responsibility and has had **NO INSIDENCES OF POACHING** . All fishers who would receive permits under the preferred alternative have adhered to all laws regarding the shutdown of the fishery and will continue to do so until the fishery opens up again.

#5)

The Oahu aquarium fishery totally supports the fledgling aquaculture industry on Oahu. However, now that the fishery is shut down, the **aquaculture operations** are now having a difficult time acquiring brood stock which we have provided in the past.

#6)

We understand the ubiquitous concerns of the Public and the DLNR regarding **coral damage**. As a responsible fishery and knowing the importance of coral in marine health, we consciously stay away from thick coral patches where coral breakage may occur. We also typically harvest in areas where coral concentrations are minimal. This allows us to set the net where the bottom of the net touches the ocean bottom, insuring less of a chance for the fish to escape under the set net. Due to the heavy fines that have been imposed by the state from coral damage due to anchors, all anchors are strategically placed in areas where coral is not affected- such as hard bottom or sand.

#7)

Supplemental Jobs:

Due to the shutdown, many of us have had to get supplemental jobs, but it has **not provide enough income** as sustainably collecting aquarium fish. Many of us have suffered due to this and the impacts of the COVID pandemic.

#8)

The total amount of **commercial permits** issued by DAR on Oahu in 2020 was **491**, the total amount of aquarium permits we are requesting on Oahu will be **15**.

#9)

The fishery supports the **creation and implementation of FRA's** on Oahu and are looking forward to working with the DLNR to create a management plan that would benefit all fisheries in the state.

#10)

Hawaiian collected fish are considered premium quality throughout the world. Exports of aquarium fish have extremely low mortality rates rangeing between 1%-2% from collection point to supplier's facility . Any fish that are damaged are returned to the ocean.

#11)

20 of the most respected marine scientists in Hawaii have championed the aquarium fishery for it's sustainable practices thus creating a model fishery that Hawaii can be proud of.

#12)

Marine fish exported throughout the world act as ambassador's to the state of Hawaii. The fish that are seen provide an impetus for people to see the types of fish that surround our island and inspires them to come visit.

Species	Scientific Name	Individual Catch Quota (per fisher)	Maximum Annual TAC (All 15 fishers)	Percent of Population (2019 PIFSC-ESD)
Yellow Tang	*Zebrasoma flavescens*	1568	23,524	3.23%
Kole	*Ctenochaetus strigosus*	799	11,983	0.71%
Potter's Angel	*Centropyge potteri*	488	7,321	1.43%
Orange-spine Unicornfish (Clown Tang)	*Naso lituratus*	162	2,432	0.29%
Moorish Idol	*Zanclus cornutus*	71	1,067	0.42%
Bandit Angelfish	*Desmoholocanthus arcuatus*	43	638	n/a
Flame Wrasse	*Cirrhilabrus jordani*	232	3,480	n/a
Crosshatch (Redtail) Trigger	*Xanthichthys mento*	51	759	n/a
Ornate Wrasse (Pinkface)	*Halichoeres ornatissimus*	271	4,066	0.19%
Shortnose (Geoffroys's) Wrasse	*Macropharyngodon geoffroy*	173	2,592	0.54%
Fourline Wrasse	*Pseudocheilinus tetrataenia*	181	2,722	2.0%
Gilded Triggerfish (Bluethroat Trigger)	*Xanthichthys auromarginatus*	99	1,483	0.91%
Yellowtail Coris (Clown Wrasse)	*Coris gaimard*	103	1,543	0.39%
Forcepsfish	*Forcipiger flavissimus*	188	2,817	0.82%
Bicolor Anthius	*Pseudanthias bicolor*	227	3,140	4.5%
Brown Surgeonfish (Lavender, Forktail Tang)	*Acanthurus nigrofuscus*	65	969	0.009%
Hawai'i Whitespotted Toby (Puffer)	*Canthigaster jactator*	225	3,382	0.13%
Crowned Puffer (Saddleback, Crown Toby)	*Canthigaster coronata*	123	1,848	0.58%
Milletseed (Lemon) Butterflyfish	*Chaetodon miliaris*	210	3,154	0.22%
Orangeband (Shoulder) Surgeonfish	*Acanthurus olivaceus*	258	3,875	0.25%
Heniocus Butterfly (Pennantfish)	*Heniochus diphreutes*	71	1,061	0.35%
Eightline Wrasse	*Pseudocheilinus octotaenia*	127	1,905	3.18%
Saddle Wrasse	*Thalassoma duperrey*	106	1,597	0.009%
Fisher's Angelfish	*Centropyge fisheri*	108	1,627	1.38%

Dragon Wrasse (Rockmover)	*Novaculichthys taeniourus*	31	470	0.86%
Zebra Moray	*Gymnothorax zebra*	17	258	2.24%
Whitemouth Moray	*Gymnothorax meleagris*	9	140	0.24%
Golden Dwarf Moray (Dwarf Moray)	*Gymnothorax melatremus*	16	215	4.5%
Spotted Boxfish	*Ostracion meleagris*	79	1,178	1.12%
Raccoon Butterfly	*Chaetodon lunula*	42	626	0.31%
Threadfin Butterfly	*Chaetodon auriga*	24	366	1.18%

Table ___. Proposed Individual Catch Quotas for four invertebrate species. Annual limit from January 1 through December 31 of each year. No population estimates are available for invertebrates.

Species	**Scientific Name**	Individual Catch Quota (per fisher)	**Maximum Annual TAC (All 15 fishers)**
Zebra Hermit	*Clibanarius zebra*	9,128	136,917
Halloween Hermit	*Calcinus elegans*	635	9,519
Cleaner Shrimp	*Lysamata amboinensis*	196	2,946
Feather Duster Worm	*Sabellastare sanctijosephi*	3,414	51,213

From: K. Ferrari
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Aquarium Fishing Agenda Item F.1 Testimony to reject.
Date: Sunday, October 3, 2021 8:51:50 AM

Aloha nui,
Please help save our 'Aina! My name is Kimberly Ferrari. I am a diver and an dedicated to Mālama ka 'aina. I need your help to ensure our 'Aina's unique biodiversity and cultural integrity.

SUMMARY: I request that agenda item F.1 be unequivocally rejected.

I am a new resident to Kihei. I lived in California most of my life. I have been visiting the islands annually since 1984 and previously owned a condo on Hawaii 7 for years.

Our oceans are in distress and we need to protect them now before it is too late. I have personally noticed a decline in the abundance of reef fish on Maui over the years. Please do not let commercial aquarium fish collectors to reduce these numbers further.

Re: the proposed EIS:
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The EIS is flawed, it relies on insufficient, faulty, inadequate and improper data. The EIS fails to accurately analyze the environmental consequences to reefs and fish abundance of 7 aquarium collectors taking over 246,000 fish, claiming it won't cause an impact; the EIS fails to accurately analyze the cultural and socioeconomic consequences of aquarium collection in West
Hawai'i and ignores the research showing that Hawai'i residents receive ZERO benefits from the trade, but suffer *all* the costs; the EIS fails to propose and analyze any meaningful mitigation or
alternatives that would reduce the impacts; the EIS fails to adequately incorporate input of Native Hawaiian practitioners, experts, community members, and consulted parties and the EIS has NO PLAN for enforcement and compliance measures, even though DLNR asked them to provide them, and even though the trade has shown itself to be full of scofflaws.
With gratitude for the work you do, I strongly and humbly request that the proposed EIS be rejected and commercial aquarium fishing be prohibited.

Thank you for your time.
Mahalo nui loa.

Kimberly Ferrari
415 328-5957

Via Email

Date: October 6, 2021

To: Chair Case and the Board of Land and Natural Resources

From: For the Fishes, Center for Biological Diversity, The Humane Society of the United States, Moana ʻOhana, The Kaupiko ʻOhana from Miloliʻi, and Kai Palaoa

Re: Meeting of the Board of Land and Natural Resources, on October 8, 2021, at 9:00 am; **Item F.1.** Determination of Whether the Final Environmental Impact Statement (FEIS) Complies with Applicable Law and Adequately Discloses the Environmental Impacts of Proposed Issuance of Commercial Aquarium Permits, and Commercial Marine Licenses, for the island of Oʻahu, for the purpose of accepting the FEIS; dated August 20, 2021, Applicant Pet Industry Joint Advisory Council (PIJAC); Island of Oʻahu, State of Hawaiʻi.

As conservation and animal protection organizations, Native Hawaiian subsistence fishers and cultural practitioners, and individuals with strong interests in preserving the State of Hawaiʻi's natural resources and protecting its delicate coral reefs, **we strongly urge the Board of Land and Natural Resources (BLNR, or "Board") to reject** the Pet Industry Joint Advisory Council's (PIJAC's, or "Applicant's") Final Environmental Impact Statement (FEIS) purporting to analyze the environmental impacts of commercial aquarium fish collection by 15 permittees on the island of Oʻahu.[1]

Executive Summary

For the numerous reasons stated below, the Board must reject the Proposed FEIS for failing to fully declare the environmental implications of the proposed action and failing to discuss all relevant and feasible consequences of the action, in violation of HEPA.

[1] Office of Planning and Sustainable Development, The Environmental Notice at 6 (Sept. 09, 2021), http://oeqc2.doh.hawaii.gov/The_Environmental_Notice/2021-09-08-TEN.pdf; PIJAC, Final Environmental Impact Statement for the Issuance of Commercial Aquarium Permits and Commercial Marine Licenses for the Honolulu, ʻEwa, Waiʻanae, Waialua, Koʻolauloa, and Koʻolaupoko Districts of the Island of Oʻahu (2021), http://oeqc2.doh.hawaii.gov/EA_EIS_Library/2021-09-08-OA-FEIS-Oʻahu-Commercial-Aquarium-Permits.pdf.

The FEIS's failure to satisfy Hawaiʻi Environmental Policy Act's (HEPA) acceptance criteria are the result of fatally flawed analyses which led the Applicants to purport minimal impacts to populations of targeted species. These flawed analyses result in insufficient disclosures and descriptions of the direct, indirect, and cumulative impacts of the action proposed. This **grave error was reflected in every meaningful aspect of the document including the main requirement to adequately disclose and describe the identifiable environmental impacts.**

- The FEIS fails to meet all of the criteria for acceptance as defined in HRS 343-2 by **failing to fulfill the content requirements of an environmental impact statement, failing to adequately describe identifiable environmental impacts, and failing to satisfactorily respond to comments** received during the review.

- The failure to accurately and adequately describe the identifiable environmental impacts is the result of **fatally flawed analyses which led the Applicants to anticipate minimal impacts to populations of targeted species**. These omissions and analytical flaws prevent the BLNR from being adequately informed about the environmental, cultural, and socio-economic impacts of the proposed alternatives.

- The FEIS reaches conclusions that **defy logic and science and are contradictory**:
    a. the applicants claim that banning aquarium collection (i.e. the No Action Alternative) would result in "minor, unquantifiable" increases in fish and invertebrate populations; yet,
    b. the applicants then claim that allowing collection with limited permits, species, and quantity are "conservation measures," that would address concerns about declining fish populations, and de facto fish replenishment areas result in "population growth" that would positively impact the collected areas

- The analytical flaws result in **significant misrepresentations of the impacts**. The flaws flow from:
    a. **the use of data with known, high levels of scientific uncertainty**, but without disclosure and discussion of that uncertainty, or mitigation for it
    b. **a shifted baseline that attempts to hide decades of cumulative impacts** caused by decades of unbridled aquarium collection that has occurred outside of HEPA review
    c. **hypothetical and false assumptions,** such as that aquarium collection occurs uniformly across Oʻahu's reefs, which is contrary to DLNR data showing intense collection in Kāneʻohe Bay and none in other areas

- A major discrepancy exists between the FEIS and the Cultural Impact Assessment (CIA), revealing that the FEIS was not prepared in good faith:
    a. **the CIA study area excludes 21% of Oahu's shoreline**, noting on several pages that aquarium collecting <u>will be</u> prohibited in four areas: AQ zones 405, 406, 408, and 418 (the majority of the windward side).[2] yet;

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[2] FEIS at 190, 191, 196.

b. **the FEIS contains no such alternative**, not even a discussion of the possibility in the section on alternatives that were considered and dismissed – although it obviously was.

- The FEIS fails to accurately analyze impacts on cultural resources, because it excludes 21% of O'ahu's coastline from its proposed action in its CIA, fundamentally fails to accurately assess the reductions in fish abundance, and artificially narrows the scope of cultural impacts disclosed.

- The FEIS White List includes **12 fish species that were not analyzed** in the DEIS, depriving the public of the opportunity to comment on their inclusion.

- The FEIS provides **no impact analysis for three fish species and four invertebrate species** in the Preferred Alternative and at least 200 more in the other alternatives allowing take.

- **The FEIS fails to respond to many substantive and detailed comments** received by the public and other stakeholders. The applicants dismissed the comments from any consideration by simply stating **748 times that "your comment has been forwarded to the decision makers."**

- **The FEIS even fails to respond to substantive comments and questions submitted by DLNR-DAR and scientists as to the Applicant's omissions and use of mischaracterized and misrepresented data, which is the very foundation of the FEIS.**

Introduction

The **FEIS fails to meet all of the criteria for acceptance as defined in HRS 343-2** by failing to fulfill the content requirements of an environmental impact statement, failing to adequately describe identifiable environmental impacts, and failing to satisfactorily respond to comments received during the review.[3]

Additionally, the FEIS **fails to disclose the effects of the proposed action** on the economic and social welfare, and the cultural practices of the community and State, fails to propose measures to minimize adverse effects, and fails to propose adequate alternatives.[4]

The FEIS's **failure to satisfy the acceptance criteria** are primarily the result of its fatally flawed analyses which led the Applicants to anticipate minimal impacts to populations of targeted species. Those flawed analyses resulted in insufficient disclosures and descriptions of the direct, indirect, and cumulative impacts of the action in the affected areas. This grave error was reflected in every

[3] HRS 343-2: "Acceptance" means a formal determination that the document required to be filed pursuant to section 343-5 fulfills the definition of an environmental impact statement, adequately describes identifiable environmental impacts, and satisfactorily responds to comments received during the review of the statement.
[4] HRS 343-2: "Environmental impact statement" or "statement" means an informational document prepared in compliance with the rules adopted under section 343-6 and which discloses the environmental effects of a proposed action, effects of a proposed action on the economic welfare, social welfare, and cultural practices of the community and State, effects of the economic activities arising out of the proposed action, measures proposed to minimize adverse effects, and alternatives to the action and their environmental effects.

meaningful aspect of the document including the main requirement to adequately disclose and describe the identifiable environmental impacts.

These insufficiencies resulted in **improper evaluations of HEPA significance criteria** and prevent the BLNR from considering fully the environmental factors involved in the proposed action.

Therefore, the FEIS **must be rejected** because it is required to "fully declare the environmental implications of the proposed action and discuss all relevant and feasible consequences of the action," yet fails to do so.[5]

The FEIS must be rejected because it **fails to propose the required mitigation measures** "to avoid, minimize, rectify, or reduce impact, including provision for compensation for losses of cultural, community, historical, archaeological, fish and wildlife resources . . . " and to include "mitigation measures to reduce significant, unavoidable, adverse impacts to insignificant levels, and the basis for considering these levels acceptable."[6]

The FEIS must be rejected because it **fails to consider the required alternatives** that "could attain the objectives of the action. . . while minimizing some or all of the adverse environmental effects, costs, and risks."[7]

The FEIS must be rejected because it **fails in its requirement** to "satisfactorily respond to comments."[8] Having entered into this process in good faith, we believe that had the comments we submitted during the consultation and public review phase been taken seriously and satisfactorily answered, the insufficiencies would have been addressed.

The end result is an FEIS that is as deeply flawed and entirely inadequate under the Hawaiʻi Environmental Policy Act (HEPA, Haw. Rev. Chapter 343) and its implementing regulations, as it was in its first form as a Draft Environmental Assessment. In addition to the reasons listed above, the FEIS fails to address these and other notable flaws that we outlined in our prior comments:

- The FEIS fails to analyze the impacts of collection over time (i.e. the expanded 5-year scope of the analysis, beyond one year, is still inadequate);
- The FEIS fails to accurately analyze the environmental consequences (i.e. direct, indirect, and cumulative impacts) of the collection of aquatic life proposed in the alternatives to biological, cultural, and socioeconomic resources on Oʻahu;
- The FEIS fails to accurately analyze the cumulative impacts of commercial collection along with recreational aquarium collection and non-aquarium take for subsistence, cultural, and commercial purposes;
- The FEIS fails to accurately analyze impacts on cultural resources;

[5] HAR 11-200-16
[6] HAR 11-200-17 (m)
[7] HAR 11-200-17 (f)
[8] HAR 11-200-23

- The FEIS fails to accurately analyze the impacts of collection practices harmful to corals;
- The FEIS relies on inaccurate, misleading, and incomplete data.

The Applicant's Preferred Alternative **does not ensure that commercial aquarium fish collection is lawful, responsible, and sustainable** for any of the targeted fish species from nearshore habitats on Oʻahu. The FEIS's conclusion—that populations of the targeted species are not anticipated to significantly decline under any of the 6 proposed alternatives and that there will be minimal to no impacts to coral reefs and the human communities who rely upon them—is unsupported.[9]

Failure to Adequately Analyze and Disclose Environmental Impacts

The failures to adequately analyze and disclose environmental impacts stem from the application of data with high degrees of scientific uncertainty to island-wide population estimates for species that are already depleted by decades of aquarium collection that has occurred outside of HEPA review and in some cases, also by overfishing.

Omissions and Mischaracterizations of Data

The FEIS impact analysis is based upon fish population data collected in the nearshore waters of Oʻahu and provided by National Oceanic and Atmospheric Administration's (NOAA) Pacific Islands Fisheries Science Center, Ecosystem Sciences Division (PIFSC-ESD). The PIFSC-ESD nearshore fish population estimate data were not collected by NOAA for this application, and their high degree of scientific uncertainty is very problematic.

The **FEIS omits this critically important information regarding the quality of the data used in the population estimates**. The data provided to the Applicant by PIFSC-ESD includes a measure of data quality, known as the coefficient of variation (CV). The CV is used to show the precision or scientific certainty/uncertainty of data, which in this case are population estimates by species. The PIFSC-ESD CV data are color coded and include descriptors ranging from "pretty good" to "terrible."[10] **They clearly show a high degree of scientific uncertainty in the population estimates, with a majority of the White List species data in the marginal to terrible range** (summarized in Table 1 with the complete list in Appendix A). **Importantly, species in the terrible range have population estimates beginning at zero.**

[9] FEIS at 138.
[10] PIFSC-ESD (2021a).

Table 1. Summary of data quality attributed to the population estimates for White List species[11]

Data Quality	No. of Species
Terrible	10
Marginal to Weak	13
OK to Pretty Good	5

The FEIS also **misrepresents the data by repeatedly noting that the population estimates could be underestimated, while omitting the fact that the population estimates are *just as likely to be overestimated.***[12] This concern with the **Applicant's mischaracterization of the data was also noted by another Hawaiʻi research group, which commented on the DEIS that the estimates are actually even *more likely* to be *overestimated***, particularly because fish density varies widely across hardbottom habitat.[13] Notably, DAR also commented in the DEIS on the wide variation in fish density across hardbottom habitat.[14]

Rather than disclosing and discussing the data quality issues and factoring them in the analyses to prevent overexploitation, the FEIS skims the surface of this critically important issue in two short sentences: 1) "all data collection methods have a range of variation, or uncertainty"; and 2) "for the PIFSC-ESD data, this results in a high and low range for population estimates, which are included in the tables. . .for reference."[15] The FEIS provides no discussion of what those ranges mean, such as by explaining why the population estimates for ten species begin at zero and that it indicates very high degrees of scientific uncertainty. Instead, it simply states "for the purposes of this FEIS, we used the mean of those ranges to assess impacts."[16, 17] See. Figure 2 for example.

Figure 2. Excerpt from FEIS Table 3-2 depicting how the low - high range for population estimates was presented[18]

Species	Scientific Name	Mean O'ahu Population Estimate (lower-upper estimation limit)	Individual Catch Quota (per fisher)	Maximum Annual TAC (All 15 fishers)	Percent of Population (2019 PIFSC-ESD)
Yellow Tang	*Zebrasoma flavescens*	728,777 (0-1,540,367)	1,568	23,524	3.23%

Furthermore, as shown in the example provided in Figure 2, the population estimates for species with terrible data quality are very widespread between the lower and the upper estimate, ranging from zero to over 1.5 million for the yellow tang. For the yellow tang and the 22 other White List

[11] PIFSC-ESD (2021a).
[12] FEIS at 49, 1127.
[13] FEIS at 1198.
[14] FEIS at 320.
[15] FEIS at 49.
[16] FEIS at 49.
[17] FEIS at 22.
[18] FEIS at 22.

species with population estimates founded on marginal to terrible data quality, this lack of scientific certainty is far too high to use the mean as the basis for assessing environmental impacts.

As DLNR suggested in its Notice of Determination to the Applicant, the FEIS should have applied the precautionary principle which DLNR suggested in its July NOD. This is especially necessary for those species in the "terrible" range of uncertainty, for endemic species such as the flame wrasse and those also listed as species of greatest conservation need, such as Fisher's angelfish and bandit angelfish, as well as for surgeonfishes which are extremely depleted.

Furthermore, the FEIS also fails to factor the high degree of scientific uncertainty in the population estimates. For example, one way to meaningfully apply the precautionary principle and factor the uncertainty would be to use the lower end of the population estimate, instead of the mean, for species with data quality values above 20%. Using the Fisher's angelfish as a further example, applying the TAC to the lower end of its island-wide population estimate, catch as a % of population is 19%, which is far above the 1.38% claimed in the FEIS.[19] Furthermore, as described below, when applied to regional populations, catch as a % of population could range as high as 100%.

The Applicant's withholding of this information prevents the public and BLNR from knowing the true implications of the proposed alternatives and, for this reason, the FEIS must be rejected.

<u>A shifted baseline that incorporates decades of unassessed impacts</u>

Flawed analyses and hypothetical and false assumptions drive the FEIS conclusions that commercial aquarium collection under the alternatives causes minimal impacts. Another **fundamental error at the core of the flawed analyses is the incorporation of "past use and potential impacts by the commercial aquarium fishery" into the baseline against which impacts are measured.**[20] That egregious decision erases decades of aquarium collection impacts and creates an artificial and extremely shifted baseline.

The Applicant attempts to justify folding decades of unbridled and unassessed impacts into the baseline—and thereby hiding them—by claiming that commercial aquarium collecting has been around since the late 1940s.[21] The Applicant's shifted baseline attempts to hide/erase the impacts of decades of over-collection and conveniently concludes that the proposed annual take of 92,238 fish would have minimal impacts.

Not only is the Applicant's deeply flawed argument illogical, it also **fails to meet the HEPA requirement to consider past actions**. For example, in the early 1970's through the mid 1980's, reported aquarium catch on Oʻahu was greater than 100,000 fish annually. That was before the aquarium fishery collapsed on Oʻahu's leeward coast from over-collection combined with storm

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[19] FEIS at 1127.
[20] FEIS at 17.
[21] FEIS at 17.

effects.[22] Prior to the collapse, it had been considered the prime collecting area. Those leeward areas *never recovered*, and collectors shifted their focus to invertebrates, while others moved to Hawaiʻi Island, and still others shifted their focus to Kāneʻohe Bay, which is now where the most intensive collecting occurs.[23, 24] Since 2000, island-wide average reported aquarium catch has been 71,983 fish, **with 29% - 60% of that coming from Kāneʻohe Bay**.[25, 26]

In addition to shifted primary collection areas, **long-term and cumulative collection pressure has depleted natural abundance of some of the most heavily targeted species by about 90%,** while others are no longer found in their shallower depth ranges due to overcollection.[27, 28] This clear evidence of ongoing collection impact proves wrong the FEIS assertion that current fish abundance for target species is the baseline against which to apply the TAC. On the contrary, the baseline is in fact, natural (i.e. unfished) abundance, and the closest approximation of that is found in MPAs, particularly in Hanauma Bay, which was used as such in a study documenting the magnitude of the impact of aquarium collection on target species on Oahu reefs.[29]

In all of those decades the industry has been allowed to operate, the impacts have—*still*—never been addressed.

In the related context of protecting habitat for endangered salmon, federal courts require that trade degradation of baseline conditions be incorporated into the analysis of potential future jeopardy.[30] In other words, the trade's past degradation of fish populations cannot be "rolled into the *status quo* as PIJAC insists; that defeats HEPA's purpose by obfuscating the true impacts of the permits requested.

HEPA requires that "agencies shall consider the sum of effects on the quality of the environment and shall evaluate the overall and cumulative effects of an action."[31] Furthermore, the Agency must consider "both primary and secondary" consequences, "and the cumulative as well as short-term and long-term effects of an action."[32] Notably, "cumulative impact" is defined as the impact resulting from "the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions," and "[c]umulative impacts can result from individually minor but collectively significant actions taking place over a period of time."[33]

The Applicant **dismissed our comments on this critically important issue** by again repeating its refrain that "your comment has been forwarded to the decision makers."

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22 Walsh et al. (2004).
23 Walsh et al. (2004).
24 DLNR catch reports.
25 FEIS at 49, 50, 101.
26 DLNR catch reports.
27 Grabowsky & Thornhill (2020).
28 Williams et al. (2008).
29 Grabowsky & Thornhill (2020).
30 *National Wildlife Federation v. National Marine Fisheries Service*, 524 F.3d 917, 929 (9th Cir. 2008).
31 HAR § 11-200-12.
32 HAR. § 11-200-12.
33 HAR. § 11-200-2.

<u>The use of hypothetical and false assumptions in impact analyses</u>

The FEIS uses hypothetical and false assumptions to analyze impacts, such as that aquarium collection occurs uniformly across Oʻahu's reefs. This ignores reality and data showing that collection pressure in some places is much more intensive than in other places, and the FEIS thus **fails to accurately disclose the impacts of focused, intensified collection pressure.**

The FEIS anticipates minimal impacts based upon what is described as "the low percentage of the overall population of each of the targeted species that would be collected annually. . . and spread across multiple areas."[34] The fact that aquarium collection occurs in *specific places* is never addressed, and thus never adequately assessed, in the FEIS.

The use of island-wide population estimates to assess impacts occurring in specific, and often, unique, reefs result in an **FEIS that grossly miscalculates and underreports the potential effects and environmental consequences** of the aquarium collection under the proposed alternatives. The Applicant's Preferred Alternative would allow take of any and all White List species to occur in a small portion of the island, but the FEIS does not analyze those impacts and does not propose mitigation.

For example, the 92,238 fishes and 200,595 invertebrates annually allowed under the Preferred Alternative might be taken from all fifteen, from several, or from just one of Oʻahu's aquarium collection trip report zones (AQ zones) that DLNR requires aquarium collectors to use when reporting aquarium catch. In fact, because DLNR has determined that understanding take levels by AQ zone is important for monitoring and analyzing management of the aquarium fishery, collectors are prohibited from combining AQ zones when reporting catch, even for catch taken the same day. We agree with DLNR that more data yields a better analysis and that for proper management, the level of catch must be understood at the spatial scale represented in the AQ zones.

If aquarium collectors cannot combine zones for reporting purposes, the FEIS should not combine and conflate zones when analyzing impacts.

DLNR collector catch report data show large variances in overall collection pressure between the 15 AQ zones. For example, zones 401, 403, 407, 412, 413 are consistently among the most heavily collected areas, especially zone 407 (Kāneʻohe Bay) with annual aquarium fish take ranging from 9,320 to 50,232 in recent years. Meanwhile, zones 406, 408, 409, 414, 418, are among the least collected, especially zone 418 (Waimānalo) with zero fish reportedly taken from this area in recent years.[35] The 2018 - 2020 catch data by AQ zone is provided below (Table 2), and 2019 data is additionally shown in Figure 3.

Note: asterisks in the table and figure denote areas where DLNR-DAR will not release catch information — even when aggregated — claiming that because fewer than 3 collectors reported, it's a confidentiality issue. This is an outdated policy position that we urge BLNR to address, given that

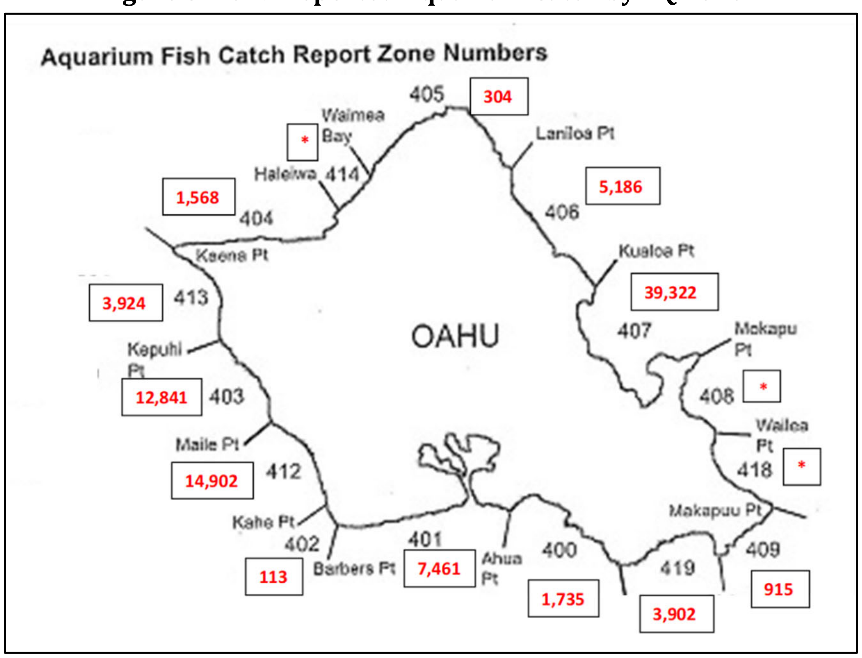
[34] FEIS at ii, 96, 132.
[35] DLNR catch reports.

no information that could identify an individual is contained in the data provided by DAR, as exemplified below.

Table 2. 2018 - 2020 Reported Aquarium Catch by AQ Zone[36]

AQ Zone	2018	2019	2020
400	2,387	1,735	*
401	5,007	7,461	4,861
402	1,692	113	*
403	6,044	12,841	10,939
404	133	1,568	647
405	*	304	*
406	76	5,186	*
407	9,320	39,322	50,232
408	0	*	*
409	*	915	*
412	16,589	14,902	8,559
413	2,765	3,924	3,790
414	*	*	*
418	0	*	0
419	1,914	3,902	4,119
Total	**45,927**	**92,173**	**83,147**

Figure 3. 2019 Reported Aquarium Catch by AQ Zone[37]



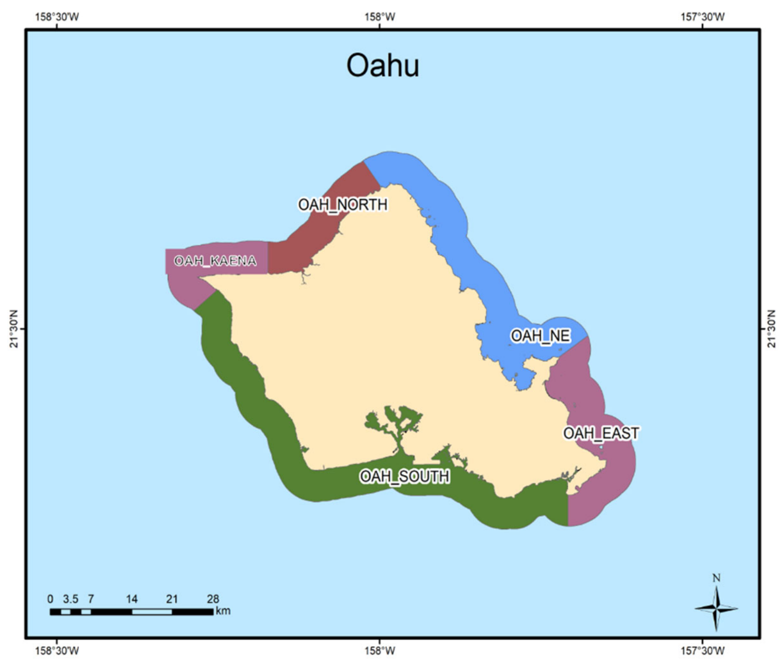
36 DLNR catch reports.
37 DLNR catch reports.

These large variances, together with the potential for all 92,238 fish to be taken from one zone each year must be addressed. Focused pressure in just a few, or even one AQ zone would have a significantly greater impact than if collection occurred in the hypothetical scenario analyzed in the FEIS where equal distribution of catch occurs across multiple areas.

Furthermore, responding to our comments on this issue, the Applicant implies that subpopulation data isn't available, writing, "population estimates included in the EIS were provided by NOAA, and were not calculated by the Applicant."[38] However, because subpopulation data were provided to us by NOAA, it appears the Applicant did not ask for anything other than island-wide data.

For the PIFSC-ESD surveys, NOAA classifies the shorelines of larger populated islands into sectors that are "designed to reflect broad differences in oceanographic exposure, reef structure, local human population density and management status."[39] O'ahu's shoreline is classified into five sectors: O'ahu north, O'ahu northeast, O'ahu east, O'ahu south, and Ka'ena (see Figure 4).

Figure 4. NOAA shoreline sectors for O'ahu



Applying the FEIS TAC to the estimated populations at the sector level, rather than island-wide, catch as a % of population far exceeds the Applicants 4.5% so-called "sustainable" level of take for 20 of the 31 White List fish species in at least one sector, and for some species, such as the yellow tang, the 4.5% threshold is exceeded in *every* sector (see Appendix B). **Alarmingly, for 10 species in at least one sector, catch as % of estimated population exceeds 25%** (see. Table 3).

[38] FEIS at 1105.
[39] Heenan (2017).

Table 3. Summary of catch as % of population by survey area.

Species	FEIS TAC Island-wide	Year*	No. of Areas w/Sightings	Catch as % of Population by Survey Area (PIFSC-ESD 2021b)**
Yellow tang	23,524	2019	5	5.0% - 299%
		2016	3	13% - 180%
Kole	11,983	2019	5	1.3% - 74%
		2016	3	1% - 4.6%
Fourline Wrasse	2,722	2019	3	2.2% - 50%
		2016	3	3.6% - 4.9%
Spotted Boxfish	1,178	2019	5	2.4% - 49%
		2016	3	2.9% - 15%
Bicolor Anthias	3,140	2019	2	5.1% - 40%
		2016	0	-
Eightline Wrasse	1,905	2019	4	5.5% - 33.4%
		2016	4	3.1% - 24%
Forcepsfish	2,817	2019	5	1.9% - 26%
		2016	3	2.4% - 26%
Bandit Angelfish***	638	2019	0	-
		2016	1	8%
Flame Wrasse	3,480	2019	0	Last sighting was 2010-2012 in 2 areas
		2016	0	
Crosshatch Triggerfish	759	2019	0	-
		2016	0	-

* Fewer surveys were conducted in 2019, thus scientific uncertainty is higher than in prior years; 2016 included for comparison[40]
** Scientific uncertainty is higher at the sector level compared to the island-wide level
*** Species of Greatest Conservation Need

The FEIS also fails to adequately respond to our DEIS comments regarding this critically important issue. It does so by ignoring the increased collection already shown in collection reports to occur in certain AQ zones; by focusing instead on the potential for *decreased* impacts in other zones; by citing research that does not apply to O'ahu; and, finally, by basing the argument for island-wide TACs on an assumption, none of which stands up to scrutiny:

> "*The DAR will receive the collection data by zone, and can review any necessary changes when they issue the permits on an annual basis. In the unlikely event that all collection occurred within a single AQ reporting zone, the DAR would be able to evaluate this information; however, this would effectively leave the rest of the coast completely free of collecting, and essentially create an FRA everywhere else. Given that on the island of Hawai'i there is connectivity between adjacent reefs (up to 184 kilometers), with fish from protected FRAs being documented to seed unprotected areas (Christie et al. 2010), it is similarly assumed that the population growth occuring in non-fished areas on O'ahu would seed the collection zones*

[40] PIFSC-ESD (2021b).

where fishing occurred, and therefore the total allowable catch limits should be based upon the entire population, not subpopulations along the O'ahu coast."[41]

The Applicant's deduction that intense collection in one or several AQ zones may leave the rest of the island free from collection does not address the central question in an EIS of what would happen in the areas experiencing heavier collection. *The omission of this essential analysis is one of the main reasons why this FEIS must be rejected.*

Additionally, the FEIS's focus on a Hawaiʻi Island study for its justification for impact analyses that are island-wide is irrelevant and ignores best available science for Oʻahu, with serious implications, as we noted in our DEIS comments.[42] The cited Hawaiʻi Island study documented larval connectivity between reefs that may be up to 184 kilometers from each other, however, **the Oʻahu study shows the opposite:** "**the majority of larvae do not disperse far. . . most dispersal is limited to less than 30 kilometers.**"[43] Additionally, the study showed how prevailing currents significantly prevent dispersal to leeward O'ahu. For example, no larval dispersal was documented to Oʻahu's southern coast, and just three instances of dispersal were documented to the west, at Kahe.[44]

Furthermore, larval dispersal and connectivity between coral reefs relates to indirect and cumulative impacts of the Applicant's actions because the effects occur "later in time [and] farther removed in distance".[45] Therefore, larval dispersal and connectivity cannot be used to justify impact analyses based upon island-wide populations.

We have repeatedly explained why place-based constraints, in much finer detail than island-wide TACs, are essential. Additionally, as DLNR, BLNR, and multiple commentors have stated, TACs should be based upon the unique life history traits of each species. They should also factor the estimated population where each species would be taken within each AQ zone or smaller area, whether or not a state of natural abundance has been achieved since January 2021, and larval sources and sinks connected to or within that area.

The Applicant's **flawed analyses inaccurately minimize the likely impacts that could occur under historical collection patterns, as well the impacts that could occur under the outer limits of what the proposed permits would allow.**

<u>Continued unresolved issues noted by DLNR and as outlined in BLNRs reasons for non-acceptance of the West Hawaiʻi FEIS</u>

In its DEIS comments, DAR noted that BLNR had recently (May 2020) declined to accept the Applicant's FEIS for the WHRFMA and suggested the Applicant consider the reasons for non-

[41] FEIS 1105, 1108, 1109.
[42] FEIS at 25, 1105, 1108, 1109.
[43] Coleman (2019).
[44] Coleman (2019).
[45] HAR 11-200-2.

acceptance when drafting the Oʻahu FEIS. The Applicant responded that "comments received on the Hawaiʻi FEIS were considered during developing of this FEIS."[46] However as detailed below**, there are glaring omissions and nearly half of BLNRs reasons for non-acceptance of the WHRFMA EIS remain equally unacceptable in this EIS for Oʻahu.**

Non-acceptance Reason #1: *"In order to properly assess the likely impact of the proposed take of the aquarium fish, the FEIS should contain a reasonably reliable estimate of the amount of future take."*

The FEIS meets the requirement to estimate the amount of future take, **yet as described above, fails to provide the constraints necessary to properly assess the likely impact**.

Furthermore, this issue is strongly aligned with non-acceptance items #6 and #7 where BLNR noted that "[collectors] could change what species they target for collection and increase the impact on some species" and "that collectors can, and do, selectively target some species more than others." Similarly, in this FEIS, collectors could change what locations they target for collection and increase the impact in some locations; and, as shown by collection reports they can, and do selectively target some locations more than others.

Non-acceptance Reason #8: "*In order to assess the likely impact of the take, the FEIS should adequately analyze the sustainable level of take. The FEIS relies on Ochavillo and Hodgson (2006) for the proposition that 5-25% of a population is a sustainable level for annual take. The FEIS has an inadequate justification for the reliance on this publication as the best available science. The FEIS does not provide data for nor statistically analyze the sustainability of that level of take for each type of fish, given each fish species' life span, population size, reproductivity rates and age at first reproduction."*

The FEIS claims to have responded to this issue by setting individual catch quotas so they limit collection to 4.5% or less of the estimated populations of the 31 White List fish species, however there is no analysis whatsoever provided for 3 of the fishes or the 4 invertebrate species.

DLNR first asked the Applicant for this statistical analysis for each fish in its July, 2018, Notice of Determination for the Applicant's Final Environmental Assessment. The Applicant has never provided the analysis and has never provided a reason for omitting it, other than stating that specific thresholds for the White List Species (or for Hawaiʻi) are not available, which is not true: methods for stock assessments for Hawaiʻi species are publicly available.[47]

As described above, the application of catch as a % of population using the PIFSC-ESD mean estimates at the island-wide level is far too fraught with scientific uncertainty to legitimately justify the levels of take proposed in the FEIS.

Lastly, an analysis of larval dispersal and connectivity patterns for the White List species is key to preventing local extirpation of heavily targeted, severely depleted, and/or rare species.

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[46] FEIS at 1193.
[47] Nadon (2017).

Non-acceptance #10: "The FEIS has an inadequate discussion of the role of herbivores. Many of the 'White List' species are herbivores."

The FEIS includes a section discussing the role of herbivores, but fails to disclose and describe the impact of the Preferred Alternative on herbivore populations. For example, five of the White list fish species are herbivorous surgeonfishes which are severely depleted on Oʻahu, and represent 42,783 of the proposed total TAC of 92,238 fishes.

The RFEIS does not disclose this impact, does not respond to our comment regarding this impact, and proposes no mitigation for this significant impact to reef fish herbivore biomass and abundance.

Furthermore, the **FEIS makes a demonstrably false statement** that research on Hawaiʻi Island shows that aquarium collection is not causing a decline in herbivores.[48] Presumably that is why the FEIS provides no impact assessment for herbivore take on Oʻahu, and omits a comparison between aquarium collection of herbivores and herbivore take for subsistence, cultural and commercial food purposes. The research cited *actually shows that herbivore biomass is greater in areas where no aquarium collection occurs* (73 g/m^2 in the MPAs compared to 43 g/m^2 in the areas open to collection).[49] On O'ahu, herbivore biomass is 2.6 times greater in MPAs, generally, and an astonishing 12.5 times greater in Hanauma Bay, the only MPA that is well-enforced.[50]

Additionally, the FEIS claims the Preferred Alternative would lessen the impact of aquarium fishing on herbivores by reducing the number of species that can be collected and establishing individual catch quotas for the herbivorous species on the White List. but it does not quantify the impact, other than describing it as "minimal."[51] **The FEIS fails to disclose and discuss the direct, indirect, and cumulative/long-term impacts of the proposed level of take on herbivores, as follows**:

- The FEIS does not quantify the impact of aquarium collecting on herbivores
- The FEIS does not quantify the reduced impacts the Applicant claims would occur under any of the Alternatives, including the Preferred Alternative
- Without TACs tied to AQ zones, collection of herbivores in any given AQ zone could *increase*

Furthermore, we note that the TACs for yellow tang and *kole*, which are the most heavily collected surgeonfishes, are greater than the average reported catch of those species by **all** (average 40) Oʻahu collectors (see Table 4.).

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[48] FEIS at 25.
[49] Gove et al. (2019) at 4, 13-16, 39.
[50] Altman-Kurosaki et al. (2021).
[51] FEIS at 138.

Table 4. Proposed TAC compared to historical reported take for two important White List herbivores.

Species	Proposed TAC by 15 collectors	Average reported catch by all (40) collectors 2000-2017[52]
Yellow Tang	23,524	15,186
Kole	11,983	9,746

The FEIS erroneously claims that "herbivores collected by the aquarium fishery typically consist of the smaller size classes which are the least effective sizes for cropping algae."[53] This is unexpected because the Applicant acknowledged the research showing the importance of small grazers in the removal of turf algae in its WHRFMA revised FEIS.[54, 55] Additionally, recent research has shown that abundance of herbivores, not biomass, determines where turf algae is most prevalent on Hawai'i's reefs.[56]

Non-acceptance Reason #11: "*The FEIS does not adequately discuss relevant negative findings, for example, the reduced numbers of aquarium fish at collection sites found by Tissot and Hallacher (2003). The FEIS need not agree or disprove the negative findings, but it should discuss them.*"

This item was **ignored by the Applicant** in its recent revised EIS for West Hawai'i, and it remains a key unresolved issue in this FEIS, despite the fact that the disclosure and discussion of findings contrary to what is claimed by the Applicant (i.e. negative findings) is key to a legal, adequate EIS. We have provided numerous examples that illustrate the need for this disclosure and discussion in our comments on the draft environmental assessment, the DEIS, and in this testimony.[57] For example:

- The paper documenting the devastating impacts of unleashed and unlimited commercial aquarium collecting on vulnerable yellow tang populations, and their subsequent collapse after Hurricane Iwa, which to this day, have not recovered [58]
- Research showing that surgeonfish larval dispersal patterns and connectivity between areas are not island-wide as claimed by the FEIS [59]
- Research using the same methods as were used by Tissot and Hallacher, mentioned by BLNR in this item, and Tissot et al. (2004) documenting that the magnitude of the impact of aquarium collection on O'ahu's heavily targeted species is a 90% reduction in natural abundance compared to the MPA baseline[60]
- Information regarding the level of scientific uncertainty in the population estimates used for the impact analyses (this is new information stemming from the FEIS use of updated 2019 population estimates)[61]

[52] FEIS at 51.
[53] FEIS at ii.
[54] RFEIS at 137, 1528, 1574.
[55] Kelly (2017).
[56] Foo and Asner (2021).
[57] RFEIS beginning at pdf pg. 475
[58] Walsh et al. (2004).
[59] Coleman (2019).
[60] Tissot & Hallacher (2003); Tissot et al. (2004); Grabowsky & Thornhill (2020).
[61] PIFSC-ESD (2021a).

- Recent research showing that abundance of herbivores, not biomass, determines where turf algae is most prevalent on Hawai‘i's reefs [62]

Non-acceptance Reason #12: "*The extreme threat of climate change on our reefs warrants extreme caution in reviewing activities that may affect them. The FEIS should further discuss potential effects of present and future levels of climate change including ocean warming, ocean acidification, coral bleaching, extreme storms, and resulting reef destruction and algae growth, and the potential for mitigating harm (i.e. further regulation) if the proposed fishery has unanticipated or greater negative effects with climate change.*"

The FEIS fails to adequately evaluate the extreme threat to targeted fish species and coral reefs from the combination of aquarium collection and climate change. The FEIS recognizes that climate change poses serious threats to Hawai‘i's coral reefs and the species targeted by the Applicant, and claims that the Preferred Alternative reduces the likelihood of overfishing and stress on the reef, and increases reef resilience." [63] Yet, it fails to quantify and evaluate the impacts of the Preferred Alternative which includes the annual removal, from reefs located in areas ranging in size from 1 to 15 AQ zones, of over 50,000 herbivorous fishes, and 250,699 invertebrates, some of which are both herbivores and detritivores, and all of which play key roles on the reef.

Further, the **FEIS completely ignores a key aspect of this nonacceptance item: a discussion or proposal for mitigation in the event of unanticipated or greater than anticipated negative impacts from aquarium collecting stemming from climate change**. For example, under the Preferred Alternative, should climate change result in habitat destruction (e.g. from storms, ocean heat waves, or acidification) or reduce the abundance of any of the White List species, during any permit period, nothing prevents the 15 aquarium collectors from focusing all of their effort in a single zone, or from removing all of any given species (in a "get it while you can" mentality). As we have noted, this is not mere speculation, as it has already happened on O‘ahu.[64]

Hawai‘i has already experienced, and is still suffering from, the impacts of overzealous commercial aquarium collection following a natural disaster. A white paper by DAR and UH researchers documents the devastating impacts of unleashed and unlimited commercial aquarium collecting on vulnerable yellow tang populations, and their subsequent collapse after Hurricane Iwa, which to this day, have not recovered.[65]

The paper documents that "I*n the weeks following the storm, . . . many fish had migrated to areas that escaped major damage . . . With the loss of collecting habitat, collectors concentrated their efforts in those sites still economically utilizable . . .*" ***"The net result was that storm effects combined with overfishing resulted in the collapse of the aquarium fishery along [the leeward] portion of the O‘ahu coastline****.*"[66]

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[62] Foo and Asner (2021).
[63] FEIS at 133.
[64] FEIS at pdf pg. 934.
[65] Walsh et al. 2004; DLNR catch reports.
[66] Walsh et al. (2004).

Prior to 1983, aquarium collectors reported taking upwards of 23,000 yellow tangs a year in those areas. Within three years of Hurricane Iwa, reported catch had dropped by more than 90%. Since 1986 reported yellow tang catch in that area has ranged from 2,000 – 6,000 per year (Fig. 5 and 6).

With no oversight from DLNR in the ensuing years, constant collection pressure, driven by consumer demand, has prevented any former abundance from returning to O'ahu's leeward coast, because aquarium collecting takes juvenile fish that are years from maturity. A sufficient number left on the reefs would have contributed to the repopulation of the yellow tangs that were at least four times more abundant four decades ago, before commercial aquarium collecting nearly wiped them out completely.

Figure 5. Catch reports document the collapse of yellow tang populations along O'ahu's SW coastline.[67]

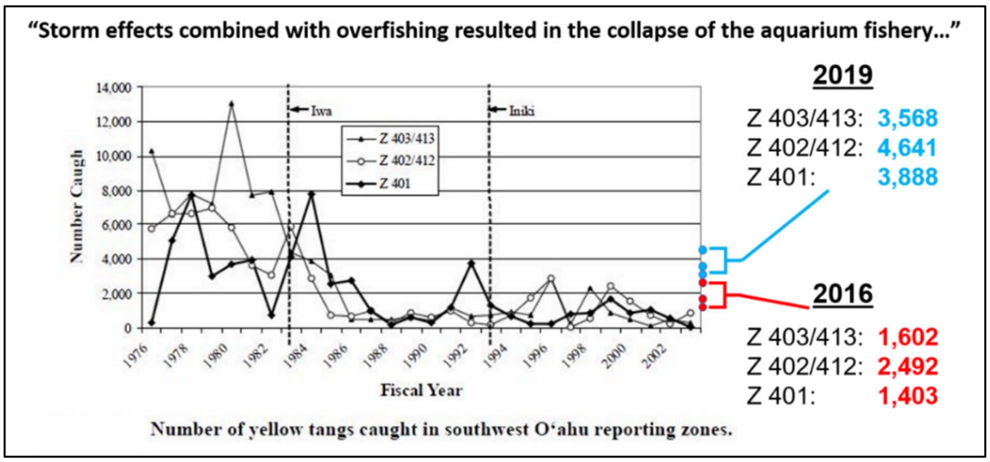
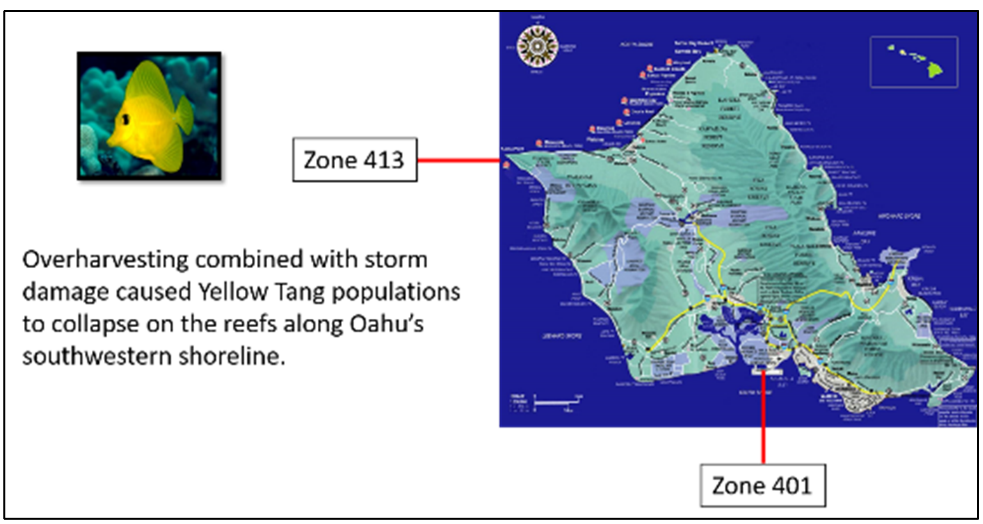


Figure. 6. Map of area encompassed within aquarium catch reporting zones 401 - 413.[68]



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[67] Walsh et al. (2004).
[68] Walsh et al. (2004).

The Applicant's refusal to respond to evidence of extreme impacts is unacceptable. Without a plan, this will happen again on Oʻahu, because coral reef damage from climate change is not a matter of "if" but of "when."[69] The FEIS does not address this, although further analysis of impacts and exacerbation of impacts due to climate change is required, as is mitigation.

The Applicant's proposed solution is inadequate, that as permits come up for annual renewal, DLNR will simply evaluate whether there are significant new circumstances, such as those created by climate change, that would require supplemental HEPA review.[70] However, the relatively short time period of the activity itself does not nullify HEPA's clear requirement for considering the long-term effects of that activity. Stating that the Agency can simply reevaluate the consequences of a year-long permit *after* that year is up entirely **contradicts HEPA's mandate to evaluate the potential consequences of an action *before* the Agency authorizes the action**. The purpose of an EIS is to anticipate an event such as the major loss of coral reef habitat that would result in the substantial decline of a target species, and propose a plan for it. Potential climate change impacts to Hawaiʻi's coral reef habitat are predicted and quantified (e.g. the loss of 70% of Hawaiʻi's coral reefs by mid-century).

Non-acceptance Reason #13: "The FEIS failed to sufficiently consider cultural impacts. The FEIS improperly concluded that the impacts to cultural resources under any of the proposed alternatives would be less than significant based on the flawed premise that cultural impacts would only occur if the proposed action would cause a significant decline in the population of a White List Species considered to be a cultural resource. A number of testimonies expressed misgivings from a cultural standpoint with the proposed activity itself, regardless of impact on resources, and this was not adequately considered in concluding no significant impact."

As set forth in HAR §§ 11-200-10, 16-18, a complete analysis and discussion of impacts to cultural resources is required. The FEIS fails to accurately analyze the direct, indirect, and cumulative impacts on cultural resources, because it (1) excludes 21% of Oʻahu's coastline from its proposed action in its CIA, an alternative that has never been proposed by the Applicant (2) fundamentally fails to accurately assess the reductions in fish abundance, and (3) artificially narrows the scope of cultural impacts disclosed. The loss and harm caused by the irrevocable commitment of natural resources equally applies to impacts to cultural resources, as well. The FEIS also fails to acknowledge and address the effects of the trade on native Hawaiian's traditional reliance on species targeted by the trade for subsistence, and most importantly, propose proper mitigation measures.

The FEIS must be rejected because the geographical extent of the CIA excludes 21% of Oʻahu's coastline. Guidance for assessing cultural impacts in the preparation of an EIS states "the geographical extent of the inquiry should, in most instances, be greater than the area over which the proposed action will take place" (emphasis added).[71] Here, cultural practitioners and others familiar with areas to the north and south of Kāneʻohe Bay, which is the most heavily

[69] Keener (2019).
[70] FEIS at 16.
[71] OEQC (1997).

collected area on the entire island, were misled and, therefore, discouraged from sharing whether and to what extent aquarium collection may be impacting their practices in those areas. Recent research shows how surgeonfish larvae are carried on currents out of Kāneʻohe Bay and into other areas to the northwest such as Hau'ula and La'ie, making Kāneʻohe Bay a source area for surgeonfishes that is linked to some of the areas excluded in the CIA.[72] Reduced abundance in one place will lead to reduced abundance in another. The physical, cultural, and socio-economic connections between unique places on O'ahu and throughout Hawaiʻi, were ignored in the CIA which requested consultation only with those with knowledge and/or engaged in cultural practices "outside of the restricted areas" which were described in a public notice in OHA's Ka Wai Ola newspaper as:

> *". . . report collection areas 405 and 406, extending from Pupukea Ahupua'a to Kualoa Point, and report collection areas 408 and 418, extending from the easternmost point of the Kaneohe Marine Corp Base to the Makapu'u lighthouse*."[73]

Decades of the Applicant's actions have directly impacted more than 200 species and indirectly impacted an unknown number of additional vertebrate and invertebrate species found in Hawaiʻi's coral reefs, one of the most complex ecosystems on Earth, where the fate of each species is determined by the existence, abundance and diverse actions of a multitude of other species that inhabit or otherwise rely upon these unique places.

While the CIA provided an extensive history of native Hawaiians and their symbiotic relationship with the ocean and its animal inhabitants, it **completely dismissed the overwhelming oral testimonies in opposition to both past and current trade practices and impacts.** More than 90 percent of those interviewed noted how the trade both directly and indirectly impacts their cultural resources, beliefs, practices and values, yet none of these concerns were addressed and no mitigation measures were proposed.

As extensively noted herein, the FEIS' CIA is extremely flawed and inadequate, with its inherent purpose – to identify cultural impacts and propose mitigations measures to limit such impacts, not being met. The FEIS provided no response to our comments on this issue.[74]

Failure to Adequately Analyze and Address Significance Criteria and Other Areas of Concern per DLNRs July 26, 2018, Notice of Determination

DLNR, in the Final Environmental Assessment, Notice of Determination, described five HEPA significance criteria and eleven additional areas requiring further analysis by the Applicant. **The Applicant failed to adequately address most of the items in the DEIS and continues to do so in the FEIS which falls far short of providing accurate analyses, and fails to reach conclusions that are supported by the evidence.**[75]

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[72] Coleman (2019).
[73] FEIS at 312.
[74] FEIS at 1129
[75] DLNR (2018).

HEPA Significance Criteria #1: The FEIS wrongly concludes "the Preferred Alternative (i.e., Limited Permit Issuance Alternative) does not involve an irrevocable commitment or loss or destruction of any natural or cultural resource." As described in our DEIS comments and detailed in this testimony, there is clear evidence of the irrevocable loss of fish abundance, a natural and cultural resource.

HEPA Significance Criteria #2: the FEIS wrongly concludes "the Preferred Alternative does not curtail the range of beneficial uses of the environment." Significant reductions in fish abundance caused by the Applicant's proposed alternatives reduces algae control provided by herbivorous fishes and invertebrates,[76] reduces the beauty of reefs and thus, visitor viewing opportunities, and reduces the integrity of diverse aquatic ecosystems, which provide $395.3 million in protection to buildings and the economy on O'ahu every year.[77]

HEPA Significance Criteria #3: the FEIS wrongly concludes that "the Preferred Alternative does not conflict with the State's long-term environmental policies, goals, or guidelines as expressed in chapter 344 HRS." As described throughout our DEIS comments and summarized here, significant adverse impacts to natural resources would occur as a result of all proposed Alternatives that allow collection.

HEPA Significance Criteria #4: the FEIS notes that the CIA concluded that "cultural impacts would occur if issuance of Aquarium Permits under an alternative would cause a significant decline in the population of a fish species considered to be a cultural resource, either directly through the collection of fish or indirectly through habitat impacts." Using the flawed analyses we've described at length, the FEIS subsequently claims that "populations of the 35 species analyzed in this EIS are not anticipated to significantly decline under the Preferred Alternative, which is demonstrably false. The FEIS adds that, "given that some Hawaiians believe any collection for aquarium purposes is contrary to cultural practices, the Preferred Alternative would impact cultural practices, but the extent of the impact is unknown." Here, the impact is unknown because the FEIS fails to accurately quantify the impacts.

HEPA Significance Criteria #8: the FEIS wrongly concludes "the Preferred Alternative does not involve a commitment for larger actions." The FEIS subsequently acknowledges there may be a significant cumulative impact to some species," but claims the measures in the Preferred Alternative may mitigate potential impacts to species.78 We challenge the proposition and likelihood of such mitigation potential given that the FEIS claims a total ban on aquarium collection would have a minor, unquantifiable increase in fish and invertebrate species.[79]

As described throughout this document, the Applicant's analyses in the FEIS are fundamentally flawed and result in erroneous evaluations of these HEPA significance criteria. By failing to properly identify the varied and significant effects of commercial aquarium collection, the FEIS fails to accurately assess both the cumulative effects of aquarium collection alone and when combined with other extractive activities.

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[76] Foo and Asner (2021).
[77] Storlanzi et al. (2019).
[78] FEIS at 145.
[79] FEIS at 144.

The evidence is clear that all proposed extractive Alternatives would significantly contribute to the cumulative effect upon the environment.

Additional Areas Requiring Further Analysis as Described in the DLNR NOD (noted in italics and followed by our response/analysis)

1) "*It is also necessary to analyze the potential impacts under the no action alternative resulting from non-issuance of aquarium permits. . .*"

The FEIS erroneously asserts that under the No Action Alternative, "a minor, although unquantifiable, increase in number of fish and invertebrates may occur over the 5-year analysis period . . ."[80]

It is well-documented in Hawaiʻi and elsewhere that the removal of fishing pressure leads to increasing abundance of fishes, which is especially true for species that have been heavily targeted. It is also well documented that Oʻahu reef fish species are severely depleted, especially surgeonfishes.[81] As the FEIS notes, the aquarium trade's take of reef fishes is at least 71,983/year, which is a substantial amount even when compared to the 194,674/year taken by food fishers (subsistence, cultural, recreational, commercial combined).[82] Surgeonfishes are heavily targeted by aquarium collectors, representing 42,783 of the proposed annual total TAC of 92,238 fishes.

Therefore, the FEIS does not properly and thoroughly analyze the impacts and reaches an erroneous conclusion.

2) "*The FEA identifies the scope of the analysis as one year and states that an EA with updated data and analysis would need to be completed on an annual basis. This improperly segments the analysis which must include the long-term and cumulative impacts over time of aquarium collection*."

The DEIS expanded the temporal scope of the analysis to 5 years, but provided no explanation for doing so. The FEIS does not respond to our comment regarding the expansion as still far too short to adequately analyze long-term and cumulative impacts over time and does not provide an explanation for the expansion to 5 years.[83]

Notably, in its revised DEIS for the WHRFMA, the Applicant *did* provide an explanation regarding the temporal scope, as follows, "the temporal scope of the impacts analysis is five years, because the WHRFMA management plan is reviewed every five years by the DLNR in cooperation with the University of Hawaiʻi (DAR 2019a)."[84]

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[80] FEIS at 125.
[81] NOAA (2018).
[82] FEIS at 129.
[83] FEIS at 1125.
[84] RDEIS at 96.

3) "*There is no statistical analysis of population growth compared to the life span of each fish and the number of years to and size of first reproduction against which this annual proposed take can be measured for purposes of estimating sustainable take*."

The FEIS entirely fails to address this issue, providing zero of the statistical analyses that were requested and zero reasons for not doing so, other than the weak claim that Ochavillo and Hodgson (2006) is the best available science because "specific research into sustainable levels of collection has not been conducted for the species collected on Oʻahu." The Applicant fails to explain why it has not conducted stock assessment modelling for target species in Hawaiʻi with known life history traits. For example, this information has been publicly available for the yellow tang since at least 2009.[85]

4) "*With regard to proposed levels of sustainable catch, using "5% to 25% annual take of estimated populations as proposed in several research papers, we note that 5% to 25% is a wide range, and the precautionary principle calls for applying the lowest estimated percentage of sustainable take in the absence of scientific certainty*."

We could not agree more with DLNR here on the importance of applying the precautionary principle in the absence of scientific certainty. Using data that is described by PIFSC-ESD staff as having high degrees of scientific uncertainty, the FEIS claims to have set sustainable levels of TACs.

We reiterate here that the so-called "sustainable" levels of catch proposed in the FEIS are far too fraught with scientific uncertainty to legitimately justify the levels of take proposed in the FEIS.

5) "*. . . Alternatives of overall annual take limits, a limited entry aquarium fishery program, and restrictions including full moratoria on the take of herbivores, species of special concern, and species evidencing severe population declines have not been proposed or analyzed*."

See our discussion below regarding the proposed alternatives.

6) "*The FEA asserts that certain types of fish such as . . . Fisher's Angelfish inhabit waters deeper than the CREP monitoring studied, resulting in populations being underestimated and thus the annual take as a percentage of estimated population being overestimated*."

See above where we describe that according to NOAA, populations are just as likely to be overestimated, as underestimated, and specifically regarding the Fisher's Angelfish at page 5.

7) "*In addition, we note the proposed alternatives for reduction in bag limits for Flame Wrasse, but do not see a scientific basis for concluding that the proposed reduction would be sufficient to sustain the population*."

The FEIS fails to provide the scientific basis for concluding that the Applicant's proposed TAC of 3,480 flame wrasse, which is more than three times greater than the annual average of 1,605 reported since 2000 by *all* aquarium collectors is sustainable, given that no current population estimate exists for flame wrasse on Oʻahu.

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[85] Claisse et al. (2009)

The FEIS provides no impact analysis for the proposed flame wrasse TAC, falsely claiming that they are a deep-water species, "and thus the O'ahu Flame Wrasse populations were not estimated in 2019.[86], [87] Not only is the flame wrasse not a deep-water species, having been surveyed by the PIFSC-ESD team in 2010-2012 in two different areas, it is scientifically described by a leading expert as "generally at depths greater than 60 feet," and by the IUCN as having an upper depth limit of 39.6 feet.[88, 89] Furthermore, the flame wrasse has been encountered and photographed in that range for decades by many people, in areas not accessed by the aquarium trade, including some of the Commenters.

Since the flame wrasse is not a deep-water species, the curtailment of its natural range is likely an indicator of severe over-collection by commercial aquarium collectors in the shallower depths they once inhabited.

The FEIS also fails to adequately respond to our comments on this issue regarding the cumulative impact of collection by providing a one-sentence response that is a simple recitation of the proposed TAC.[90]

8) "*We note the proposed alternative for an expansion of the Waikiki Marine Life Conservation District, but do not see a scientific review of the beneficial impact of Fishery Replenishment Areas on restoring populations, such as has been demonstrated in West Hawaiʻi, nor an analysis of the optimal placement of the Fishery Replenishment Areas on Oʻahu to protect and restore populations of aquarium fish.*"

The FEIS fails to discuss or analyze the direct impacts of expanding the Waikīkī MLCD, such as the extent to which fish abundance would increase and what the limiting factors might be, but does discuss the indirect impacts, such as the likely increase in collection pressure elsewhere that would result from the closure, and the potential for larval export elsewhere.[91]

The FEIS also fails to discuss the optimal placement of Fishery Replenishment Areas (FRAs) on Oʻahu, even though it is apparent by the CIA study area that excludes AQ Zones 405, 406, 408, and 418, at some point the Applicant seriously considered proposing the establishment of FRAs on Oʻahu.

Furthermore, in its DEIS comments, DAR recommended "the applicant consider proposing the creation of a network of FRAs on Oʻahu as an alternative or in addition to the Waikiki MLCD expansion." The Applicant responded that "this was not included as an alternative since the

[86] FEIS at 56.
[87] PIFSC-ESD (2021a).
[88] John Randall (1996).
[89] Rocha (2010).
[90] FEIS at 1128.
[91] FEIS at 116.

Applicant does not have the authority/ability to establish FRAs," which is nonsensical given that they proposed an expansion of the Waikīkī MLCD.[92]

The FEIS also fails to adequately respond to our comments on this issue by providing a one-sentence response, "the Preferred Alternative no longer includes an expanded Waikiki MLCD."[93]

9) "*Enforcement and compliance needs and challenges are key factors in the effectiveness of fisheries management, and should be analyzed as part of the environmental impact statement*."

The FEIS does not analyze the enforcement and compliance needs and challenges and fails to address this issue. It also fails to adequately respond to our comments on this issue by providing a one-sentence response: "enforcement is within the purview of the state of Hawaiʻi."[94] At least eight people have been involved in illegal aquarium collecting on Hawaiʻi Island over the last 18 months, five of whom have been cited, and two of whom have been convicted, to date, but the FEIS fails to discuss this major problem or to propose any solutions.

Furthermore, DLNRs extreme lack of resources prevents it from providing the oversight necessary ensure catch and reporting requirements.

At the very least, to ensure compliance, a catch verification system that does not rely upon funding from DLNR for execution should have been proposed. This is essential, given that **DLNR has estimated an annual cost of $300,000 to $500,000 for the administration of aquarium permits, not including enforcement or catch verification, and which far exceeds the tax and permit revenues generated by the aquarium trade.**

Additionally, an important avenue for validation, tallies of the species and their numbers leaving the state via air cargo, which are required by federal law, are not being provided, exposing both aquarium trade members and air cargo carriers to violations of the federal Lacey Act.

10) "*We appreciate that as an applicant action, the applicant can propose but not ensure regulations aimed at protecting and restoring populations of aquarium fish. We are interested in proposals for self-regulation by aquarium permit holders which could be incorporated into permit conditions even in the absence of or prior to establishing other regulations to accomplish the same purposes*."

The EFIS fails to address this issue, providing no proposals for self-regulation that could be incorporated into permit conditions. It also fails to adequately respond to our comments on this issue by providing a one-sentence response: "reporting of catch is already a permit condition."[95]

One proposal the Applicant could have made is public disclosure of what was caught, what was sold, and what was shipped out of the state. The trade could develop a searchable website that includes documentation of aquarium catch, dealer sales, and air waybills showing the tallies of the species and their numbers leaving the state via air cargo.

[92] FEIS at 1192.
[93] FEIS at 1129.
[94] FEIS at 1130.
[95] FEIS at 1130.

11) "*Overall, we appreciate that certain alternatives have been proposed, but believe they are more appropriately proposed as mitigation measures in an environmental impact statement to mitigate potential environmental impacts, rather than as alternatives in an environmental assessment, which, if implemented, might result in a finding of no significant impact. The Department of Land and Natural Resources is obligated to ensure full analysis under HRS Chapter 343 of potential environmental impacts of its actions in issuing aquarium permits. We believe this is most appropriate in an environmental impact statement.*"

The FEIS fails to address this issue and proposes no mitigation measures. Instead it concludes through erroneous analyses and omissions of essential information that their proposed actions will cause minimal impacts. It also fails to adequately respond to our comments on this issue by providing no response.[96]

Failure to accurately analyze alternatives

The FEIS fails to accurately and adequately analyze the direct, indirect, cumulative and long-term impacts of the proposed alternatives. The analyses of the collection of fish and invertebrates is merely a recitation of the number of animals that would be taken under each alternative.[97] According to the Applicant, taking zero fishes and invertebrates results in the same impacts as taking hundreds of thousands of them.

The FEIS claims that even after 5 years, the No Action alternative would result in "a minor, although unquantifiable, increase in number of fish and invertebrates."[98] This position defies logic: the No Action Alternative would effectively create an island-wide fish replenishment area (FRA), but with minor, unquantifiable impacts. It also defies science and a fundamental premise of marine resource management that reducing or prohibiting take can and does replenish abundance.

More importantly, if disallowing take via an island-wide FRA will not measurably increase fish abundance, then certainly neither will allowing take. Calling the proposed limits "conservation measures" will not change this fundamental law of nature.

The key conservation aspects of the Applicant's proposed Alternatives that are contradicted by the claim in the No Action Alternative include:

- Expanding the Waikīkī marine life conservation district
- Limiting the number of permits and licenses issued
- Limiting take to 35 species, with all others off limits
- Limiting take by setting annual TACs

The FEIS also refers to the three limits above as "mitigative measures. . .which would minimize impacts to biological resources."[99] However, **the Applicant fails to explain what measurable**

[96] FEIS at 1130.
[97] FEIS at 138.
[98] FEIS at 125.
[99] FEIS at 100, 137.

conservation or mitigation results from the above measures, if total conservation in the No Action Alternative results in no quantifiable increases in populations.

Furthermore, additional and serious contradictions occur in the positions and statements made by the Applicant in response to comments, such as:

- Acknowledging that the fish replenishment areas (FRAs) on Hawai'i Island do replenish fish.
- Referring to the "population growth" that would similarly occur in O'ahu AQ zones where no collection would occur, and stating the population growth would seed the areas where collection occurs.[100]

The Applicants dismissal and denial of the most basic, sound scientific principles in order to deny the impacts of their proposed contradicts all pretense of conservation value contained within the various alternatives.

Additional issues contained with the various alternatives include:

- The inclusion of species lacking sufficient data, though DAR suggested proposing a moratorium on such species.[101]
- The inclusion of species lacking impact analyses, though DAR noted "if species will be subject to collection under the proposed action, the applicant must analyze the impacts to these species."[102]
- The inclusion of species on DLNRs Species of Greatest Conservation Need (SGCN) list, though the Applicant specifically excluded all such species from its Hawai'i Island FEIS.
- The inclusion of the bandit angelfish, an SGCN species, which in a published report is described by DAR staff as "heavily targeted by the aquarium trade and has substantially declined in abundance within normal diving depths on heavily-collected reefs.[103]
- The omission of information pertaining to species that have been identified previously as overfished, in a state of overfishing, or otherwise population depleted, though DAR requested that information and it is publicly available. For example, the orangespine unicornfish which is included in the White List, is included in a list of surgeonfish that are in a state of overfishing.[104]
- The inclusion of the Moorish Idol, a species with especially poor captive survivability, which was excluded from the Hawai'i Island White List for that very reason.
- The claim that, aside from *reducing* permit numbers, species, and take, the Preferred Alternative is no different from what has occurred in the past, which is false given that the TACs would *increase* take for 28 species by 23% - 226% above the historical reported average by *all aquarium collectors* (see Appendix C.).[105]

[100] FEIS at 1105, 1108, 1109.
[101] FEIS at 321.
[102] FEIS at 321.
[103] Williams et al. (2008).
[104] Nadon (2017).
[105] FEIS at 142.

- The omission of an independent cost/benefit analysis of the Hawaiʻi aquarium trade which determined that ending the trade was the only option that yielded positive annual benefits, and in addition, negatively impacted the fewest stakeholders.[106]

Conclusion:

For the reasons explained in detail above, as well as those found in our prior comments on the DEIS, the FEIS remains patently insufficient as required by HEPA and in its analysis of the impacts of the issuance of commercial aquarium collection permits.

The legislature has decreed it the "policy of the State" that DNLR and other agencies must "[c]onserve natural resources . . . by preserving or augmenting natural resources, and by safeguarding the State's unique natural environmental characteristics . . . ."[107] The Agency must also "[e]ncourage management practices which conserve . . . all natural resources," and encourage all individuals "to fulfill the responsibility as trustees of the environment for the present and succeeding generations."[108] In enacting HEPA, the State legislature found "that the quality of humanity's environment is critical to humanity's well-being, [and] that humanity's activities have broad and profound effects upon the interrelations of all components of the environment . . . ."[109]

The Agency simply cannot meet these mandates where decision-making is based upon an EIS such as this one that is so fundamentally flawed. This FEIS prevents BLNR from being adequately informed about the environmental, cultural, and socio-economic impacts of the proposed action.

Respectfully submitted,

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[106] Schaar and Cox (2021).
[107] Haw. Rev. Stat. § 344-3(1).
[108] Haw. Rev. Stat. § 344-4(2)(A), (10)(A).
[109] Haw. Rev. Stat. § 343-1.

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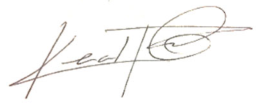

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Appendix A. Quality of data used to determine population estimates per PIFSC-ESD (2021a): "green is pretty good to OK (~<20%), yellow is OK to marginal (~20-30%), orange is weak (~30-50%), red is terrible (~>50%)."[110]

Species	FEIS Mean Population Estimate	Estimated Population	Data Quality (Coefficient of Variation)	FEIS TAC	Catch as % of population w/data quality factored
			"Terrible"		
Zebra Moray Eel	11,501	0 - 34,495	**100%**	258	
Dwarf Moray Eel	4,761	0 - 14,275	**100%**	215	
Bicolor Anthias	69,760	0 - 194,445	**89%**	3,140	
Pennantfish	301,466	0 - 697,765	**66%**	1,061	
Milletseed Butterflyfish	1,452,891	0 - 3,298,935	**64%**	3,154	
Eightline Wrasse	59,945	0 - 135,882	**63%**	1,905	
Yellow Tang	728,777	0 - 1,540,367	**56%**	23,524	
Fourline Wrasse	134,617	0 - 285,987	**56%**	2,722	
Threadfin Butterflyfish	31,081	0 - 65,523	**55%**	366	
Gilded Triggerfish	162,831	0 - 333,479	**52%**	1,483	
			"Weak"		
Dragon Wrasse	54,784	2,249 - 107,318	**48%**	470	
Fisher's Angelfish: SGCN	117,920	8,395 - 227,445	**46%**	1,627	
Orangespine Unicornfish	837,112	89,180 - 1,575,044	**45%**	2,432	
Whitemouth Moray Eel	58,821	5,662 - 111,981	**45%**	140	
Potter's Angelfish	512,697	69,122 -	**43%**	7,321	

[110] PIFSC-ESD (2021a)

		956,271			
Ornate Wrasse	2,137,281	568,609- 3,705,953	**37%**	4,066	
Forcepsfish	345,009	88,777 - 601,240	**37%**	2,817	
Spotted boxfish	104,861	27,348 - 182,375	**37%**	1,178	
Raccoon Butterflyfish	201,288	57,190 - 345,385	**36%**	626	
			"Marginal"		
Shortnose Wrasse	481,899	207,785 - 756,013	**28%**	2,592	
Yellowtail Coris	397,004	181,127 - 612,880	**27%**	1,543	
Crowned Puffer	319,076	151,702 - 486,450	**26%**	1,848	
Kole	1,690,372	803,819 - 2,576,925	**26%**	11,983	
			"OK"		
Moorish Idol	251,451	129,331 - 373,571	**24%**	1,067	
Orangeband Surgeonfish	1,534,094	821,719 - 2,246,470	**23%**	3,875	
Brown Surgeonfish	10,523,860	6,948,387 - 14,099,332	**17%**	969	
			"Pretty good"		
Hawaiian Whitespotted Toby	2,513,096	1,939,093 - 3,087,100	**11%**	3,382	
Saddle Wrasse	17,655,664	14,778,717 - 20,532,611	**8%**	1,597	
Bandit Angelfish: SGCN	0	0		638	
Flame Wrasse	0	0		3,480	
Crosshatch Triggerfish	0	0		759	

Appendix B. Estimated 2019 Mean Abundance by PIFSC-ESD Survey Sector with TAC as % of Sector Population [111]

			Estimated 2019 Mean Abundance by PIFSC-ESD Survey Sector (TAC as % of Sector Population)				
Species	**FEIS TAC**	**Year**	**Northeast**	**East**	**South**	**Kaena**	**North**
Yellow tang	23,524	2019	18,185 (129%)	501,941 (5%)	178,134 (13%)	22,646 (103%)	7,870 (299%)
		2016	45,463 (52%)	13,074 (180%)	186,508 (13%)	-	0
Kole	11,983	2019	180,199 (6.6%)	924,687 (1.3%)	457,247 (2.6%)	112,016 (10.7%)	16,224 (74%)
		2016	908,153 (1.3%)	261,547 (4.6%)	1,076,547 (1%)	-	0
Potter's Angelfish	7,321	2019	57,105 (13%)	284,888 (2.6%)	30,925 (23.7%)	71,412 (10%)	68,367 (10.7%)
		2016	75,772 (9.7%)	22,307 (33%)	86,703 (8.4%)	-	39,350 (18.6%)
Orangespine Unicornfish	2,432	2019	118,879 (2%)	508,294 (.5%)	76,018 (3%)	77,717 (3%)	56,204 (4%)
		2016	420,462 (.6%)	347,689 (.7%)	314,648 (.8%)	-	0
Moorish Idol	1,067	2019	36,371 (3%)	55,397 (2%)	113,048 (1%)	30,412 (3.5%)	16,224 (6.6%)
		2016	97,538 (1.1%)	0	145,557 (.07%)	-	0
Bandit Angelfish*	638	2019	0	0	0	0	0
		2016	0	0	0	-	7,870 (8%)
Flame Wrasse	3,480	2019	0	0	0	0	0
		2016	0	0	0	-	0
Crosshatch Triggerfish	759	2019	0	0	0	0	0
		2016	0	0	0	-	0
Ornate Wrasse	4,066	2019	633,770 (.6%)	290,773 (1.4%)	1,061,221 (.4%)	57,101 (7%)	94,416 (4.3%)
		2016	286,003 (1.4%)	78,443 (5.2%)	152,855 (2.7%)	-	16,224 (25%)
Shortnose Wrasse	2,592	2019	237,906 (1.1%)	82,871 (3.1%)	69,147 (3.7%)	35,771 (7.2%)	56,204 (4.6%)
		2016	186,534 (1.4%)	91,517 (2.8%)	490,324 (.5%)	-	39,834 (6.5%)
Fourline Wrasse	2,722	2019	5,710 (48%)	0	123,499 (2.2%)	0	5,408 (50%)
		2016	60,618 (4.5%)	74,602 (3.6%)	55,544 (4.9%)	-	0
Gilded Triggerfish	1,483	2019	0	0	162,831 (.9%)	0	
		2016	0	0	281,759 (.5%)	-	0
Yellowtail Coris	1,543	2019	113,168 (1.4%)	87,958 (1.8%)	147,550 (1%)	32,168 (4.8%)	16,160 (9.5%)
		2016	71,501 (2.2%)	130,739 (1.2%)	122,164 (1.3%)	-	0
Forcepsfish	2,817	2019	96,637 (2.9%)	149,721 (1.9%)	64,518 (4.4%)	23,317 (12.1%)	10,816 (26%)
		2016	15,154 (18.6%)	10,907 (26%)	115,683 (2.4%)	-	0
Bicolor Anthias	3,140	2019	0	0	0	61,890 (5.1%)	7,870 (40%)
		2016	0	0	0	-	0
Brown Surgeonfish	969	2019	2,725,802 (.04%)	3,738,913 (.03%)	2,672,999 (.04%)	730,942 (.13%)	655,204 (.15%)
		2016	5,724,037 (.02%)	5,123,865 (.02%)	6,266,343 (.02%)	-	366,373 (.26%)

[111] PIFSC-ESD (2021b).

Hawaiian Whitespotted Toby	3,382	2019	675,700 (.5%)	515,976 (.7%)	1,043,388 (.3%)	73,626 (4.6%)	204,407 (1.7%)
		2016	233,928 (1.4%)	230,255 (1.5%)	723,832 (.5%)	-	72,039 (4.7%)
Crowned Puffer	1,848	2019	0	21,813 (8.5%)	135,909 (1.4%)	19,043 (9.7%)	142,311 (1.3%)
		2016	0	9,233 (20%)	110,522 (1.7%)	-	62,959 (2.9%)
Milletseed Butterflyfish	3,154	2019	64,923 (4.9%)	923,888 (.3%)	371,972 (.8%)	51,790 (6%)	40,318 (7.9%)
		2016	60,618 (5.2%)	26,148 (12%)	78,938 (4%)	-	0
Orangeband Surgeonfish	3,875	2019	195,823 (2%)	146,937 (2.6%)	772,113 (.5%)	164,607 (2.4%)	254,614 (1.5%)
		2016	192,736 (2%)	342,668 (1.1%)	567,877 (.7%)	-	48,430 (8%)
Pennantfish	1,061	2019	0	191,750 (.6%)	90,673 (1.2%)	19,043 (5.6%)	0
		2016	0	0	58,180 (1.8%)	-	0
Eightline Wrasse	1,905	2019	5,710 (33.4%)	34,864 (5.5%)	11,501 (16.6%)	0	7,870 (24%)
		2016	60,618 (3.1%)	13,074 (14.6%)	47,463 (4%)	-	7,870 (24%)
Saddle Wrasse	1,597	2019	7,437,221 (.02%)	2,923,897 (.05%)	4,160,822 (.04%)	1,432,073 (.11%)	1,701,650 (.09%)
		2016	5,564,479 (.03%)	3,166,625 (.05%)	2,868,431 (.055%)	-	452,942 (.35%)
Fisher's Angelfish*	1,627	2019	0	0	72,158 (2.3%)	14,282 (11.4%)	31,480 (5.2%)
		2016	0	0	13,744 (11.8%)	-	0
Dragon Wrasse	470	2019	0	0	0	19,043 (2.5%)	24,240 (1.9%)
		2016	0	0	29,090 (1.6%)	-	0
Zebra Moray Eel	258	2019	0	0	11,501 (2.2%)	0	0
		2016	0	0	0	-	0
Whitemouth Moray Eel	140	2019	0	17,432 (.8%)	33,310 (.4%)	0	8,080(1.7%)
		2016	15,154 (.9%)	0	54,727 (.25%)	-	8,112 (1.7%)
Dwarf Moray Eel	215	2019	0	0	0	4,761 (4.5%)	0
		2016	0	0	11,109 (1.9%)	-	0
Spotted Boxfish	1,178	2019	23,896 (4.9%)	13,849 (8.5%)	48,530 (2.4%)	2,426 (49%)	16,160 (7.3%)
		2016	41,192 (2.9%)	0	33,327 (3.5%)	-	7,870 (15%)
Raccoon Butterflyfish	626	2019	0	122,023 (.5%)	69,004 (.9%)	4,853 (12.9%)	5,408 (11.6%)
		2016	0	10,907 (5.7%)	69,004 (.9%)	-	0
Threadfin Butterflyfish	366	2019	0	0	23,001 (1.6%)	0	8,080 (4.5%)
		2016	0	0	23,001 (1.6%)	-	-

* Species of Greatest Conservation Need

Appendix C. Proposed TACs compared to average reported catch 2000-2017.

Species	Average Reported by 40 Collectors 2000 - 2017	FEIS TAC by 15 collectors	Difference
Yellow tang	15,186	23,524	+55%
Kole	9,746	11,983	+23%
Ornate Wrasse	2,562	4,066	+59%
Flame Wrasse	1,605	3,480	+117%
Fourline Wrasse	1,604	2,722	+70%
Hawaiian Whitespotted Toby	1,590	3,382	+113%
Forcepsfish	1,583	2,817	+78%
Milletseed Butterflyfish	1,405	3,154	+124%
Shortnose Wrasse	1,355	2,592	+91%
Bicolor Anthias	1,343	3,140	+134%
Orangeband surg.	1,343	3,875	+189%
Eightline wrasse	892	1,905	+114%
Crowned Puffer	809	1,848	+128%
Saddle Wrasse	804	1,597	+99%
Fisher's Angelfish: SGCN	756	1,627	+115%
Yellowtail Coris	673	1,543	+129%
Pennantfish	631	1,061	+68%
Spotted Boxfish	576	1,178	+105%
Gilded Triggerfish	497	1,483	+198%
Brown Surgeonfish	454	969	+113%
Crosshatch Triggerfish	389	759	+95%
Raccoon Butterflyfish	310	626	+102%
Bandit Angelfish: SGCN	286	638	+123%
Threadfin Butterflyfish	239	366	+53%
Dragon Wrasse	155	470	+203%
Zebra Moray	110	258	+135%
Dwarf Moray	66	215	+226%
Whitemouth Moray	48	140	+192%

PATTERNS OF CONNECTIVITY IN CORAL REEF FISHES
ACROSS THREE SPATIAL SCALES

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAIʻI AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

ZOOLOGY (ECOLOGY, EVOLUTION AND CONSERVATION BIOLOGY)

DECEMBER 2019

By

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Dissertation Committee:

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ABSTRACT

The vast majority of reef fish have a life history consisting of a pelagic larval phase of typically 20 to 60 days and followed by larval settlement where they remain through their juvenile and adult phase. It is during the pelagic larval phase that nearly all dispersal across great distances is accomplished. Understanding connectivity and dispersal pathways, as well as identifying the underlying mechanisms influencing these patterns are essential to properly understand how biodiversity is generated and maintained in the sea. The scale in which these patterns can be identified can also illuminate evolutionary processes, and can inform conservation strategies. Since direct observation of larvae is impractical, a variety of methods have been developed to characterize connectivity and dispersal patterns in marine organisms. Here, I incorporated several different genetic based approaches to assess connectivity across a suite of spatial scales: across ocean basins (Indian and Pacific Oceans), across an isolated archipelago (Hawaiian Archipelago), and at the island scale (Oʻahu). From an ocean basin scale, the results of this work identified historic barriers to dispersal, refugia during the Pleistocene, and recovered cryptic diversity. At the archipelago and island scale, this work shows how biogeographic distribution can be predictive of dispersal potential. recovered previous unknown management units and showed the complex system of dispersal pathways and the role these systems play in regards to informing management strategies. By evaluating connectivity across different spatial scales, this work highlights the different processes facilitating evolution as well as enhancing our ability to inform conservation and management goals.

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CHAPTER 1 INTRODUCTION

The vast majority of reef fish have a life history consisting of a pelagic larval phase of typically 20 to 60 days and followed by larval settlement where they remain through their juvenile and adult phase. It is during the pelagic larval phase that nearly all dispersal across great distances is accomplished (Leis & McCormick 2002). Previous studies that have investigated marine organisms with pelagic larvae often can often show little genetic differentiation across thousands of kilometers and are associated with high levels of gene flow and wide range distributions (Hellberg *et al.* 2002; Palumbi 2003). However, studies have also demonstrated high levels of self-recruitment and local larval retention in reef fishes illustrating that not all marine organisms exhibit broad-scale dispersal (Planes *et al.* 1998a; Swearer *et al.* 2002; Planes *et al.* 2009; Berumen *et al.* 2012; Jones 2015).

Since direct observation of larvae is impractical, a variety of methods have been developed to characterize connectivity and dispersal patterns in marine organisms. Common techniques include chemical tagging, hydrodynamic and biophysical models, and genetic based methods (Jones 2015). Genetic based approaches are well-suited for studying connectivity since identifying genetically differentiated populations only require minor differences in gene flow (Hellberg *et al.* 2002). Additionally, genetic signatures can be used to assign parents and offspring (e.g. parentage analysis) and therefore a direct measure of connectivity by identifying dispersal pathways from the natal spawning location to where the larvae ultimately settled.

Understanding connectivity and dispersal pathways, as well as identifying the underlying mechanisms influencing these patterns are essential to properly understand how biodiversity is generated and maintained in the sea. The scale in which these patterns can be identified can also illuminate evolutionary processes, and can inform conservation and management strategies. For the studies presented here, I assessed connectivity across a suite of spatial scales: across ocean basins (i.e. Indian and Pacific Oceans), across an isolated archipelago, and at the island scale. By evaluating connectivity across different spatial scales, I was able to add to our understanding of the different processes facilitating evolution as well as inform conservation and management goals.

A phylogeographic approach was implemented to assess connectivity in the Regal Angelfish, *Pygoplites diacanthus,* a species whose distribution extends across the Red Sea, Indian and Pacific Oceans. Phylogeography is the study of the historical processes that are responsible for the contemporary distribution of genetic lineages within a species. These studies have been essential in identifying areas of endemism (DiBattista *et al.* 2015; DiBattista *et al.* 2016), cryptic species (Rocha *et al.* 2007; DiBattista *et al.* 2016), and the locations of biogeographic barriers (Rocha *et al.* 2007; Toonen *et al.* 2016) which often fall at the edge of biogeographic provinces (Briggs & Bowen 2013; Toonen *et al.* 2016). Often, after identifying cryptic genetic lineages, previously unobserved morphological characters are identified. For this study, two *P. diacanthus* morphotypes exist: one distributed in the Indian Ocean and Red Sea, the other one in the Pacific Ocean. By undertaking a phylogeographic approach we aimed to resolve the taxonomic distinction between the different morphotypes and identify historic geological processes that have promoted or restricted diversification within this species.

Assessing connectivity across the Hawaiian Archipelago provided an opportunity to compare connectivity against an evolutionary and contemporary framework. Hawaii is the most isolated archipelago in the world, with the closest land mass nearly 1000 km away, and its geological history has been extensively studied. Uniquely, every organism that is found there originated elsewhere in the Pacific. Over the past few decades the archipelago has acted as natural laboratory to investigate connectivity patterns of more than 40 marine species representing a variety of organisms that are ecological and taxonomically distinct (see Toonen et al. (2011); Selkoe et al. (2016), and references therein). The capacity to assess connectivity across a broad spectrum of taxa, including endemic and wide-ranging species, has provided insight into the origins of biodiversity (Bird 2011; Eble *et al.* 2011b; Skillings *et al.* 2011), the evolutionary consequences of invasive species (Gaither *et al.* 2010a; Coleman *et al.* 2014), the ability to identify the location of ecological barriers to dispersal (Toonen *et al.* 2011), fishery related impacts (Iacchei *et al.* 2014), and the role of life history on influencing genetic structure and diversity (Selkoe *et al.* 2014; Selkoe *et al.* 2016b).

Phylogeographic and traditional population genetic approaches were typically used to characterize connectivity patterns for Hawaiian organisms. A common trait among these past studies was the use of targeted loci, including single markers, to describe connectivity within each species. Although, utilizing targeted loci methods are useful for describing patterns of connectivity across an evolutionary timescale, they have limited ability to identify contemporary connectivity patterns. By incorporating high-throughput sequencing, which generates thousands of loci in a single run, we now have the power to describe contemporary patterns that could not be accomplished in a practical manner using a targeted loci approach.

For this portion of my research, I identified two species of surgeonfishes, *Acanthurus triostegus* (*manini*) and *Ctenocheatus strigosus* (*kole*), that exhibit similar life history strategies and occupy similiar habitat. However, they differ greatly in their biogeographic distribution, thus providing an excellent framework to compare patterns of connectivity across Hawaii. Additionally, connectivity across the Hawaiian Archipelago has been previously described for *kole*, a Hawaiian endemic, using a single mtDNA (Eble *et al.* 2009). *Manini* has a Indo-Pacific distribution and although connectivity descriptions in Hawaii are limited to between Oahu and Hawaii Island, there has been studies in other parts of the range based on allozymes and mtDNA (Planes *et al.* 1998a; Planes & Fauvelot 2002; Mirams *et al.* 2011). These previous descriptions provide a framework to compare connectivity between an evolutionary and contemporary timescale and will be the first archipelago-wide study describing population strucutre for reef fishes based on genomic-based sequencing. Here, I hypothesized that RADseq data will illuminate levels of population structure not yet described in each of these species as well as confirming the presence of ecological breaks found with other species.

Manini is a heavily targeted by recreational fisheries on the island of Oʻahu (e.g. sport, leisure or subsistence) and has been described as an exploited fish by Hawaiʻi's Division of Aquatic Resources (Longenecker *et al.* 2008). Current management strategies for *manini* are ineffective as the majority of females enter the fishery before reaching maturity (Longenecker *et al.* 2008; Schemmel & Friedlander 2017). In response, Native Hawaiian community leaders identified *manini* as a species of concern and an effort began to implement a community-based management plan for the eastern side of Oʻahu. To advance this goal, one of the first steps is to determine the source of fish populations.

A traditional population genetics approach is an effective means to characterize connectivity across ocean basins and archipelagos; however, it is ineffective at smaller spatial scales, such as individual islands, where it is difficult to detect signals of isolation within the existing pool of genetic diversity (Saenz-Agudelo *et al.* 2009). As most coral reefs fishes have limited home ranges as adults, the potential to disperse occurs at the larval planktonic stage (Leis & McCormick 2002). In understanding this dynamic, we can identify direct routes of dispersal by assigning individuals back to the parents. Genetic parentage analyses has proven to be powerful tool at identifying this form of fine scale connectivity in a variety of taxa including butterflyfishes (Abesamis *et al.* 2017), clownfish (Jones *et al.* 1999; Saenz-Agudelo *et al.* 2012), gobies (D'aloia *et al.* 2013), groupers (Almany *et al.* 2013), snappers (Harrison *et al.* 2012), and surgeonfish (Christie *et al.* 2010).

For the island scale study, I used SNPs generated from RADseq to conduct a parentage analysis of *manini* to describe dispersal patterns around the island of Oʻahu. A concerted effort was made to describe dispersal pathways along the windward coast as part of an interdisciplinary project, involving ecologists, oceanographers and social scientists, titled *Fish Flow*. Within this working group the goal is to describe the route from spawning, including the use of biophysical models, the community level interactions after settlement, and identifying the route of consumption by local fishers. Although *Fish Flow* is focused on the windward coast, an attempt was made to describe connectivity across the entire island of Oʻahu. Based on the biophysical models and circulation patterns, I predicted that there would be high rates of local retention along the windward coast, particularly within Kāneʻohe Bay. The results of this research will describe the flow of fish from reproduction to reef residency, which then can be used to identify key areas of larval productivity and recruitment. In turn, we can inform community-based management efforts by identifying propagule sources and sinks, and areas that are vulnerable to fishing pressure.

As the field of genetics continues to evolve and move towards genomics based efforts, the ability to identify evolutionary and contemporary processes will become easier to accomplish. By assessing connectivity across the spatial scales using a variety of genetic methods, I intend to showcase how different scales can be used to inform different processes.

Some techniques can lend themselves better to understanding evolutionary processes such as evaluating connectivity across a species range using targeted loci. Whereas, a parentage analysis provides more refinement for identifying connectivity on an island scale which can be valuable for informing management strategies, as well as for describing dispersal potential which can contribute to evolutionary processes. I anticipate that this research will enhance our growing knowledge of dispersal and connectivity in coral reef fishes and how these patterns promote biodiversity in both an evolutionary and a contemporary framework.

CHAPTER 2 REGAL PHYLOGEOGRAPHY: RANGE-WIDE SURVEY OF THE MARINE ANGELFISH *PYGOPLITES DIACANTHUS* REVEALS EVOLUTOINARY PARTITION BETWEEN THE RED SEA, INDIAN OCEAN AND PACIFIC OCEAN

ABSTRACT

The regal angelfish (*Pygoplites diacanthus*; family Pomacanthidae) occupies reefs from the Red Sea to the central Pacific, with an Indian Ocean/Rea Sea color morph distinct from a Pacific Ocean morph. To assess population differentiation and evaluate the possibility of cryptic evolutionary partitions in this monotypic genus, we surveyed mtDNA cytochrome *b* and two nuclear introns (S7 and RAG2) in 547 individuals from 15 locations. Phylogeographic analyses revealed four mtDNA lineages (d = 0.006 – 0.015) corresponding to the Pacific Ocean, the Red Sea, and two admixed lineages in the Indian Ocean, a pattern consistent with known biogeographical barriers. Christmas Island in the eastern Indian Ocean had both Indian and Pacific lineages. Both S7 and RAG2 showed strong population-level differentiation between the Red Sea, Indian Ocean, and Pacific Ocean (Φ_{ST} = 0.066 – 0.512). The only consistent population sub-structure within these three regions was at the Society Islands (French Polynesia), where surrounding oceanographic conditions may reinforce isolation. Coalescence analyses indicate the Pacific (1.7 Ma) as the oldest extant lineage followed by the Red Sea lineage (1.4 Ma). Results from a median-joining network suggest radiations of two lineages from the Red Sea that currently occupy the Indian Ocean (0.7 – 0.9 Ma). Persistence of a Red Sea lineage through Pleistocene glacial cycles suggests a long-term refuge in this region. The affiliation of Pacific and Red Sea populations, apparent in cytochrome *b* and S7 (but equivocal in RAG2) raises the hypothesis that the Indian Ocean was recolonized from the Red Sea, possibly more than once.

Assessing the genetic architecture of this widespread monotypic genus reveals cryptic evolutionary diversity that merits subspecific recognition

INTRODUCTION

The majority of reef fishes have a pelagic larval phase typically lasting 20 to 60 days, followed by settlement at a location where they remain through juvenile and adult phases. It is during the pelagic larval phase that nearly all dispersal is accomplished, sometimes across great distances (Leis & McCormick 2002; Hellberg 2009). However, even closely related species with similar life histories can show markedly different genetic structure across their respective ranges (Rocha *et al.* 2002; DiBattista *et al.* 2012). Despite these differences in realized dispersal, genetic partitions frequently align with boundaries between biogeographic provinces, which mark abrupt changes in species composition accompanied by obvious geological or oceanographic barriers (Kulbicki *et al.* 2013; Bowen *et al.* 2016). However, phylogeographic reef surveys usually examine genetic partitions both within and between congeneric species (e.g. Robertson et al., 2006; Leray et al., 2010; DiBattista et al., 2013; Gaither et al., 2014; Ahti et al . 2016; Waldrop et al., 2016). Less attention has been paid to monotypic genera, and it is unknown whether these species have evolutionary or ecological traits that promote species cohesion across time.

The family Pomacanthidae (marine angelfishes) is comprised of more than 85 species across seven genera. All of the genera have at least eight species (*Centropyge* has more than 30) except for the monotypic genus *Pygoplites*. The regal angelfish, *Pygoplites diacanthus* (Boddaert 1772), has a wide distribution from East Africa and the Red Sea to the Tuamotu Archipelago in the central Pacific. This distribution encompasses four biogeographic provinces (Fig. 2 in Briggs and Bowen, 2013): the Indo-Polynesian Province (IPP), the Sino-Japanese Province, the Western

Indian Ocean Province, and the Red Sea Province (which includes the Gulf of Aden; see Briggs and Bowen, 2012). Additionally, the range of *P. diacanthus* spans the Indo-Pacific Barrier, an episodic land bridge separating Pacific and Indian Ocean fauna during low sea levels associated with glaciation (Randall 1998; Rocha *et al.* 2007). *Pygoplites* diverged from the sister genus *Holacanthus* about 7.6 – 10.2 Ma (Alva-Campbell *et al.* 2010), and is monotypic despite occupying a very broad range and a variety of ecological conditions.

Randall (2005b) noted coloration differences between an Indian Ocean morph, with a yellow chest, and a Pacific Ocean morph with a gray chest and less yellow coloring on the head (Fig. 2.1), invoking the possibility of nomenclatural recognition of the two morphotypes. Historically color has been used for species delineation in reef fishes, however, coloration alone can be a deceptive foundation for taxonomical classification; molecular tools have been useful for identifying cryptic genetic partitions and resolving taxonomic uncertainty over color morphs (McMillan *et al.* 1999; Schultz *et al.* 2006; Drew *et al.* 2008; Drew *et al.* 2010; DiBattista *et al.* 2012; Gaither *et al.* 2014; Ahti *et al.* 2016; Andrews *et al.* 2016)

Here we obtained samples from across the range of *P. diacanthus* to assess genetic connectivity with mitochondrial (mtDNA) and nuclear (nDNA) markers. Our sampling allowed us to test for cryptic evolutionary partitions and evaluate the hypothesis of taxonomic distinction between Indian and Pacific morphotypes. We were further motivated to resolve the ecological and evolutionary conditions that restrict diversification within the genus *Pygoplites*, the sole monotypic genus in an otherwise speciose family of fishes.

MATERIAL AND METHODS

Sample Collections

Between 2004 and 2014, 547 tissue samples (primarily fin clips) of *P. diacanthus* were collected from 15 locations across the species distribution (Fig. 2.1), using nets and pole-spears while scuba diving or snorkeling. Tissues were preserved in salt-saturated DMSO buffer (Amos & Hoelzel 1991) and stored at room temperature. Total genomic DNA was isolated from preserved tissue following the “HotSHOT” method of Meeker *et al.* (2007) and stored at -20°C. Due to variation in DNA amplification and sequence resolution, not all specimens were resolved at all three loci outlined below, hence sample sizes in Fig. 2.1 do not match samples sizes provided in the tables.

MtDNA Analyses

A 568-base pair (bp) fragment of the mtDNA cytochrome *b* (cyt *b*) gene was resolved to identify the maternal lineage of each individual using the forward primer (5’-GTGACTTGAAAAACCACCGTTG-3’) (Song *et al.* 1998) and reverse primer (H15573; 5’-AATAGGAAGTATCATTCGGGTTTGAT-3’) (Taberlet *et al.* 1992). PCR was performed in 10 μl reactions containing 10-15 ng of DNA, 5 μl of premixed BioMixRed™ (Bioline, Inc., Springfield, NJ, USA), 0.2 μM primer for each primer, and nanopure water (Thermo Scientific Barnstead, Dubuque, IA, USA) to volume and using the following conditions: 4 min at 94°C, 35 cycles of denaturing for 30 s at 94°C, annealing for 30 s at 50°C, extension for 45 s at 72°C, and a final extension for 10 min at 72°C.

PCR products were visualized using a 1.5% agarose gel with GelStar™ (Cambrex Bio Science Rockland, Rockland MA, USA) and then purified by incubating with 0.75 units of Exonuclease and 0.5 units of Shrimp Alkaline Phosphatase (ExoSAP; USB, Cleveland, OH, USA) per 7.5 μl of PCR product for 30 min at 37°C, followed by 15 min at 85°C. DNA sequencing was performed using fluorescently-labeled dideoxy terminators on an ABI 3730XL Genetic Analyzer (Applied Biosystems, Foster City, CA, USA) at the University of Hawai‘i Advanced Studies of Genomics, Proteomics and Bioinformatics sequencing facility.

Sequences were aligned and edited using GENEIOUS v.8.0.3 (Gene Codes, Ann Arbor, MI, USA) and unique sequences were deposited into GenBank (Accession numbers: RAG2, KU885737 - KU885756; S7, KU885757 - KU885843; cyt *b*, KU885844 - KU885892). A model for DNA sequence evolution was selected using the program JMODELTEST v.2.1 (Guindon & Gascuel 2003; Darriba *et al.* 2012). The best-fit model of TIM1+G (gamma=0.0760) was identified by the Akaike Information Criterion (*AIC*) and the closest matched used for subsequent analyses. Mean genetic distance between lineages was calculated in DNASP v.5.10 (Librado & Rozas 2009). A haplotype network was constructed for each locus with NETWORK v.4.6.1.1 (http://www.fluxus-engineering.com/network_terms.htm) using a median-joining algorithm (Bandelt *et al.* 1999) and default settings.

To estimate the time to most recent common ancestor (TMRCA), we formatted the data with BEAUTI v.1.4.7 and used a Bayesian MCMC approach in BEAST v.2.2.0 (Drummond & Rambaut, 2007). We conducted our analysis with a strict clock of 2% per million years between lineages (Bowen et al., 2001; Reece et al., 2010a) and used a coalescent tree prior assuming exponential growth. We used default priors under the HKY+G+I model of mutation, the closest available model, and ran simulations for 10 million generations with sampling every 1000 generations. Ten independent runs were computed to ensure convergence, and log files were combined and ages averaged across runs using TRACER v.1.6 (http://tree.bio.ed.ac.uk/software/tracer/).

ARLEQUIN v.4.11 was used to generate haplotype and nucleotide diversity, as well as to test for population structure (Excoffier *et al.* 2005). Genetic structure among and between regions was estimated by performing an analysis of molecular variance (AMOVA). Deviations from null distributions were tested with non-parametric permutation procedures (N = 9999). Pairwise Φ_{ST} statistics, an analog of Wright's F_{ST} that incorporates sequence evolution and divergence, were generated to assess structure and identify phylogeographic partitions. Locations where samples sizes were < 8 were excluded from population genetic analyses but included in overall diversity estimates. False discovery rates were controlled for and maintained at $\alpha = 0.05$ among all pairwise tests (Benjamini & Yekutieli 2001; Narum 2006).

Time since the most recent population expansion was estimated for each location using the equation $\tau = 2\mu t$, where t is the age of the population in generations and μ is the mutation rate per generation for the entire sequence (μ = number of bp x divergence rate within a lineage x generation time in years). We used a sequence divergence estimate within lineages of 1-2% per million years (Bowen *et al.* 2001; Reece *et al.* 2010a) to estimate population age. While generation time is unknown for *P. diacanthus*, we conditionally used the equation $T = (\alpha + \omega)/2$, where α is the age at first reproduction and ω is the age of last reproduction (or lifespan; Pianka, 1978). We obtained a generation time of 8.5 years based on an estimated reproductive age of 2 years and longevity of more than 15 years (Hinton 1962). Due to the tentative nature of generation time and mutation rates estimates, population age should be interpreted with caution, however rank-order comparisons among populations are robust to such approximations. Fu's F_S (Fu 1997) was calculated to test for evidence of selection or (more likely) population expansion using 10,000 permutations with significance determined at $P < 0.02$. A significant negative value of Fu's F_S is evidence for an excess number of alleles, as would be expected from a recent population expansion, whereas, a significant positive value is evidence for a deficiency of alleles, as would be expected from a recent population bottleneck.

Nuclear DNA Analysis

We sequenced two nuclear loci: the recombination-activating gene 2 (RAG2) and intron 1 of the S7 ribosomal protein (S7). We resolved 431-bp of RAG2 using modified primers from Lovejoy (1999); the forward primer is 5’-SACCTTGTGCTGCAAAGAGA-3’ and reverse primer is 5’-AGTGGATCCCCTTBTCATCCAGA-3’. We resolved 510-bp of S7 using primers S7RPEX1F and S7RPEX2R from Chowand Hazama (1998). For each intron, PCR was performed using the same reaction as described for cyt *b* but using the following temperature conditions: 5 min at 94°C, 35 cycles of denaturing for 30 s at 94°C, annealing for 30 s at 58°C, extension for 45 s at 72°C, and a final extension for 10 min at 72°C.

Allelic states with more than one heterozygous site were estimated using PHASE v.2.1 (Stephens & Donnelly 2003) as implemented in DNASP. Unique sequences were deposited in GenBank (Accession numbers: XXX - XXX). Three separate runs, each of 100,000 repetitions after a 10,000 iteration burn-in, were conducted for each locus; all runs returned consistent allele identities. Median-joining networks were created for each nuclear dataset as outlined above. To minimize circularity between closely related alleles, singletons were removed from the S7 network. However, this did not alter our overall interpretation of the results. Pairwise Φ_{ST} statistics were calculated for each nuclear dataset. The best-fit model of K80 and TPM1uf+I (proportion of invariable sites = 0.89) were identified for RAG2 and S7, respectively as determined by JMODELTEST. Observed heterozygosity (H_O) and expected heterozygosity (H_E)

were calculated for each locus and an exact test of Hardy-Weinberg Equilibrium (HWE) using 100,000 steps in a Markov chain was performed in ARLEQUIN.

Phylogenetic reconstruction

Phylogenetic reconstruction based on cyt *b* was rooted with *Holacanthus africanus* (family Pomacanthidae; GenBank accession number KC845351 and KC845352), as this genus is sister to *Pygoplites* (Bellwood et al., 2004; Alva-Campbell et al., 2010). Bayesian inference was conducted using MRBAYES v.4.1.2 (Huelsenbeck *et al.* 2001; Ronquist 2004) running a pair of independent searches for 1 million generations, with trees saved every 1000 generations and the first 250 sampled trees of each search discarded as burn-in. Due to high divergence between *P. diacanthus* and *H. africanus* (14.7% at cyt *b*) we were unable to resolve phylogenetic relationships within the genus *Pygoplites* using an outgroup, therefore an unrooted tree was also constructed with MRBAYES based on the concatenated dataset of all loci. A maximum likelihood tree was created using PHYML v.3.0.1 (Guindon *et al.* 2010) as implemented in GENEIOUS with clade support assessed with 1000 non-parametric bootstrap replicates. A neighbor-joining tree was created using GENEIOUS with clade support assessed after 1000 non-parametric bootstrap replicates.

RESULTS

Phylogenetic and coalescence analyses

All tree-building methods yielded identical topologies. The unrooted phylogenetic analysis recovered four lineages: a Pacific lineage that extends to Christmas Island in the eastern Indian Ocean (henceforth referred to as “Pacific lineage”), a lineage detected around Saudi

Arabia and Djibouti (henceforth referred to as "Red Sea lineage"), and two lineages with overlapping ranges in the Maldives and Diego Garcia (henceforth referred to as "Indian lineage 1" and "Indian lineage 2") (Fig. 2.2). The phylogenetic analyses were unable to resolve branch order among these lineages using an outgroup (Fig 2.2a), in part because the sister genus (*Holacanthus*) is deeply divergent at cyt *b* (Alva-Campbell *et al.* 2010). The Pacific lineage is 0.6% divergent from the Red Sea lineage and 1.2% and 1.5% from Indian lineage 1 and 2, respectively. The Red Sea lineage is 0.6% divergent from Indian lineage 1 and 1.0% from Indian lineage 2, and the two Indian lineages are distinguished by 1.5% divergence. Coalescence analysis based on cyt *b* yielded a TMRCA of 1.7 Ma for the Pacific lineage, and identified the Pacific as the oldest extant lineage (Table 2.1). The Red Sea lineage dates to 1.4 Ma and the two Indian lineages were the youngest: Indian lineage 1 at 0.7 Ma; Indian lineage 2 at 0.9 Ma.

MtDNA Sequences

Mitochondrial DNA molecular diversity indices are summarized for lineages in Table 2.1 and among populations in Table 2.2. Total haplotype diversity was h = 0.817 with 49 unique haplotypes. Among lineages, the Red Sea had the highest haplotype diversity (h = 0.701) with the lowest being observed in Indian Ocean lineage 2 (h = 0.284). Within populations, Indonesia had the highest haplotype diversity (h = 1.00) followed by Okinawa (h = 0.867) and the Maldives (h = 0.808). The lowest haplotype diversity was observed at Fiji (h = 0.427) and Mo'orea (h = 0.483). Total nucleotide diversity was π = 0.005. Among lineages, the Pacific Ocean and Red Sea had the higher nucleotide diversity (π = 0.002) with the lowest nucleotide diversity observed in both Indian Ocean lineages (π = 0.001). Among populations, the Maldives and Diego Garcia had the highest nucleotide diversity for all locations, each at $\pi = 0.009$, whereas the lowest nucleotide diversity is observed at Fiji ($\pi = 0.0008$).

The median-joining haplotype network illustrates the low level of divergence between the four evolutionary lineages recovered from the phylogenetic analysis (Fig. 2.3a). However, the network also reveals that Red Sea haplotypes lie between the Pacific and Indian haplotypes. The presence of two Indian lineages radiating from the most common Red Sea haplotype provides evidence for two independent colonization events. The two Indonesia specimens are associated with Indian Ocean lineage 1; however, low samples size precludes any interpretation about lineage distribution. Christmas Island, located at the edge of the IPP, a region where Pacific and Indian Ocean fauna come into contact (Gaither & Rocha 2013), had both Pacific and Indian lineages. In subsequent comparisons between ocean basins, Christmas Island specimens grouped with Indian and Pacific cohorts based on mtDNA identity.

Population pairwise Φ_{ST} values for cyt *b* results are summarized in Table 2.3. Significance was determined after controlling for false discovery rates (corrected $\alpha = 0.009$). Φ_{ST} values show congruence with the haplotype network further supporting the Pacific, Indian, and Red Sea groups. There was little or no population structure detected within these groups, with two exceptions: Mo'orea (French Polynesia) shows significant genetic differentiation from all Pacific locations, with pairwise Φ_{ST} values ranging from 0.123 with Pohnpei to 0.229 with Fiji. Elsewhere in the Pacific, significant genetic structure was detected between the Marshall Islands and Fiji ($\Phi_{ST} = 0.061$, $P < 0.001$). Although population level data is not reported for the single location in the Sino-Japanese Province (Okinawa) due to low sample size ($N = 6$), preliminary runs show no significant population structure between the Sino-Japanese Province and the Pacific samples of *P. diacanthus*. The Red Sea lineage shows high levels of population differentiation from all other samples (pairwise Φ_{ST}: 0.284 – 0.837). Likewise, the Indian lineages show significant population differentiation from all other samples (pairwise Φ_{ST}: 0.284 – 0.753). The AMOVA analysis supports the Pacific, Indian, and Red Sea geographic groupings based on mtDNA (Table 2.4) with the majority of the variation (Φ_{CT} = 0.66, P < 0.001) existing among the groups.

The demographic results for cyt *b* show indications of population expansion at every Pacific location with the exception of Okinawa, the Marshall Islands, and Mo‘orea (Table 2.2). Estimates of population expansion indicate that the youngest dates are in the Pacific: Fiji and Christmas Island, with estimates of 39,000 and 49,000 years, respectively. The oldest Pacific expansion dates are in Okinawa, Pohnpei, and American Samoa, at 271,000, 230,000, and 212,000 years, respectively. Within the Red Sea Province, Saudi Arabia shows evidence for a population expansion (Fu's F_S: - 4.73, P < 0.01) at 65,000 – 130,000 years, whereas Djibouti shows evidence for a neutral population (Fu's F_S, P = 0.35) aged at 105,000 – 209,000 years. Locations in the Indian Ocean singularly show no evidence of population expansion (Fu's F_S, P > 0.02) and have the oldest population expansions dates at 807,000 – 1,742,000 years. However, these estimates are shaped by the presence of two lineages that are not monophyletic (Fig. 2.3a). When considered individually, Indian lineage 1 has a population expansion date at 48,000 – 97,000 years (Fu's F_S: -3.70, P < 0.001), and Indian lineage 2 has a population expansion date at 264,000 – 528,000 years (Fu's F_S: -2.75, P = 0.01).

Nuclear DNA Sequences

A total of 10 variable sites yielded 12 alleles at the RAG2 locus and 31 variable sites yielded 46 alleles at the S7 locus. Samples from Palau and Tokelau were out of Hardy-Weinberg equilibrium (Palau, $P < 0.001$; Tokelau, $P = 0.04$) with excess homozygotes at the S7 locus (Table 2.5). Overall expected heterozygosity (H_E) was 0.43 and 0.86 for RAG2 and S7, respectively. Across all samples $H_E = 0.06 – 0.64$ for RAG2 and $H_E = 0.41 – 1.00$ for the S7 intron. The median-joining networks based on intron sequences do not show distinct lineages in the Red Sea, Indian Ocean, and Pacific Ocean (Fig. 2.3b, c). However, both RAG2 and S7 networks include common alleles that are observed only in the Pacific, or only in the Indian Ocean locations. For S7, an Indian Ocean specific allele is also shared with a single individual from Christmas Island.

The population genetic results for the nuclear dataset are strongly concordant with mtDNA analyses for *P. diacanthus,* although they differ by degree. Genetic structure was absent within the Red Sea and within the Indian Ocean. The only significant differentiation in the Pacific was in 7 of 8 comparisons to Mo'orea (Society Islands, French Polynesia) with RAG2 ($\Phi_{ST} = 0.111 – 0.271$; Table 2.6). Curiously, none of the same pairwise comparisons for Mo'orea were significant with S7, however Mo'orea showed the highest differentiation from Red Sea populations.

Both nuclear markers show high levels of genetic structure that correspond to a Pacific, Indian, and Red Sea lineage. RAG2 was significant in 17 of 18 Pacific versus Indian comparisons ($\Phi_{ST} = 0.137 – 0.343$), significant in all Indian versus Red Sea comparisons ($\Phi_{ST} = 0.091 – 0.258$), and significant in 15 of 18 Pacific versus Red Sea comparisons ($\Phi_{ST} = 0.066 – 0.359$). The S7 differences were significant in all Pacific versus Indian comparisons ($\Phi_{ST} = 0.073 – 0.188$), all Indian versus Red Sea comparisons ($\Phi_{ST} = 0.253 – 0.512$), and all Pacific versus Red Sea comparisons ($\Phi_{ST} = 0.159 – 0.443$). The exceptions to these patterns were comparisons between the Red Sea lineage and Tokelau, as well as between Saudi Arabia and Pohnpei. For S7 the highest genetic structure was observed between the Indian and Red Sea populations. This contrasts with the RAG2 and cyt *b* comparisons, where the highest genetic structure differentiated the Pacific from both Indian and Red Sea regions.

DISCUSSION

Summary of results

Our data demonstrates that cryptic diversity exists within the monotypic genus *Pygoplites* as evidenced by significant levels of genetic structure among three regions: the Pacific Ocean (which includes a cohort at Christmas Island), the Indian Ocean (with two sympatric mtDNA lineages), and the Red Sea (Table 2.4). This pattern of genetic structure corresponds to known biogeographic provinces and phylogeographic barriers observed in other reef fishes (Rocha *et al.* 2007; Briggs & Bowen 2013; DiBattista *et al.* 2013; Eble *et al.* 2015; Gaither *et al.* 2015). The Red Sea biogeographic province is distinguished by a faunal break at the Gulf of Aden, and the Indo-Pacific Barrier is an intermittent terrestrial bridge between Australia and SE Asia that impedes water movement between Pacific and Indian Oceans during glacial low-sea levels (see Gaither & Rocha, 2013). The Sino-Japanese Province shows no genetic differentiation from the Pacific population (based on $N = 6$), but Mo'orea is highly isolated, a finding we attribute to prevailing oceanographic conditions (see Gaither et al., 2010). Below we discuss the phylogenetic implications of cryptic lineages and examine each of these regions in light of biogeographic theory

Phylogenetic considerations

Differences in coloration reviewed by Randall (2005) suggested that cryptic linages of *P. diacanthus* might exist in the Pacific and Indian Oceans. The three loci evaluated here support this Indian-Pacific distinction with diagnostic (albeit shallow) mtDNA differences and strong population genetic separations at two nuclear loci. A rooted phylogeny was unable to resolve relationships within the genus *Pygoplites* due to shallow separations and the deep divergence from the outgroup, *H. africanus*, (*d* = 15.5% at cyt *b*, this study), despite being the most closely related species to *P. diacanthus* (Alva-Campbell *et al.* 2010). Therefore, we were unable to determine the basal lineage from among the four lineages recovered. The oldest TMRCA in *P. diacanthus* is the Pacific lineage at 1.7 Ma, but the divergence between *Pygoplites* and *Holocanthus* is much older, estimated at 7.6 – 10.2 Ma (Alva-Campbell et al., 2010). Hence much of the evolutionary history of *Pygoplites* has been erased, at least for the loci examined here.

There are two possible explanations for the lack of diversity within the genus. First, there has been no evolutionary or selective pressure for *P. diacanthus* to diversify, a feature that may be attributed to the species ability to occupy a variety of ecological niches. *P. diacanthus* can be considered a generalist in that its range occupies more than half the globe in subtropical and tropical environments, its diet consists of sessile invertebrate, such as sponges and tunicates, and it appears to be a reef-habitat generalist where its range extends from the surface to depths greater than 60 m, a zone where shallow coral reef habitat is replaced by mesophotic ecosystems (Puglise *et al.* 2009). An alternative explanation is that other species within the genus went extinct while *P. diacanthus* persisted. However, with a poor fossil record, the evolutionary history of the marine angelfishes is poorly understood and limited to extant species. Therefore, we know of no species that may have existed during the 10 million year separation between

Holacanthus and *Pygoplites*. Nonetheless, the phylogeographic record for *Pygoplites* begins with a radiation in the last 2 MY. Although phylogenetic reconstruction was unable to determine branch order among the four lineages, the median-joining network indicates that the Red Sea lineage is basal to the two mtDNA lineages in the Indian Ocean. Coloration differences distinguish the Pacific lineage from both Indian and Red Sea lineages (Fig. 2.1); however, a preliminary morphological examination revealed no additional morphological characters that discriminate between Indian and Red Sea lineages (pers. comm. Luiz Rocha).

The geographical delineation between the Pacific and Indian lineages correspond with the exposure of the Sunda Shelf, which separates the Pacific and Indian Oceans during low sea level. The Red Sea lineage corresponds to the Red Sea biogeographic province, which encompasses the adjacent Gulf of Aden (Briggs & Bowen 2012) and whose populations have a disjunct distribution with the remainder of the range (see below). During glacial maxima the Red Sea is effectively cut off from the Indian Ocean by closure of the Strait of Bab al Mandab, the only natural gateway into the Red Sea, allowing sufficient time for populations to diverge into distinct evolutionary lineages (DiBattista et al., 2013, 2016a).

The mechanisms facilitating two sympatric mtDNA lineages in the Indian Ocean are less clear. Coalescence estimates indicate that lineages arose independently during roughly the same period (0.72 – 0.93 Ma). As there are no known phenotypic differences within this region, the unexpected recovery of two distinct lineages requires further investigation. Indian Ocean samples contained similar number of each lineage (Maldives: Lineage 1, $N = 8$; Lineage 2, $N = 8$; Diego Garcia: Lineage 1, $N = 17$; Lineage 2, $N = 11$) indicating that the two lineages are approximately equally represented.

The recovery of multiple evolutionary partitions within the monotypic genus *Pygoplites* may not be indicative of other monotypic genera. Cryptic evolutionary partitions are routinely discovered within species of marine fishes (Colborn *et al.* 2001; Rocha *et al.* 2008; DiBattista *et al.* 2012; Fernandez Silva *et al.* 2015), and in this regard *P. diacanthus* is similar to the more speciose inhabitants of Indo-Pacific reefs. The factors that produce a deep, monotypic lineage are therefore not reflected in an unusual phylogeographic architecture. However, part of the explanation for this monotype may be that five to eight million years after the divergence of *Pygoplites* and *Holocanthus*, the ancestor of all modern *Pygoplites* likely radiated out of the West Pacific Ocean, an extensive source of Indo-Pacific diversity (Cowman & Bellwood 2013).

In considering the phylogenetic results through a taxonomic lens, there are several issues. First, the Pacific and Indian morphs are distinguished by diagnostic differences, but they are not monophyletic. The Indian Ocean contains two mtDNA lineages, each more closely related to the Red Sea lineage than to each other. Second, the coloration difference between Pacific and Indian forms, now matched by $d = 0.006$ divergence, could be a platform to describe them as separate species. Third, the genetic divergence observed at all three loci is low in comparison to typical divergences for fish species ($d = 0.03 – 0.12$; Grant and Bowen, 1998; Johns and Avise, 1998). Fourth, the two morphs form mixed groups where they co-occur at Christmas Island (Hobbs and Allen, 2014). Since we lack diagnostic nDNA alleles for the two morphs, we do not have the power to test for hybrids between the lineages, but this is certainly a possibility. Given these considerations, we believe that it is problematic to invoke species status for these three regional forms and we endorse subspecies recognition distinguishing the Pacific lineage from the Indian and Red Sea lineages based on shallow but diagnostic distinctions in genetics and morphology. We propose the name *P. diacanthus flavescens* for the Indian Ocean and Red Sea lineages to give recognition to the yellow chest coloration, a character not found in individuals from the Pacific lineage (*P. d. diacanthus*).

Red Sea isolation and refugia

The Red Sea Province is distinguished from the Indian Ocean by high levels of endemism found across a suite of taxa (Randall 1994; Cox & Moore 2000) as well as many fish species whose ranges extend from the Red Sea into the Gulf of Aden (Briggs & Bowen 2012; DiBattista *et al.* 2016). This distinction is supported by our findings that show the Djibouti population of *P. diacanthus* forms a genetically homogenous population with the Red Sea, coupled with a population break separating these two locations from adjacent populations in the Indian Ocean.

Population breaks between the Red Sea and Indian Ocean have previously been documented in *P. diacanthus*, in addition to other species (Vogler *et al.* 2008; DiBattista *et al.* 2013; Fernandez Silva *et al.* 2015). One possible explanation for breaks across multiple species in this region is the presence of an ecological barrier. Based on differences in fish assemblages, Kemp (1998) proposed that such a barrier separated the Red Sea and western Gulf of Aden from the eastern Gulf of Aden and Indian Ocean. Furthermore, the upwelling that occurs along the Arabian coast of southern Yemen, Oman and the Indian Ocean coast of Somalia impedes the formation of continuous reefs from Djibouti to Oman and southern Somalia, limiting opportunities for dispersal from the Gulf of Aden (for review see DiBattista et al., 2016a). Notably, we did not detect *P. diacanthus* during collection efforts in the Socotra Archipelago, Oman, and Somolia, which are located at the periphery of the Gulf of Aden and the Arabian Sea. This observation coincides with previous surveys conducted in the region indicating a gap in the distribution of *P. diacanthus* between the Gulf of Aden and the western Indian Ocean, a phenomenon found in other wide-ranging species (Kemp 1998).

The parsimonious conclusion that a population of *P. diacanthus* has been in the Red Sea Province (including western Gulf of Aden) for over a million years implies that this population has been subjected to and survived Pleistocene glacial conditions. The only natural connection to the Indian Ocean is through the narrow (18 km) and shallow (137 m) Strait of Bab al Mandab at the southern end of the Red Sea. During periods of low sea level associated with glaciation, the connection from the Indian Ocean through the strait is reduced, and the Red Sea experiences extreme fluctuations in temperature and salinity (Bailey 2009). During the last 400,000 years in particular, the Red Sea has undergone at least two periods of hypersalinity (c. 19,000 and 30,000 years ago) that caused an aplanktonic environment in which larvae of many marine organisms presumably could not survive (Siddal et al., 2003; DiBattista et al., 2016a). Coalescence analysis dates the Red Sea lineage to 1.44 Ma (95% HPD = 0.51 – 2.53 Ma), which coupled with the Saudi Arabian population expansion (65,000 – 130,000 years) indicates that *P. diacanthus* likely survived the temperature and salinity crises that occurred during these periods, a conclusion that is corroborated by other species (DiBattista *et al.* 2013). Our neutrality tests show no evidence for changes in population size (Fu's Fs = -3.60, P = 0.035) providing evidence that refugia may have existed in the Red Sea Province (possibly in the Gulf of Aden) to support a large stable population of *P. diacanthus* despite the extreme environmental conditions.

Biogeographic inferences in the Indian Ocean

Christmas Island is located in the eastern Indian Ocean, a region (which includes Cocos-Keeling Island) of secondary contact between Indian and Pacific species that diverged in allopatry during Pleistocene glacial cycles (Gaither & Rocha 2013). Indian and Pacific Ocean phenotypes of *P. diacanthus* have both been recorded in the eastern Indian Ocean region, and both Pacific and Indian Ocean mtDNA haplotypes are present at Christmas Island, indicating an area of overlap (Hobbs and Allen, 2014 , Fig 2.3a). This region is recognized as a hybridization hotspot (suture zone) with interbreeding documented between at least 27 reef fish species-pairs from across eight families, and it has been suggested that Indian and Pacific *P. diacanthus* lineages hybridize in this region (Hobbs & Allen 2014). However, additional molecular work will be needed to evaluate this hypothesis.

Genetic differences between Indian and Pacific Ocean populations are consistent with Pleistocene closures of the Indo-Pacific Barrier. Despite being located in the Indian Ocean basin and the presence of haplotypes that are associated with Indian Ocean lineages, our results indicate that Christmas Island is genetically differentiated from other locations in the Indian Ocean and instead has a stronger affiliation with the Pacific Ocean. A barrier to dispersal has been previously proposed to exist west of the Cocos-Keeling Islands and east of the Chagos-Laccadive ridge based on the presence of many Pacific species with distributions that extend no further west than Christmas and the Cocos-Keeling Islands (Blum 1989; Hodge & Bellwood 2016).

Elsewhere in the Indian Ocean, the Maldives and Diego Garcia (Chagos Archipelago) are genetically differentiated from the Pacific and Red Sea, but not from each other. Both archipelagos are located in the central Indian Ocean, which is the western extent of the IPP, although they also share faunal affinities with the Western Indian Ocean Province (Winterbottom & Anderson 1997; Gaither *et al.* 2010b; Eble *et al.* 2011a; Briggs & Bowen 2012). The grouping of Diego Garcia and the Maldives within the IPP is further evidenced by Pacific Ocean mtDNA being found at Diego Garcia (Fig. 2.3a), which provides a signal that some degree of gene flow occurs between the Indian and Pacific Ocean. Coalescence estimates of the two Indian Ocean *P. diacanthus* lineages indicate they arose from an ancestor affiliated with the Red Sea.

The ability of *P. diacanthus* to persist throughout major geological and climatic shifts is demonstrated by the age of expansion for all populations of *P. diacanthus* which predate the Last Glacial Maximum, peaking at 26.5 – 19 ka (Clark *et al.* 2009) when global sea level dropped 130 m below present levels (Voris 2000). During this period, habitable shelf in the Pacific was reduced by as much as 92% from present day values and this reduction in habitat area has been linked to population bottlenecks (Ludt and Rocha, 2014), a feature not observed in *P. diacanthus*. As previously discussed, *P. diacanthus* can be considered an ecological generalist with a vertical range that extends to mesophotic depths. Thus, a reduction of shallow reef habitat due to sea level change may not have substantially reduced suitable ecological niches for this species.

Gene flow within the Pacific

Despite the wide expanse of the central and western Pacific Ocean, many species exhibit a high degree of genetic connectivity across the region (Schultz et al., 2006; Reece et al., 2010b; Gaither et al., 2011). However, populations breaks have been associated with isolated regions such as the Hawaiian Archipelago and the Marquesas, which are also known for high levels of endemism (Randall 2005b; Briggs & Bowen 2012). Here we found population genetic differentiation of Mo’orea (Table 2.3, Table 2.6), a pattern observed in other widely distributed Pacific species (Planes 1993; Bernardi *et al.* 2001; DiBattista *et al.* 2012; Timmers *et al.* 2012; Lemer & Planes 2014).

The isolation of Mo'orea may be attributed to ocean circulation patterns. The westward flow of the Southern Equatorial Current (SEC) and eddies created in the wake of Tahiti, located approximately 17 km east of Mo'orea, contribute to a strong counterclockwise flow around the island promoting the local retention of larvae (Leichter *et al.* 2013). _ENREF_42Plankton tows conducted in this region revealed that fish larvae were not recovered more than 300 km from the nearest reef (Lo-Yat *et al.* 2006). Additionally, Bernardi *et al.* (2012) found that 14% of juvenile damselfish (*Dascyllus trimaculatus*) recruiting to reefs around Mo'orea were very close relatives, including full siblings, indicating that the larvae traveled and settled together despite a PLD of several weeks.

Although the counterclockwise flow surrounding Mo'orea may explain local retention of larvae, it does not explain how larvae produced elsewhere in the Pacific are restricted from emigrating and settling onto Moorean reefs. One possible explanation may be that the westward flowing SEC restricts larvae from dispersing in an easterly direction. The SEC, located between 4°N and 17°S (Wyrtki & Kilonsky 1984; Bonjean & Lagerloef 2002), has been implicated in limiting connectivity between the Marquesas, located 1300 km northeast of Mo'orea, and other Pacific locales (Gaither et al., 2010; Szabo et al., 2014). Populations of *P. diacanthus* west of Mo'orea, located at the southern extent of the SEC, may be restricted in easterly dispersal by the strong current; however, the SEC may facilitate a western dispersal. American Samoa is the closest sample location downstream from Mo'orea; it is the only sample location that is not significantly differentiated from Mo'orea at RAG2 (Φ_{ST} = 0.039, P=0.054) and has one of the lowest levels of differentiation from Mo'orea at cyt *b* (Φ_{ST} = 0.128). Fine-scale sampling across French Polynesia would be required to determine the extent of genetic isolation. Additionally, further sampling from neighboring localities east and west of Mo'orea are needed to test our hypothesis regarding the SEC. It is likely that a number of physical processes surrounding Mo'orea promote local retention of larvae and prevent the recruitment of larvae from elsewhere in the Pacific.

CONCLUSION

Pygoplites diacanthus is the first large angelfish to be surveyed across the Indo-Pacific. It appears to be highly dispersive, joining the ranks of smaller Pomacanthids such as the pygmy angelfish in showing little structure across ocean basins (Schultz *et al.* 2006; DiBattista *et al.* 2012). Pelagic larval duration tends to be shorter in the large angelfishes (~25 days in *Pygoplites* compared to 30 days or more in pygmy angelfishes; Thresher and Brothers, 1985), but this does not seem to restrict dispersal among the closely associated islands of the West and Central Pacific. However, this monotypic genus exhibits deep population genetic partitions between ocean basins. In every case, historical barriers existed at the junctions between observed populations, and in at least two cases (Red Sea and Mo'orea) oceanographic conditions may contribute to contemporary isolation. On the genetic continuum between isolated populations and evolutionary distinctions (Wright 1978; Frankham *et al.* 2002), the deep divergences between oceans indicate that the monotypic *Pygoplites* may be on the pathway to three emerging species. The genetic and morphological divergences are certainly sufficient to recognize subspecific evolutionary (and taxonomic) partitions.

Figure 2.1. Map of collection locations, sample sizes (in parentheses), and the two recognized morphotypes of *Pygoplites diacanthus*. (*left*) Indian Ocean and Red Sea individuals are characterized by a yellow chest and head, whereas the (*right*) Pacific Ocean morph is characterized by a gray chest and head. *Photos by L. Rocha (Djibouti; Great Barrier Reef, Australia)*

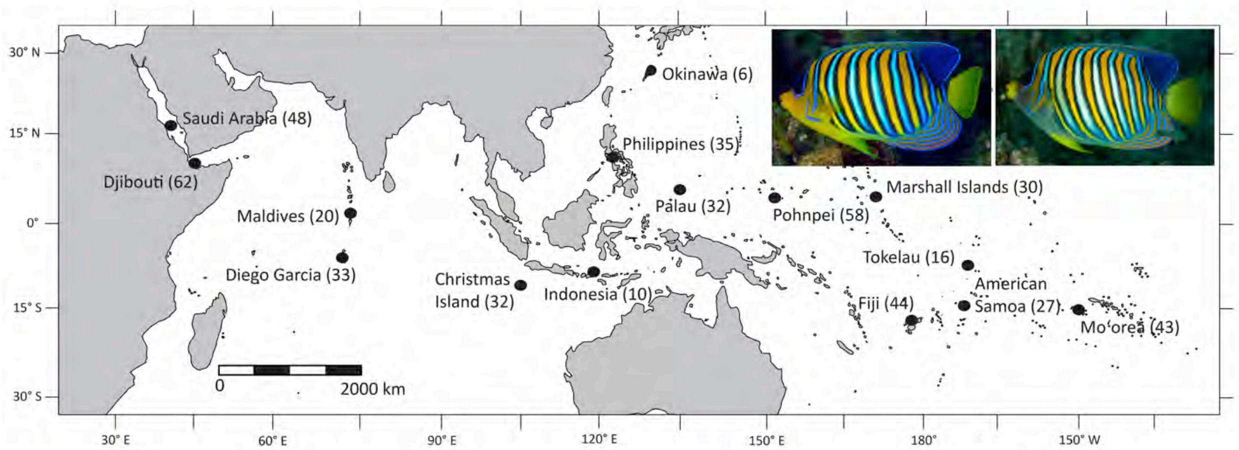

Figure 2.2. Molecular phylogenetic reconstruction of *Pygoplites diacanthus.* A) Rooted Bayesian tree based on mitochondrial cytochrome *b* with posterior probabilities, B) an unrooted maximum-likelihood tree based on mitochondrial and nuclear markers (cytochrome *b*, intron 1 of the S7 ribosomal protein, and the recombination-activating gene 2) with consensus values based on posterior probabilities from Bayesian inference (BI), maximum-likelihood bootstrap support (ML), and neighbor-joining bootstrap support (NJ). Percent sequence divergence is represented on the scale bar. The sizes of black triangles are proportional to the number of individuals within the lineage. Abbreviations: Red Sea Province, RS; Indian Ocean, IO.

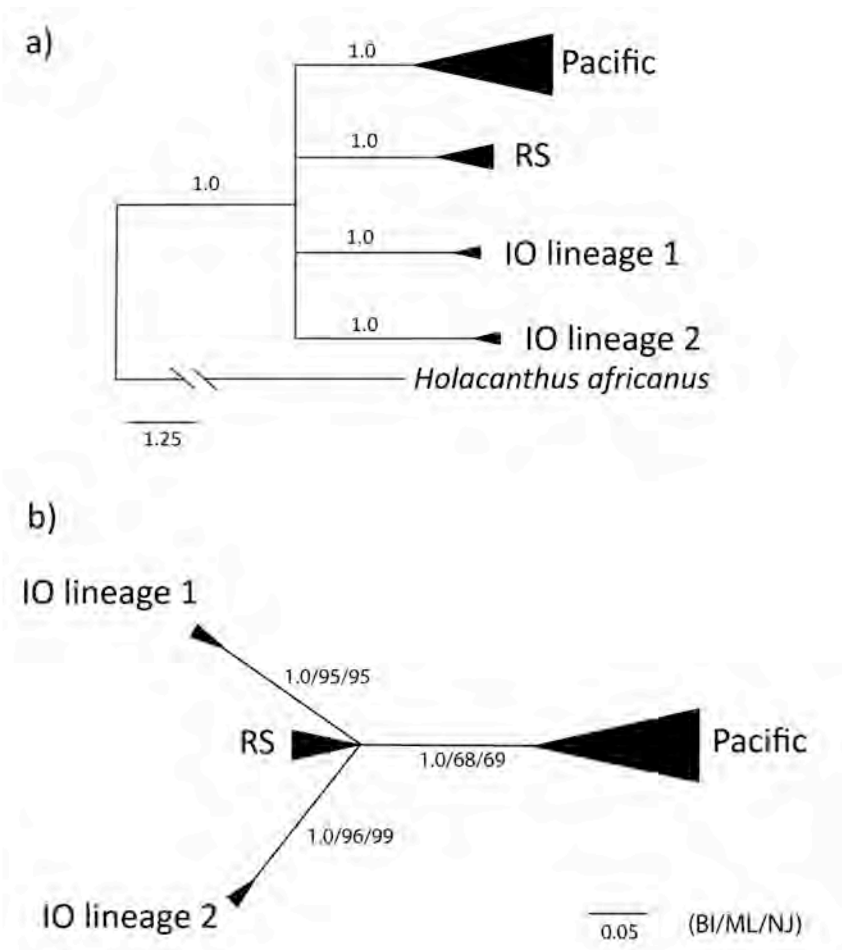

Figure 2.3. Median-joining network for *Pygoplites diacanthus* constructed using NETWORK for A) cytochrome *b* sequences (568 bp) from 386 individuals, B) alleles for RAG2 (431 bp) from 366 individuals, and c) alleles for the S7 intron (510 bp) from 288 individuals. Each circle represents a unique mitochondrial haplotype or nuclear allele, with the size being proportional to the total frequency. Open circles represent unsampled alleles, branches and crossbars represent a single nucleotide change, and color represents collection location (see key). All singleton alleles (N = 22) were removed from the S7 analysis to minimize circularity between closely related alleles.

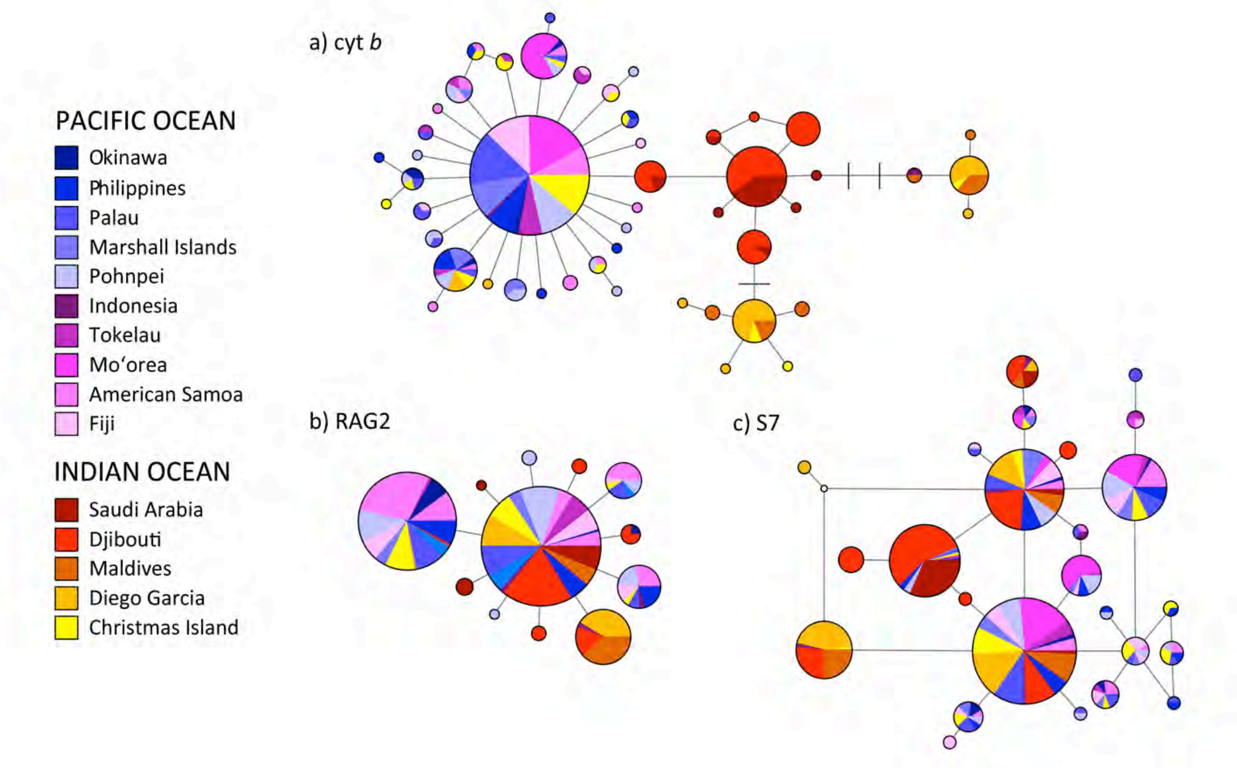

Table 2.1. Molecular diversity indices for lineages of *Pygoplites diacanthus* based on mitochondrial DNA (cytochrome *b*, 568 bp). Number of individuals sequenced (n), number of haplotypes (N_h), number of segregating (polymorphic) sites (S), haplotype diversity (h), and nucleotide diversity (π) are presented. Times to most recent common ancestor (TMRCA) are presented as million years. Bolded numbers denote significance at $P < 0.02$.

Lineage	n	N_h	S	$h \pm$ SD	$\pi \pm$ SD	TMRCA (95% HPD)	Fu's F_S	Fu's F_S P-value
Pacific Ocean[a]	257	33	37	0.628 ± 0.034	0.002 ± 0.010	1.71 (0.91 - 2.65)	-29.51	<0.001
Red Sea[b]	81	9	8	0.701 ± 0.042	0.002 ± 0.003	1.44 (0.51 - 2.53)	-3.602	0.035
Indian Ocean Lineage 1	28	6	5	0.439 ± 0.114	0.001± 0.001	0.72 (0.14 - 1.52)	-3.695	<0.001
Indian Ocean Lineage 2	20	4	3	0.284 ± 0.128	0.001 ± 0.001	0.92 (0.27 - 1.75)	-2.749	0.001
All Locations	386	49	45	0.817 ± 0.018	0.005 ± 0.003	--	-25.90	<0.001

[a]Pacific includes all Pacific Ocean populations plus Christmas Island
[b]Red Sea includes Saudi Arabia and Djibouti

Table 2.2. Molecular diversity indices for populations of *Pygoplites diacanthus* based on mitochondrial DNA (cytochrome *b*, 568 bp) divided into phylogeographical groupings. Number of individuals sequenced (n), number of haplotypes (N_h), number of segregating (polymorphic) sites (S), haplotype diversity (h), and nucleotide diversity (π) are presented. τ is used to estimate the age of most recent population expansion (population age) using the equation $\tau = 2\mu t$ (see Material and Methods). ∞ denotes values that could not be resolved. Bolded numbers denote significance at $P < 0.02$.

Sample Location	n	N_h	S	$h \pm SD$	$\pi \pm SD$	τ	Population Age (years)	Fu's F_S	Fu's F_S P-value
Pacific Ocean									
Okinawa	6	4	3	0.867 ± 0.129	0.002 ± 0.002	1.54	135,000 - 271,000	-1.454	0.052
Philippines	21	7	8	0.657 ± 0.104	0.001 ± 0.001	1.04	92,000 - 183,000	-3.473	0.003
Palau	32	9	8	0.488 ± 0.109	0.001 ± 0.001	0.67	59,000 - 118,000	-7.928	< 0.001
Marshall islands	23	4	3	0.549 ± 0.105	0.001 ± 0.001	0.78	69,000 -138,000	-0.936	0.208
Pohnpei	33	12	13	0.760 ± 0.076	0.002 ± 0.001	1.30	115,000 - 230,000	-8.754	< 0.001
Indonesia	2	2	7	1.000 ± 0.500	0.012 ± 0.013	∞	∞	1.946	0.519
Tokelau	16	6	5	0.617 ± 0.135	0.001 ± 0.001	0.92	81,000 - 162,000	-3.692	< 0.001
Mo'orea	42	2	1	0.483 ± 0.039	0.001 ± 0.001	0.73	64,000 - 128,000	1.766	0.738
American Samoa	25	10	9	0.730 ± 0.094	0.002 ± 0.001	1.20	106,000 - 212,000	-7.128	< 0.001
Fiji	25	6	5	0.427 ± 0.122	0.001 ± 0.001	0.56	49,000 - 98,000	-4.423	< 0.001
Christmas Island	32	13	19	0.720 ± 0.087	0.004 ± 0.003	0.44	39,000 - 77,000	-5.445	0.006
Red Sea Province									
Saudi Arabia	23	7	7	0.522 ± 0.124	0.001 ± 0.001	0.74	65,000 - 130,000	-4.731	< 0.001
Djibouti	58	6	4	0.738 ± 0.034	0.002 ± 0.001	1.19	105,000 - 209,000	-0.879	0.349
Indian Ocean									
Maldives	16	6	11	0.808 ± 0.069	0.009 ± 0.005	9.89	871,000 - 1,742,000	1.858	0.804
Diego Garcia	32	7	17	0.692 ± 0.059	0.009 ± 0.005	9.17	807,000 - 1,614,000	4.177	0.898
Pacific Ocean	257	33	37	0.628 ± 0.034	0.002 ± 0.009	0.94	83,000 - 165,000	-29.511	<0.001
Red Sea Province	81	9	8	0.701 ± 0.042	0.002 ± 0.003	1.09	96,000 - 192,000	-3.602	0.035
Indian Ocean	48	11	19	0.738 +/- 0.045	0.009 ± 0.008	9.37	825,000 - 1,649,000	1.013	0.700
All Locations	386	49	45	0.817 ± 0.018	0.005 ± 0.003	3.61	318,000 - 636,000	-25.897	<0.001

Table 2.3. Matrix of pairwise Φ_{ST} statistics for 13 populations of *Pygoplites diacanthus* based on mitochondrial DNA (cytochrome *b*, 568 bp) sequences. Bolded numbers indicate significance after controlling for false discovery rates at α = 0.05 (as per Narum, 2006). The corrected α = 0.009. Owing to low sample size, Okinawa and Indonesia have been excluded. Abbreviations: Red Sea Province, RS; Indian Ocean, IO.

		Pacific Ocean									RS		IO
	Sample location	1	2	3	4	5	6	7	8	9	10	11	12
Pacific Ocean	1. Philippines	--											
	2. Palau	0.02286	--										
	3. Marshall Is.	-0.00690	0.04436	--									
	4. Pohnpei	-0.00113	-0.00003	-0.00602	--								
	5. Tokelau	-0.00088	0.00970	0.02593	-0.00273	--							
	6. Mo'orea	**0.21137**	**0.15115**	**0.24879**	**0.12293**	**0.21718**	--						
	7. American Samoa	0.00241	0.01337	0.01878	-0.00796	-0.00602	**0.12806**	--					
	8. Fiji	0.04077	0.00310	**0.06141**	0.00599	-0.00058	**0.22924**	0.01738	--				
	9. Christmas Is.	0.02264	0.04064	0.02876	0.02685	0.01493	**0.13152**	0.02805	0.03767	--			
RS	10. Saudi Arabia	**0.76918**	**0.80926**	**0.80834**	**0.73676**	**0.79578**	**0.83717**	**0.75536**	**0.82668**	**0.55505**	--		
	11. Djibouti	**0.73859**	**0.76222**	**0.75577**	**0.72292**	**0.74532**	**0.78731**	**0.73266**	**0.76756**	**0.58986**	0.05789	--	
IO	12. Maldives	**0.64673**	**0.71028**	**0.67118**	**0.67292**	**0.63123**	**0.75342**	**0.65734**	**0.69346**	**0.53679**	**0.42875**	**0.50323**	--
	13. Diego Garcia	**0.51036**	**0.56474**	**0.52244**	**0.53912**	**0.49451**	**0.61025**	**0.52284**	**0.54533**	**0.41311**	**0.28493**	**0.35104**	-0.00728

Table 2.4. Results of the analysis of molecular variance (AMOVA) based on mitochondrial DNA (cytochrome *b*) sequence data for *Pygoplites diacanthus*. Bolded values denote significance at $P < 0.05$.

	Among groups			Among populations (within groups)			Within populations		
Regions	Φ_{CT}	*P*-value	% variation	Φ_{SC}	*P*-value	% variation	Φ_{ST}	*P*-value	% variation
Pacific Ocean vs. Indian Ocean	0.60	0.058	59.91	**0.19**	< 0.001	**7.46**	**0.67**	< 0.001	**32.63**
Pacific[a] vs. Indian[b] vs. Red Sea[c]	**0.66**	< 0.001	**65.53**	**0.04**	0.017	**1.44**	**0.67**	< 0.001	**33.03**
Indian[b] vs. Red Sea[c] vs. Christmas Is.	0.44	0.078	44.09	**0.02**	< 0.001	**0.92**	0.45	0.269	54.99
Pacific[a] vs. Mo'orea	0.08	0.184	7.92	**0.05**	< 0.001	**4.82**	**0.13**	< 0.001	**87.26**

[a]Pacific includes all Pacific Ocean populations plus Christmas Island.
[b]Indian includes the Maldives and Diego Garcia.
[c]Red Sea includes Saudi Arabia and Djibouti.

Table 2.5. Molecular diversity indices for populations of *Pygoplites diacanthus* based on nuclear DNA (introns RAG2 and S7) for all populations. Number of individuals sequenced (*n*), number of alleles (N_a), number of segregating (polymorphic) sites (*S*), observed heterozygosity (H_O), expected heterozygosity (H_E), and the corresponding *P*-value

	RAG2						S7					
Sample Location	*n*	N_a	*S*	H_O	H_E	*P*-value	*n*	N_a	*S*	H_O	H_E	*P*-value
Pacific Ocean												
Okinawa	6	3	1	0.50	0.59	1.00	5	8	8	0.80	0.93	0.37
Philippines	21	3	2	0.38	0.46	0.32	15	11	9	0.73	0.85	0.19
Palau	30	4	3	0.47	0.41	0.67	22	14	12	0.88	0.82	< 0.001
Marshall islands	27	3	2	0.26	0.29	0.55	14	9	8	0.71	0.82	0.16
Pohnpei	39	5	4	0.38	0.43	0.20	21	15	16	0.76	0.87	0.24
Indonesia	4	3	2	0.50	0.46	1.00	3	6	7	1.00	1.00	1.00
Tokelau	16	2	1	0.06	0.06	1.00	8	8	8	0.63	0.81	0.04
Mo’orea	31	4	3	0.61	0.64	0.83	30	7	7	0.80	0.71	0.33
American Samoa	18	3	2	0.44	0.54	0.40	16	10	10	0.75	0.85	0.14
Fiji	21	4	3	0.43	0.43	0.83	16	12	10	0.88	0.85	0.74
Christmas Island	25	4	3	0.28	0.39	0.14	18	12	11	0.78	0.84	0.58
Red Sea Province												
Saudi Arabia	19	3	2	0.21	0.20	1.00	15	5	7	0.47	0.41	1.00
Djibouti	59	6	5	0.22	0.22	0.61	52	8	7	0.85	0.80	0.43
Indian Ocean												
Maldives	19	2	1	0.37	0.46	0.61	18	5	5	0.61	0.70	0.24
Diego Garcia	31	3	2	0.39	0.38	0.25	31	8	9	0.84	0.72	0.93
All Locations	366	12	10	0.35	0.43	<0.001	284	44	31	0.77	0.86	< 0.001

Table 2.6. Matrix of pairwise *F*-statistics for 13 populations of *Pygoplites diacanthus*. Φ_{ST} values for RAG2 (below diagonal) and S7 (above diagonal). Bolded numbers indicate significance after controlling for false discovery rates at α = 0.05 (as per Narum, 2006). The corrected α = 0.009. Owing to low sample size, Okinawa and Indonesia have been excluded. Abbreviations: Red Sea Province, RS; Indian Ocean, IO.

		Pacific Ocean									RS		IO	
	Sample location	1	2	3	4	5	6	7	8	9	10	11	12	13
Pacific Ocean	1. Philippines	--	-0.00920	-0.01362	-0.01360	-0.01687	0.01687	0.01128	-0.00514	0.01515	**0.34364**	**0.17142**	**0.10393**	**0.09571**
	2. Palau	-0.00538	--	0.00508	-0.00296	-0.02460	0.02700	0.00922	-0.01550	-0.00726	**0.38275**	**0.22126**	**0.09033**	**0.08852**
	3. Marshall Is.	0.00818	-0.01120	--	-0.00031	-0.00704	0.05734	0.00961	-0.00460	0.04995	**0.34476**	**0.15924**	**0.14964**	**0.13677**
	4. Pohnpei	-0.00668	-0.01082	-0.00789	--	-0.02035	0.01691	0.00989	-0.00473	0.01182	**0.30090**	**0.18403**	**0.07945**	**0.08287**
	5. Tokelau	0.07767	0.04393	0.04048	0.02592	--	0.00217	-0.01313	-0.02998	-0.01183	**0.37543**	**0.20290**	**0.09332**	**0.09858**
	6. Mo'orea	**0.11389**	**0.13061**	**0.16703**	**0.16493**	**0.27102**	--	0.07372	0.03949	0.03840	**0.44338**	**0.25787**	**0.07336**	**0.07570**
	7. American Samoa	-0.00096	0.02568	0.05152	0.03906	**0.17279**	0.03921	--	-0.01129	0.02085	**0.36682**	**0.24862**	**0.18011**	**0.18764**
	8. Fiji	-0.02068	-0.01577	-0.00644	-0.01574	0.05125	**0.12489**	0.01209	--	0.00554	**0.40033**	**0.23471**	**0.13818**	**0.13340**
	9. Christmas Is.	-0.00815	-0.01338	-0.01051	-0.00520	0.07526	**0.11113**	0.00810	-0.01339	--	**0.43065**	**0.26948**	**0.09838**	**0.10584**
RS	10. Saudi Arabia	**0.10905**	**0.08062**	**0.08407**	0.06289	0.02759	**0.29673**	**0.19761**	**0.08516**	**0.11256**	--	0.07234	**0.51195**	**0.50068**
	11. Djibouti	**0.12103**	**0.08643**	**0.07487**	**0.06583**	0.00215	**0.3587**	**0.22863**	**0.09234**	**0.11642**	0.02992	--	**0.25737**	**0.25281**
IO	12. Maldives	**0.23970**	**0.23544**	**0.26566**	**0.23347**	**0.28203**	**0.34276**	**0.27897**	**0.23017**	**0.25607**	**0.25779**	**0.22058**	--	-0.00921
	13. Diego Garcia	**0.16033**	**0.14521**	**0.15459**	**0.1368**	0.13833	**0.31590**	**0.22167**	**0.14479**	**0.16565**	**0.13958**	**0.09067**	0.01181	--

CHAPTER 3 CONTEMPORARY CONNECTIVITY ACROSS THE HAWAIIAN ARCHIPELAGO IN TWO SPECIES OF SURGEONFISHES, *ACANTHURUS TRIOSTEGUS* AND *CTENOCHEATUS STRIGOSUS*, REVEAL FINESCALE STRUCTURE

ABSTRACT

The Hawaiian Archipelago has served as a natural lab to assess genetic connectivity patterns across a variety of organisms that are taxonomically and ecologically diverse. The ability to assess connectivity across a broad spectrum of taxa has provided insight into the location of ecological breaks, and the role of life history in influencing genetic structure and diversity. One common factor among these studies is the use of targeted loci, which illuminates connectivity over evolutionary timescales but is limited in explaining contemporary patterns. To evaluate contemporary connectivity patterns, we conducted a genomics-based analysis using SNPs generated from individual libraries as well as pooled DNA. The two species of surgeonfishes used in this study, *Acanthurus triostegus* (*manini*) and *Ctenochaetus strigosus* (*kole*), exhibit similar life history strategies but differ greatly in their biogeographic distribution. *Kole*, a Hawaiian endemic, showed island-by-island population structure, a pattern not previouosly exhibited amoug Hawaii reef fishes and countering previous results based on a single mtDNA marker. *Manini*, which has an Indo-Pacific distribution, showed highly structured population in the main Hawaiian Islands, but genetic homogeneity across the the northwestern extent of the archipelago. These results highlight the efficacy of genomic sequencing to characterize contemporary connectivity and invokes a mandate to revist past connetivity studies using targeted loci and reassessing them in a genomics framework.

INTRODUCTION

The linear Hawaiian Archipelago has hosted extensive research into genetic connectivity patterns across a variety of organisms that are taxonomically and ecologically diverse (e.g. Eble et al., 2009; (Andrews *et al.* 2010; Gaither *et al.* 2010a; Skillings *et al.* 2011; Timmers *et al.* 2011; Coleman *et al.* 2014; Iacchei *et al.* 2014; Tenggardjaja *et al.* 2016). This research has cumulated in several meta-analysis studies that aimed to identify common barriers to dispersal across the archipelago (Toonen *et al.* 2011), assess how life history traits influence population genetic structure (Selkoe *et al.* 2014), and to show how high coral cover harbors the greatest genetic diveristy (Selkoe *et al.* 2016b). Common amongst the data that was the foundation for these meta-analysis studies was the use of a targeted locus approach, which in some cases was conducted using a single mtDNA marker.

Population genetic studies have historically used a targeted loci approach to characterize genetic connectivity. However, during the past decade the field of genetics has steadily shifted to using high-throughput sequencing due in part to a reduction in cost (Wetterstrand 2019) and the ability to generate thousands of loci in a single run. Furthermore, when studies have incorporated a genomic component they are able to describe trends and patterns that could not be accomplished using a targeted loci approach (Keller *et al.* 2013; Gaither *et al.* 2015). With an increased number of loci from across the genome, we now have a greater ability to relate genomic trends to the ecology of the organism being investigated.

For this study, we used restriction site associated DNA sequencing (RADseq), a reduce genomic approach, to characterize connectivity across the Hawaiian Archipelago for two species of surgeonfish. By using RADseq, we were able to resolve contemporary pattern of connectivity as opposed to a targeted loci approach (i.e. mtDNA) which, in essence, uses loci that resolve connectivity averaged across thousands to millions of years. Additionally, we can revist and compare our RADseq results against past studies.

The two species of surgeonfishes (family Acanthuridae) in this study exhibit similar life history strategies and occupy similiar habitat. However, they differ greatly in their biogeographic distribution, thus providing an excellent framework to compare patterns of connectivity across Hawaii. *Ctenocheatus strigosus*, locally known as *kole*, and *Acanthurus triostegus*, locally known as *manini*, are both distributed throughout the Hawaiian Archipelago as well as Johnston Atoll. *Kole* is endemic to Hawaiʻi and Johnston Atoll. *Manini* has a broad Indo-Pacific distribution, although the Hawaiʻi population is recognized as a sub-species (*A. triostegus sandvicensis*) based on diagnostic differences in coloration and morphology (Randall 1961; Randall 2007).

Genetic patterns of connectivity have previously been described for each species. Genetic connectivity across Hawaiʻi was characterized for *kole* and found no population structure across the majority of the island chain except between Maro Reef and Pearl and Hermes Atoll located in the northwestern part of the archipelago (Eble *et al.* 2009). The single study that investigated connectivity of *manini* within Hawaiʻi found isolation between Hawaiʻi Island and Oʻahu (Planes & Fauvelot 2002). However, studies in other parts of the range have provided conflicting patterns of dispersal. In Northern Australia, *manini* had no significant (mtDNA) population structure across the Torres Strait (Mirams *et al.* 2011), a known biogeographic barrier (Voris 2000). However, by using allozymes, genetic structure was observed across various spatial scales from adjacent islands to a range-wide scale (Planes 1993; Planes *et al.* 1998a; Planes & Fauvelot 2002).

This will be the first analysis using a genomic approach to assess connectivity across the Hawaiian Archipelago for a marine fish species. We anticipate that RADseq data will uncover patterns that are not found using a targeted loci approach. The existence of previous single-locus surveys provides a valuable foundation for measuring the increased resolution expected with RADseq data.

MATERIAL AND METHODS

Taxon sampling and DNA extraction

Between 2003 and 2006, a total of 461 tissue samples (primarily fin clips) of *manini* from 10 locations and 790 samples of *kole* from 16 locations were collected from across the Hawaiian Archipelago and Johnston Atoll using pole spears with SCUBA or snorkeling (Tables 1, 2; Fig. 1). Tissues were preserved in salt-saturated DMSO buffer (Amos & Hoelzel 1991) and stored at room temperature. For *manini*, genomic DNA was extracted using Omega Bio-Tek E-Z 96® Tissue DNA Kit (Norcross, GA, USA) following the manufacturers protocol, and resuspended in nanopure water. High molecular weight was confirmed by visualizing on a 1.5% agarose gel with GelRed® (Biotium, Inc. Fremont, CA, USA). For *kole* when samples sizes were > 30, a random subsample of 30 individuals were selected to be included in the library pool.

Manini analysis

Library preparation and sequencing

RADseq library preparation and sequencing was conducted by the core lab at Texas A&M Corpus Christi, starting with 150 ng of high-molecular weight genomic DNA per sample and following the double-digest RAD (ddRAD) protocol (Peterson *et al.* 2012). Briefly, this process included digesting each sample with *Msp*l and *Eco*RI (New England Biolabs, Ipswich, MA, USA) followed by cleaning each sample with PEG solution using retained beads. Samples were then normalized to the same concentration followed by ligation of adapters. After digestion and ligation, a PCR was performed using dual-indexed primers. Fragments of between 325 bp and 400 bp were selected using BluePippin (Sage Science, Beverley, MA, USA). Following size selection, a Fragment Analyzer was run to visualize library size range followed by a qPCR to determine molarity of libraries. The resulting libraries were sequenced on a Illumina HiSeq® 4000 (150 paired-end reads, perfromed by NYU Langone Health Genome Technology Center). Sequence data for the samples were demultiplexed based on the barcodes from the adapters using *process_radtags*. Each individual library was sequenced across two or three independent runs for the purpose of increasing the number of sequence reads for each sample and to ensure congruence in nucleotide assignments.

Genotyping and de novo assembly of RADseq libraries

Raw reads obtained from Illumina runs were assessed for sequence quality, AT/GC content and overrepresented and duplicate sequences using *FastQC* v.0.10.1. As a reference genome is not available for *A. triostegus*, after initial quality assessment a *de novo* reference genome was assembled using *Rainbow* v. 2.0.4 as performed in the dDocent pipeline (Puritz *et al.* 2014a; Puritz *et al.* 2014b). After generating the reference genome and read mapping, single nucleotide polymorphisms (SNPs) detection was performed using *FreeBayes* v.1.10.54. A second filtering step was performed where variants were excluded if they were not genotyped in 50% of individuals, had a minimum quality score of 30, and minor allele count of 3. Individuals with 10% missing genotypes were also excluded. Additionally, SNPs that did not meet expectations for Hardy-Weinberg Equilibrium were excluded.

Population genetic analyses

GENODIVE v.2.0b27 (Meirmans & Van Tienderen 2004) was used to generate genetic diversity indices, as well as to test for population structure. Genetic structure among sample locations was evaluated with an analysis of molecular variance (AMOVA; (Excoffier *et al.* 2005). Deviations from null distributions were tested with non-parametric permutation procedures (N = 9999). Pairwise F_{ST} statistics were generated to assess genetic structure between locations. False discovery rates were controlled for and maintained at $\alpha = 0.05$ among all pairwise tests (Benjamini & Yekutieli 2001; Narum 2006). Populations for the east and west side of Hawai‘i Island, Maui, and O‘ahu were analyzed as separate populations but no genetic differentiation was identified. The results being presented combined all the samples from both sides and are presented as a single island population.

Genetic partitioning was assessed using STRUCTURE v.2.3.2 (Pritchard *et al.* 2000), a Bayesian method that estimates ancestry and categorizes individuals into discrete populations. The simulation was run for 1 million generations with the first 100,000 discarded as burn-in. Five replicates of each simulation from K=1 to 10 genetic clusters were run. We determined the most likely number of genetic clusters (K) using STRUCTURE HARVESTER v.0.6.93 (Earl & von Holdt 2012). STRUCTURE results were analyzed using the on-line tool CLUMPAK (http://clumpak.tau.ac.il/index.html) (Kopelman *et al.* 2015) which integrates the program CLUMPP v.1.1.2 (Jakobsson & Rosenberg 2007), which minimizes the variance across all iterations. CLUMPAK then creates the final visualized output.

Kole analysis

Pooled library preparation

To save on sequencing costs, samples of *kole* were pooled into a single library. Pooling multiple individuals from the same species and sequencing the homogenized DNA (Pool-seq) is a cost-effective method to estimate allele frequencies within populations that has been utilized to evaluate population structure across of suite of diverse taxa (Kozak *et al.* 2014; Guo *et al.* 2016; Dennenmoser *et al.* 2017; Fischer *et al.* 2017). Despite the controversy regarding the use of Pool-seq versus individual sequencing (Cutler & Jensen 2010), it has been demonstrated that estimations of allele frequencies for high-frequency alleles are robust when individuals DNA are pooled in equal molar concentrations, even when taking sequencing error into account (Futschik & Schlötterer 2010), making Pool-seq an economical approach for population genomic analyses.

To confirm the quantity and purity, DNA was quantified using an AccuBlue assay (Biotium, Hayward, CA, USA) and assessed with the software SoftMax Pro 4.8. DNA samples were precipitated, dried using a speedvac, and resuspended in nanopure water (Thermo Scientific*, Barnstead, Dubuque, IA, USA). Equal molar concentrations from individual samples were then pooled to a total volume of 25 µl for a final number of 16 pooled DNA samples representing each island population.

DNA digestion and library preparation followed the ezRAD protocol by Toonen *et al.* (2013). Briefly, we first used the Kapa Hyper prep kit (Kapa Biosystems, Wilmington, MA, USA) and the Truseq PCR-free kit (Illumina, Inc., San Diego, CA, USA). This process included digesting each sample with *Dpn*II (New England Biolabs, Ipswich, MA, USA), which cleaves sequences at GATC cut sites, followed by cleaning each sample with AMPure XP beads

(Beckman Coulter Life Sciences, Indianapolis, IN, USA). Samples were then normalized to the same concentration followed by end repairs, A-tailing, and ligation of adapters. Fragments of between 350 bp and 700 bp were selected using SPRI beads (Applied Biological Materials, Inc., Richmond, BC, Canada). Afterwards, libraries were amplified by conducting PCR. The resulting libraries were sequenced on a Illumina MiSeq® (paired-end 150 bp; perfromed by Hawai‘i Institute of Marine Biologys Genetic Core Facility). Raw reads were subsequently processed using the dDocent bioinformatics pipeline as described for *manini* with the exception that it was adjusted for analysing pooled sequence data.

Population level analyses

Genetic differentation between populations was calculated using assessPool (https://github.com/ToBoDev/assessPool). *AssessPool* is a R pipeline designed to analyze population structure from pooled data. It incorporates *PoPoolation2* v.1.201 (Kofler *et al.* 2011b) to generate pairwise F_{ST} values and the associated Fishers T-test. General population molecular indices were calculated using *Popoolation* v1.2.2 (Kofler *et al.* 2011a). *AssessPool* conducts a pre-analysis filtering step based on population pool size, miniumum total coverage per variable site, and maximum insertion/deletion length. This was followed by an additional filtering step conducted by *PoPoolation2*. The *PoPoolation2* parameters were set as: minimum depth threshold, 4; = maximum indel length, 5; minimum count, 2; minimum coverage, 22; pool size, 30. All other parameters remained at their default settings.

RESULTS

Population structure of manini

After the initial trimming, filtering and demultiplexing, we retained 80,955 loci. Following the second filtering step which accounted for coverage, minimum allele frequency and presence among the individuals included in the dataset, we identified 716 loci that met all the criteria to be used in downstream analyses.

Molecular diversity indices are summarized in Table 1. The number of alleles present in all populations ranged from 1.17 to 1.46 at Kure and Kaua‘i. The effective number of alleles were similar across locations and ranged from 1.046 to 1.067. Total heterozygosity ranged from 0.031 at Maui to 0.045 at Kure. A review of the inbreeding coefficient found that the influence of inbreeding is negligible across all population.

Population pairwise F_{ST} values are summarized in Table 3. Significance was determined after controlling for false discovery rates (corrected $\alpha = 0.009$). In the main Hawaiian Islands (MHI), population structure was found to be significant between all islands. The highest differentiation found was between Hawai‘i Island and O‘ahu (F_{ST} =0.071). After correcting for false discovery rates Hawai‘i Island no longer was differentiated from Kaua‘i. In the Northwestern Hawaiian Islands (NWHI), all island expect Kure grouped with Johnston Atoll to form one panmictic population. Kure was differentiated from the other NWHI with the greatest differentiation between Kure and Pearl and Hermes (F_{ST} =0.070). When comparing between the MHI and the NWHI, O‘ahu was not significantly differentiated from Johnston Atoll and the islands in the NWHI with the exception of Kure (F_{ST} =0.073). Kure was also found to be significantly differentiated from Maui (F_{ST} =0.057) but was not differentiated from Hawai‘i Island or Kaua‘i. Johnston Atoll also showed significant differentiation from Hawai‘i Island, Maui and Kaua‘i. The AMOVA analysis found significant differences among populations overall (F_{ST} =0.033, $P < 0.001$; Table 4).

The STRUCTURE analysis recovered two population clusters (k=2) (Fig. 2, Fig. S1). The analysis found one population consisting of Hawai‘i, Maui, Kaua‘i, and Kure, and a second population consisting of the remaining islands in the NWHI, O‘ahu and Johnston Atoll. Various levels of admixture were observed in all locations.

Population structure of kole

After the initial trimming, filtering and demultiplexing, we retained a total of 69,387 loci. After following the additional filtering steps as implement in PoPoolation2, we retained 4,292 loci that were called in all pools and were used for all downstream analyses.

Population pairwise F_{ST} values are summarized in Table S1 and presented as a heat map (Fig. 3). All pairwise comparisons showed differentiation between locations with F_{ST} values ranging from 0.019 between Ni‘ihau and Lana‘i, up to 0.041 between Kure and Kaua‘i. The average F_{ST} across all populations was 0.029. Within the MHI, Moloka‘i and O‘ahu were the more differentiated that the other islands and less differentiated with the islands in the NWHI. Within the NWHI, Gardiner had relative low differentiation between all islands (F_{ST}: 0.022 - 0.029).

DISCUSSION

Patterns of dispesal across the archipelago

Studies of connectivity along the Hawaiian Archipelago have added to our understandng on how dispersal patterns are shaped and the mechanisms that influence how biodiversity is exchanged in the marine realm. By undertaking a genomics approach we have uncovered patterns of dispersal that have not been previously observed in Hawaiian marine reef fishes. The island-by-island structure observed in *kole* is inconsistent with patterns of structure found in other fishes and has only been observed in one other species, vermetid gastrodpods (Faucci et al., unpublished), whose genetic structure can be explained by their crawl-away larvae mode of reproduction. The high structure of *kole* contrasts with previous research which, using a single mtDNA maker, found a genetically homogenous population across most of the range and only showing structure at Maro Reef and Pearl and Hermes Atoll (Eble *et al.* 2009). By utilizing RADseq we were able to illuminate fine scale population structure that the use of a single marker was unable to reveal.

The results of this study also show patterns that corroborate previously identified patterns of connectivity. An allozyme analysis of *manini* showed structure between Hawai‘i Island and O‘ahu (Planes & Fauvelot 2002). Furthermore, the multi-species genetic breaks identified by Toonen *et al.* (2011) found that each island in the MHI is genetically distinct, a pattern consistent with our findings for *manini* (Table 3). Along the rest of the range, connectivity shows partial concordance with trends in other species. We recovered a highly connected population extending from French Frigate Shoals to Midway Atoll, which also includes Johnston Atoll. However, the furthest northwestern ecological break was found to occur between Midway Atoll and Pearl & Hermes (to the east) in most other species (Toonen *et al.* 2011), however, we found a break between Midway Atoll and Kure (to the west). Nonetheless, the long expanses of connectivity in the middle of the archipelago is recurring pattern in Hawaiian marine species.

The high connectivity of *manini* between Johnston Atoll and the archipelago is a pattern documented in other fish species (Craig *et al.* 2010; DiBattista *et al.* 2011; Fernandez-Silva *et al.* 2015). Johnston Atoll is the nearest land mass to the Hawaiian Archipelago, 885 km southwest of French Frigate Shoals, and is included in the Hawaiian biogeographic province based on high faunal similarity. Many endemic Hawaiian fishes are found there (Randall, 2007; Briggs and Bowen, 2012), and it is likely a stepping stone for Indo-Pacific biodiversity to colonize into Hawaii (Bowen, 2016). Johnson Atoll has been implicated as the source of propagules in the middle of the archipelago (Rivera *et al.* 2004; Gaither *et al.* 2011b; Andrews *et al.* 2014). Dispersal from Johnston Atoll into the archipelago is further supported by biophysical models. Kobayashi (2006) identified two potential corridors into the archipelago from Johnston Atoll for species with PLDs greater than 40 days - one being French Frigate Shoals (Kobayashi 2006).

Two anamolous patterns were observed: no significant population partitions between O‘ahu and the NWHI, and between Kure and the MHI (Table 3, Figure 2). It is not clear what biological or physical drivers are facilitating this pattern, which has not been observed in other species.

Factors influencing dispersal

The two surgeonfish under investigation share similar life histories, including similar pelagic larval duration (PLD). The PLD for *kole* is estimated at 50-60 days (based on sisters species *C. striatus* in Doherty *et al.* (1995) and the PLD for *manini* ranges from 54-70 (Randall 1961; Longenecker & Langston 2008). Despite exhibiting comparable PLDs, the patterns of genetic structure and connectivity across the Hawaiian Archipelago are quite dissimilar: *manini* shows genetic subdivisions between each of the islands that make up the MHI as well as Kure, while the islands found along the nearly 1300 km distance between French Frigate Shoals and Midway, along with Johnston Atoll, were not genetically distinguishable from one another. Conversely, *kole* shows genetic structure between every pairwise comparison along the archipelago. This corroborates previous studies that show that PLD alone is not a strong predictor of genetic dispersal (Weersing & Toonen 2009; Selkoe & Toonen 2011), particularly as it relates to Hawaiian endemic fishes (Selkoe *et al.* 2014).

Nonetheless, the disparity between these patterns of connectivity for the two surgeonfishes is grounded in some aspect of the dispersal capability of each species. Previous researchers have hypothesized that endemic Hawaiian fishes are descendents of poor dispersers (Hourigan & Reese 1987; Eble *et al.* 2009). Based on this scenario, after a rare colonization event into Hawai‘i they were unable to maintain connectivity with the widespread Pacific population. Although interspecific patterns varies, studies that have investigated population structure of endemic Hawaiian fishes, including groupers, damselfish, and surgeonfishes, have shown that endemic species have higher levels of population structure across the archipelago, relative to widespread species (Rivera *et al.* 2004; Ramon *et al.* 2008; Eble *et al.* 2009; Tenggardjaja *et al.* 2016). An exception to this pattern are the three endemic butterflyfishes which were all found to be genetically homogenous (Craig *et al.* 2010). Widespread species show very little to no structure across the archipelago (Craig *et al.* 2007; Eble *et al.* 2009; DiBattista *et al.* 2011; Eble *et al.* 2011a; Andrews *et al.* 2014).

The population structure of *manini* has traits associated with endemic species as well as wide-ranging species in that structure is observed across most of the MHI and Kure, but is genetically homogenous across the remainder of the NWHI and Johnston Atoll. Recall that due to diagnostic physical characters, Hawaiian *manini* are classified by some authors as a subspecies (Randall 1961; Randall 2007). However, research based on allozymes which characterized genetic structure of *manini* across the entire Indo-Pacific range found that the Hawaiian population was genetically distinct from the rest of the range, albiet with F_{ST} values that indicate an isolated population rather than a species designation (Planes & Fauvelot 2002). A thorough analysis using more sophisticated genetic techniques would need to be conducted to properly characterize Hawaiian *manini* as truly an endemic species. The conflicting patterns of dispersal in *manini* are not unknown. High population structure between small distances was documented in other archipelagos and even in lagoons (Planes *et al.* 1996; Planes *et al.* 1998a). Additionally. recent evidence from a parentage analysis conducting on Oʻahu found that the majority of larval settle less than 30 m from their spawning grounds, even in the face of strong currents (Coleman, unpublished). However, *manini* has also shown the ability to maintain connectivity across vast distances (Planes & Fauvelot 2002; Mirams *et al.* 2011). The dispersal ability of *manini* is clearly not static and is likely influenced by a variety of abioic and biotic factors.

Habitat preference and larval behavior are known to play a key role in dispersal and settlement queues (Jones 2015). The ecosystem of the MHI differs greatly from the relatively pristine ecosystem of the NWHI which was designated as the Papahānaumokuākea Marine National Monument in 2006, thereby limiting anthropogentic impacts. The MHI are made of up of high islands with steady freshwater run off that transport nutrients into surrounding water. Whereas, the NWHI are the oldest land in the archipelago and consist of low islands and atolls. The human impact in the MHI has also lead to degraded reefs, overfishing, and pollution, among other pressures, and have distorted many of the natural processes in this region. Also, many species that are present in the NWHI are rare or not found in the MHI such as *Acropora* corals (Grigg *et al.* 1981), a common species found throughout the Indo-Pacific, as well as many endemic fishes (Kosaki *et al.* 2016). However, differences in ecosystems does not seem to explain why Oʻahu *manini* shows high connectivity with the NWHI or why Kure shows connectivity with the MHI. Although, identifying the underlying factors promoting or inhibiting dispersal across the archipelago remain elusive, this research provides further support for the theme that Hawaiian endemic species exhibit limiting disepersal.

CONCLUSIONS

Here, we have highlighted the utility of using two different genomic methods for assessing population structure to describe dispersal and connectivity in a contemporary framework. Although not directly compariable, they have both shown the ability to uncover fine scale connectivity patterns. A comparative analysis in *kole* against the targeted locus approach, which showed highly connected populations, and a genomic approach, which revealed higher levels of isolation across the archipelago than have been previously described, underscores the need to include genomics to identify contemporary patterns of dispersal.

As the field of population genetics continues to evolve, a suite of tools are becoming more readily available to evaluate patterns of connectivity (Germer *et al.* 2000; Andrews & Luikart 2014; Puritz *et al.* 2014b). The exponential increase in data will continue to revolutionize our ability to identify many factors that influence species ability to diversify including ecological important traits (Hohenlohe 2014), historic role of hybridization in shaping biodiversity (Meier *et al.* 2017), genetic basis for species interactions and adaptation (Allendorf *et al.* 2010; Hohenlohe *et al.* 2010), among others.

The utility of conducting a targeted marker analysis is not obsolete, and can effectively be used in concert to describe evolutionary and contemporary patterns of connectivity, along with the associated mechanisms facilitating these patterns (Gaither *et al.* 2015). As we move forward in assessing connectivity across the Hawaiian Archipelago, it may be worthwhile to revist many of these past studies that used a targeted loci, and integrate a genomics perspective to uncover contemporary patterns of dispersal and identify the mechanisms that shaped the evolution of Hawaii's unique biodiversity.

Figure 3.1. Colletion locations and sample sizes of *Acanthurus triostegus* (left) and *Ctenocheatus strigosus (right).* Solid line designates the Northwestern Hawaiian Islands which, in 2006, was designated the Papāhanaumokuākea Marine National Monument. Filled darker areas represent current coastlines while light areas represent the maximum historical above-water island area. Sample sizes for each species are in parentheses (*A. triostegus*, *C. strigosus*). *Photo credit: Keoki Stender*

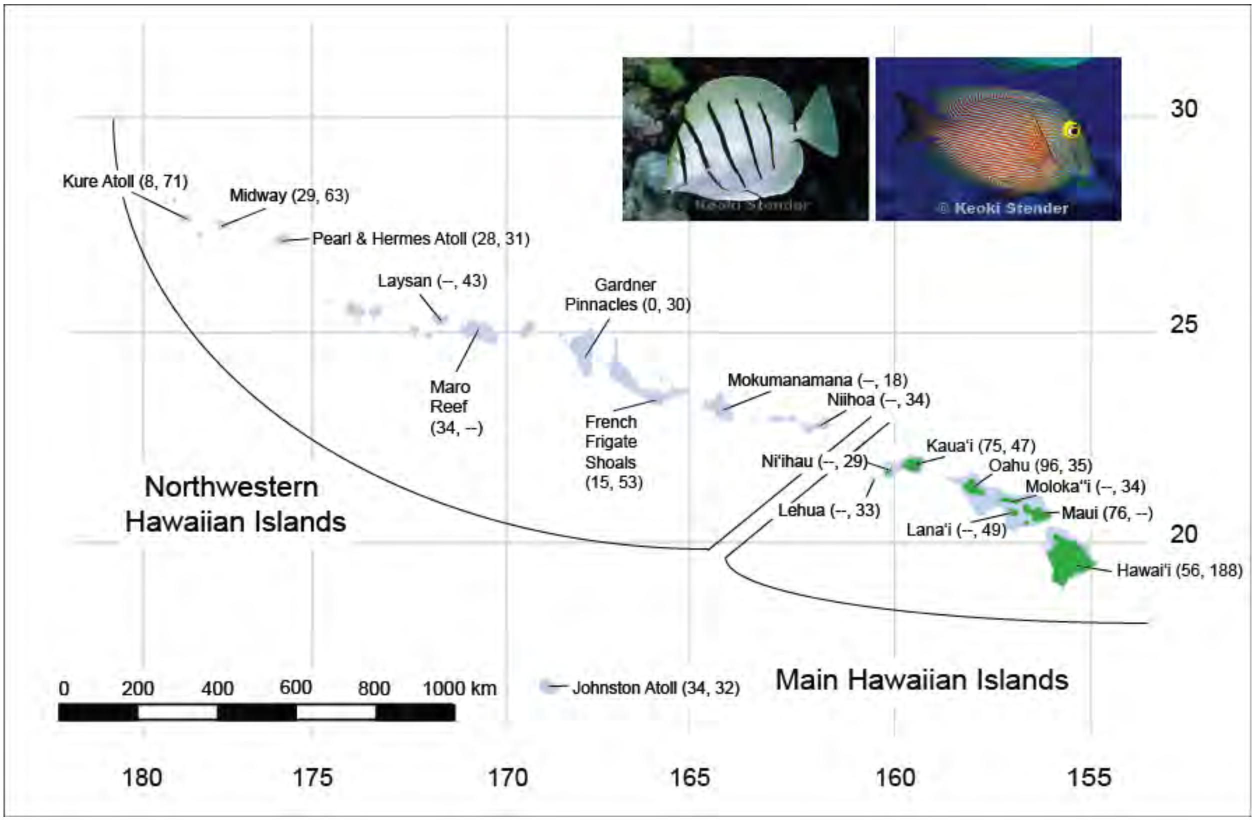

Figure 3.2. STRUCTURE bar plot (k=2) for Hawaiian populations of *Acanthurus triostegus* using 761 SNPs. Abbreviations: Hawaii, HAW; Maui, MAU; O‘ahu, OAH; Kaua‘i, KAU; French Frigate Shoals, FFS; Maro Reef, MAR; Pearl and Hermes Atoll, PH; Midway Atoll, MID; Johnston Atoll, JOH; Kure Atoll, KUR.

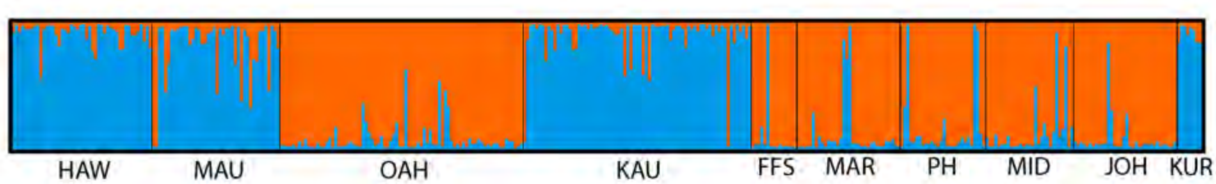

Figure 3.3. Heat map of F_{ST} values for *Ctenochaetus striogsus* based on Pool-seq libraries (No.of SNPs=4,292). Abbreviations: Hawai‘i Island, HAW; Moloka‘i, MOK; Lana‘i, LAN; O‘ahu, OAH; Kauai, KAU; Ni‘ihau, NII; Lehua Rock, LEH; Nihoa, NIH; Mokukmanana, MOK; Frigate Shoals, FFS; Gardiner, GAR; Laysan, LAY; Pearl and Hermes Atoll, PH; Midway Atoll, MID; Kure Atoll, KUR; Johnston Atoll, JOH.

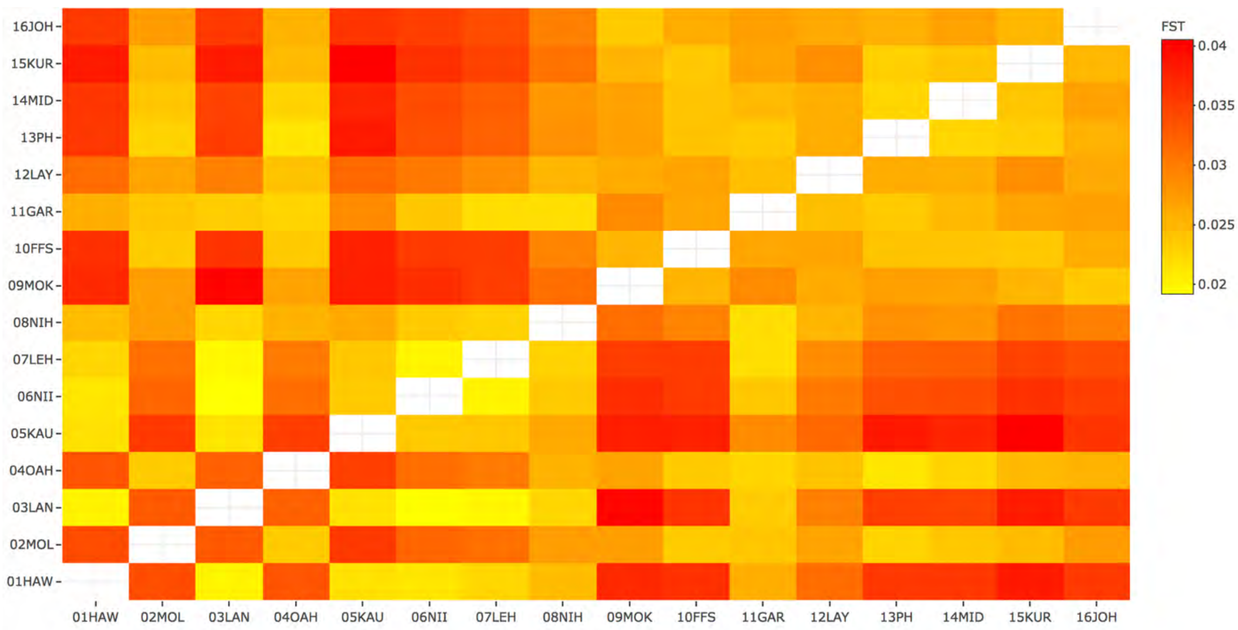

Table 3.1. Molecular diversity indices for populations of *Acanthurus triostegus* based on 761 SNPs. Number of individuals sequenced (n), average number of alleles per locus (N_a), effective number of alleles (N_{eff}), Observed heterozygosity (H_O), heterozygosity between populations (H_S), total heterozygosity (H_T), and inbreeding coefficient (G_{IS}) are presented.

Sample Location	*n*	N_a	N_{eff}	H_O	H_S	H_T	G_{IS}
Hawaii	56	1.340	1.054	0.047	0.037	0.037	-0.251
Maui	76	1.281	1.046	0.040	0.031	0.031	-0.281
Oahu	96	1.453	1.055	0.048	0.039	0.039	-0.248
Kauai	75	1.461	1.061	0.050	0.043	0.043	-0.176
French Frigate Shoals	15	1.195	1.056	0.050	0.038	0.038	-0.318
Maro Reef	34	1.325	1.055	0.049	0.038	0.038	-0.284
Pearl and Hermes	28	1.287	1.054	0.048	0.037	0.037	-0.293
Midway	29	1.308	1.056	0.051	0.039	0.039	-0.299
Kure	8	1.168	1.067	0.055	0.045	0.045	-0.217
Johnston	34	1.303	1.055	0.047	0.038	0.038	-0.253
All locations	451	1.312	1.056	0.049	0.039	0.039	-0.262

Table 3.2. Summary of collections for Ctenochaetus strigosus across the Hawaiian Archipelago

Sample Location	n
Hawai‘i Island	188
Moloka‘i	34
Lana‘i	49
O‘ahu	35
Kaua‘i	47
Ni‘ihau	29
Lehua	33
Nihoa	34
Mokumanamana	18
French Frigate Shoals	53
Gardiner	30
Laysan	43
Pearl and Hermes	31
Midway	63
Kure	71
Johnston Atoll	32
Total	790

Table 3.3. Matrix of pairwise F_{ST} statistics for 10 populations of *Acanthurus triostegus* based on 761 SNPs. Bolded numbers indicate significance at $p<0.05$. Italicized numbers indicate significance after controlling for false discovery rates at $\alpha = 0.05$ (as per Narum, 2006). The corrected $\alpha = 0.009$. Owing to low sample size Ni‘ihau has been excluded from the analysis. Abbreviations: Hawai‘i Island, HAW; Maui, MAU; O‘ahu, OAH; Kauai, KAU; French Frigate Shoals, FFS; Maro Reef, MARO; Pearl and Hermes Atoll, PH; Midway Atoll, MID; Kure Atoll, KUR; Johnston Atoll, JOH.

	HAW	MAU	OAH	KAU	FFS	MARO	PH	MID	JOH
HAW	--								
MAU	***0.026***	--							
OAH	***0.071***	***0.043***	--						
KAU	**0.007**	***0.022***	***0.051***	--					
FFS	***0.054***	***0.043***	<0.001	***0.048***	--				
MARO	***0.054***	***0.038***	0.006	***0.053***	<0.001	--			
PH	***0.048***	***0.033***	0.004	***0.044***	<0.001	<0.001	--		
MID	***0.048***	***0.026***	0.002	***0.045***	<0.001	<0.001	<0.001	--	
KUR	0.005	***0.057***	***0.073***	<0.001	***0.064***	***0.065***	***0.070***	***0.065***	--
JOH	***0.065***	***0.050***	0.001	***0.060***	<0.001	<0.001	0.005	0.002	***0.076***

Table 3.4. Results of the analysis of molecular variance (AMOVA) based on 761 SNPs for *Acanthurus triostegus*. Bolded values denote significance at $P < 0.05$

Source of Variation	F-statistic	% variation	F-value	Std.Dev.	P-value
Within Individual	F_{IT}	1.214	-0.214	0.04	--
Among Individual	F_{IS}	-0.248	-0.256	0.041	1.000
Among Population	F_{ST}	**0.033**	**0.033**	**0.008**	**0.001**

Table S3.1 Matrix of pairwise F_{ST} statistics for 16 populations across the Hawaiian Archipelago of *Ctenochaetus strigosus* using pooled DNA libraries. Abbreviations: Hawai‘i Island, HAW; Moloka‘i, MOK; Lana‘i, LAN; O‘ahu, OAH; Kauai, KAU; Ni‘ihau, NII; Lehua Rock, LEH; Nihoa, NIH; Mokumanamana, MOK; Frigate Shoals, FFS; Gardiner, GAR; Laysan, LAY; Pearl and Hermes Atoll, PH; Midway Atoll, MID; Kure Atoll, KUR; Johnston Atoll, JOH.

	HAW	MOL	LAN	OAH	KAU	NII	LEH	NIH	MOK	FFS	GAR	LAY	PH	MID	KUR
HAW	--														
MOL	0.0341	--													
LAN	0.0202	0.0329	--												
OAH	0.0333	0.0235	0.0324	--											
KAU	0.0217	0.0356	0.0216	0.0351	--										
NII	0.0212	0.0320	0.0192	0.0312	0.0236	--									
LEH	0.0226	0.0311	0.0198	0.0302	0.0238	0.0200	--								
NIH	0.0247	0.0273	0.0225	0.0254	0.0264	0.0237	0.0228	--							
MOK	0.0371	0.0273	0.0398	0.0268	0.0380	0.0367	0.0353	0.0313	--						
FFS	0.0364	0.0234	0.0361	0.0236	0.0377	0.0355	0.0354	0.0294	0.0253	--					
GAR	0.0258	0.0239	0.0233	0.0227	0.0288	0.0238	0.0219	0.0220	0.0288	0.0265	--				
LAY	0.0313	0.0267	0.0297	0.0241	0.0317	0.0303	0.0285	0.0253	0.0261	0.0267	0.0245	--			
PH	0.0358	0.0228	0.0351	0.0213	0.0383	0.0337	0.0322	0.0283	0.0271	0.0242	0.0236	0.0259	--		
MID	0.0359	0.0238	0.0348	0.0227	0.0373	0.0340	0.0326	0.0279	0.0269	0.0240	0.0249	0.0258	0.0226	--	
KUR	0.0384	0.0248	0.0381	0.0249	0.0405	0.0364	0.0348	0.0308	0.0253	0.0237	0.0267	0.0285	0.0231	0.0239	--
JOH	0.0356	0.0274	0.0356	0.0255	0.0360	0.0351	0.0341	0.0298	0.0235	0.0260	0.0270	0.0263	0.0257	0.0268	0.0252

Table S3.2.

Table S3.2. Evanno output identifying the ideal number of clusters present across populations						
# K	Reps	Mean Ln P(K)	St.dev Ln P(K)	Ln'(K)	|Ln''(K)|	Delta K
1	5	-33918.76	1.3813	NA	NA	NA
2	5	-32588.04	5.8833	1330.72	1246.84	211.92935
3	5	-32504.16	10.26	83.88	1170.84	114.116742
4	5	-33591.12	1246.8203	-1086.96	1701.54	1.364704
5	5	-32976.54	1382.7738	614.58	2957.68	2.138947
6	5	-35319.64	3776.1411	-2343.1	2846.96	0.753934
7	5	-34815.78	4854.4566	503.86	10977.02	2.261225
8	5	-45288.94	11566.0673	-10473.16	18067.32	1.562097
9	5	-37694.78	9498.7453	7594.16	4895.78	0.515413
10	5	-34996.4	1430.4382	2698.38	NA	NA

CHAPTER 4 GENOMIC ASSESSMENT OF THE LARVAL ODYSSEY: SEL-RECRUITEMETN AND BIASED SETTLEMENT IN THE HAWAIIAN SURGEONFISH *ACANTHURUS TRIOSTEGUS SANDVICENSIS*

ABSTRACT

The gap between spawning and settlement location of marine fishes, wherein the larvae occupy an oceanic phase, is a great mystery in both their natural history and conservation. Recent genomic approaches offer some promise, most especially in linking parent to offspring with assays of nucleotide polymorphisms. Here, we apply this methodology to the endemic Hawaiian manini (*Acanthurus triostegus sandvicensis*), a surgeonfish with a long pelagic larval stage of ~54 – 77 days. We collected 606 adults and 607 juveniles from 23 locations around the island of Oʻahu, Hawaiʻi. Based on 399 SNPs, we assigned 68 of these juveniles back to a parent (11.2% assignment rate). The western and northern sides of the island, which are subject to westerly currents, had little or no detected recruitment. In contrast, the majority of juveniles (94%) sampled along the eastern shore originated on this side of the island, primarily within semi-enclosed Kāneʻohe Bay. Nearly half of the assigned juveniles were found in the southern part of Kāneʻohe Bay, with local settlement likely facilitated by extended water residence time in this region. Several instances of self-recruitment were observed along the eastern and southern shores. Cumulatively, these findings indicate that most dispersal is between adjacent regions on the eastern and southern shores. Regional management efforts for manini and possibly other reef fishes will be effective only with collaboration among adjacent coastal communities, consistent with the traditional *moku* system of native Hawaiian resource management.

INTRODUCTION

Long-range dispersal in reef fishes is limited to the pelagic larval stage, as most coral reef organisms maintain confined home ranges as juveniles and adults (Leis 1991; Leis & McCormick 2002; Hellberg 2009). The pelagic larval phase lasts from weeks to months in marine fishes thereby making it difficult to determine the spawning location of origin. Identifying this gap in knowledge and understanding the extent of connectivity between locations on a local scale is essential for proper stewardship of these coastal resources throughout their life cycles (Johnson *et al.* 2018).

The convict surgeonfish (*Acanthurus triostegus sandvicensis*), known locally as *manini*, is a common surgeonfish in the Hawaiian Islands (Randall 2010). *Manini* is heavily targeted by recreational fisheries (e.g. sport, leisure, or subsistence) and is described as an exploited species by Hawai‘i's Division of Aquatic Resources (Longenecker *et al.* 2008). In Hawai‘i, it is estimated that up to 24% of the households participated in recreational fishing and that nearly 1.2 million kg year^{-1} of reef-associated catch, 84% of which comes from non-commercial fisheries, are extracted from the Main Hawaiian Islands (McCoy *et al.* 2018). Therefore, the pressure of recreational fisheries on coastal resources is substantial, and as a result target species in the Main Hawaiian Islands have 50% lower biomass than in the uninhabited Northwest Hawaiian Islands (Friedlander *et al.* 2018). In addition to extensive exploitation, current regulations may be ineffective because the minimum legal size is smaller than the average minimum size at sexual maturity, resulting in a majority of females entering the fishery before reproduction (Longenecker *et al.* 2008; Schemmel & Friedlander 2017).

Under-managed fisheries can lead to overfishing and can inhibit long-term sustainability for communities that rely on these resources for subsistence. In response to this potential threat, legislation was passed in 1994 that allowed state and local agencies to create community-based subsistence fishing areas (CBSFAs), which have so far been implemented on the islands of Kauaʻi and Molokaʻi. Community members on Oʻahu have recognized that maintaining food security will require new management approaches or a return to *moku*, traditional Hawaiian management strategies to protecting coastal resources. As a result, *manini* was identified by Native Hawaiian community leaders as a species of concern, prompting this effort to identify connectivity patterns between offspring and adults. To advance this goal, one of the first steps is to determine the source of fish populations.

Several methods can be used to identify connectivity and dispersal patterns among reef fishes (Jones 2015). A traditional population genetics approach is effective to characterize connectivity across distances of 100s to 1,000s of km; however, it is usually ineffective at smaller spatial scales, such as individual islands or archipelagos, where it is difficult to detect signals of isolation within the existing pool of genetic diversity (Saenz-Agudelo *et al.* 2009). Chemical tagging has proven to be an effective method (Jones *et al.* 1999), but it is labor intensive, expensive, and has only been applied a handful of times. Hydrodynamic and biophysical models have potential to identify general patterns of larval dispersal (Kobayashi 2006; Jones 2015). This computational approach simulates the movement and dispersal of virtual particles and incorporates physical characteristics of the surrounding environment as well as complex biological components to make predictions of larval dispersal. Ideally these models are concordant with empirical data (Galindo *et al.* 2010; Leray *et al.* 2010; White *et al.* 2010; Bowen 2016) particularly by matching genetic connectivity to oceanic circulation models. However, despite some success, model predictions often fail to match what is observed in nature (Selkoe *et al.* 2016a).

Genetic parentage analyses have proven to be powerful tool for identifying fine scale connectivity. However, these analyses are limited, and may explain no more than 26% of the variation in true connectivity within a population (Christie *et al.* 2017). Nonetheless, parentage analyses have described connectivity in a variety of taxa including butterflyfishes (Abesamis *et al.* 2017), clownfishes (Jones *et al.* 1999; Saenz-Agudelo *et al.* 2012), gobies (D'aloia *et al.* 2013), groupers (Almany *et al.* 2013), snappers (Harrison *et al.* 2012), and surgeonfish (Christie *et al.* 2010). In the case of the yellow tang (*Zebrasoma flavescens*), Christie *et al.* (2010) provided direct evidence of connectivity within an existing network of marine protected areas (MPAs) around Hawai‘i Island. In the clownfish *Amphiprion percula*, Planes *et al.* (2009) found high levels of local recruitment to natal reefs in Kimbe Bay, Papua New Guinea, as well as recruitment to adjacent locations within a network of MPAs. These studies show the efficacy of parentage analyses as a tool for characterizing dispersal patterns across small spatial scales.

With advances in genomic technology, single nucleotide polymorphisms (SNPs) are becoming increasingly popular for parentage analyses. Comparable studies have consistently shown that SNPs more accurately assign parent-offspring pairs when compared to microsatellites (Hauser *et al.* 2011; Andrews *et al.* 2018; Flanagan & Jones 2018; Thrasher *et al.* 2018) with as few as 100 SNPs being sufficient to resolve parentage (Flanagan & Jones 2018). Here, we use SNP-based parentage analysis to describe dispersal and connectivity patterns of manini around the island of O‘ahu, with a focus on Kāne‘ohe Bay on the eastern side of the island. This is the largest semi-enclosed bay in the main Hawaiian Islands with an area of 45 km^2, and a popular fishing spot with well-described oceanographic properties and biotic communities (Bahr *et al.*

2015). Our results are intended to inform community-based management efforts by identifying propagule sources and sinks of the larvae of a locally important fish species, as well as highlight areas that may be particularly vulnerable to excessive fishing pressure.

MATERIAL AND METHODS

Study species

Manini is an herbivorous surgeonfish found throughout the Indo-Pacific that specializes on benthic algae. It often occurs in large schools along reef flats and the outer reef. Schemmeland Friedlander (2017) recently described aspects of the reproductive biology of *manini* across the Hawaiian Islands: On O‘ahu, group spawning occurs before dusk where aggregations of 25-800 individuals form a few days before the new and full moon. Spawning takes place at depths from 7-30 m and peaks during February-June. However, spawning occurs throughout the year and is likely to be highly variable across the Hawaiian Islands. The pelagic larval duration (PLD) is estimated to range from 54 days (Longenecker & Langston 2008) up to approximately 77 days (Randall 2005a), a longer interval than most surgeonfishes (Leis & McCormick 2002; Eble *et al.* 2009).

Sampling and DNA extraction

Between May 2015 and July 2017, a total of 1,213 tissue samples of *manini* (606 adults; 607 juveniles) were collected from 23 locations around the island of O‘ahu, Hawai‘i using pole spears with SCUBA or snorkeling (Table 4.1, Fig. 4.1). Individuals < 121 cm were classified as juveniles (i.e., reproductively immature) based on the average of size of maturity for males and females (Randall 1961; Longenecker *et al.* 2008; Schemmel & Friedlander 2017). Tissues were transferred to 95% ethanol and stored at room temperature. Genomic DNA was extracted using Omega Bio-Tek E-Z 96® Tissue DNA Kit (Norcross, GA, USA) and following the manufacturers protocol. Genomic DNA was resuspended in nanopure water. High molecular weight DNA was confirmed by visualizing on a 1.5% agarose gel with GelRed® (Biotium, Inc. Fremont, CA, USA).

Library preparation and sequencing

Restriction-site associated DNA (RAD) library preparation and sequencing was conducted by the Texas A&M core lab, starting with 150 ng of high-molecular weight genomic DNA per sample and following the double-digest RAD (ddRAD) protocol (Peterson *et al.* 2012). Briefly, this process included digesting each sample with *Msp*I and *Eco*RI (New England Biolabs, Ipswich, MA, USA) followed by cleaning each sample with PEG solution using retained beads. Samples were then normalized to equimolar concentration followed by ligation of sequencing adapters. After digestion and ligation, a PCR was performed using dual-indexed primers. Fragments of between 325 bp and 400 bp were selected using BluePippin (Sage Science, Beverley, MA, USA). Following size selection, a Fragment Analyzer was run to visualize library size range followed by qPCR to determine molarity of libraries. The resulting libraries were sequenced on a Illumina HiSeq® 4000 (150 paired-end reads, performed by NYU Langone Health Genome Technology Center). Sequence data were demultiplexed based on the barcodes from the adpaters using *process_radtags* found in the software package *STACKS* v. 2.41 (Catchen *et al.* 2011; Catchen *et al.* 2013). Each individual library was sequenced across two or three independent runs to increase the number of sequence reads for each sample and to ensure congruence in assignments between parents and offspring.

Genotyping and de novo assembly of RADseq libraries

Raw reads obtained from Illumina runs were assessed for sequence quality, AT/GC content and overrepresented and duplicate sequences using *FastQC* v. 0.10.1 (Andrews 2010). As a reference genome is not available for *A. triostegus*, after initial quality assessment, a *de novo* reference genome was assembled using *Rainbow* v. 2.0.4 (Chong *et al.* 2012) as performed in the dDocent pipeline (Puritz *et al.* 2014a; Puritz *et al.* 2014b). After generating the reference genome and mapping reads, SNP detection was performed using *FreeBayes* v. 1.10.54 (Garrison & Marth 2012). A second filtering step was performed where variants were excluded if they were not genotyped in 50% of individuals, had a minimum quality score of 30, and minor allele count of 3. Individuals with 10% missing genotypes were also excluded. Additionally, SNPs that did not meet the Hardy-Weinberg Equilibrium assumption were excluded.

Genetic parentage analysis

We conducted a parentage analysis using CERVUS v. 3.0.7 (Marshall *et al.* 1998; Kalinowski *et al.* 2007). This program calculates the likelihood that each candidate is the parent, taking into account population allele frequencies and genotype errors. An allele frequeny analysis was conducted to determine the suitability of loci for downstream assessment. CERVUS requires a parentage analysis simulation to determine the feasibility of the analysis given the set of loci and to calculate the critical likelihood ratios (LOD) to provide confidence in parent-offspring assignments. For the simulation to determine the critical LOD scores, we used 100,000 offspring (as recommended by the authors of CERVUS), an estimated genotyping error rate of 0.01, a proportion of loci typed across all individuals of 0.6868, and using an estimated number of candidate parents sampled. To get the estimated number of sampled parents we first needed the population size of *manini* around O‘ahu which was estimated to be 1,058,942 +/- 265,902 (Mean +/- SE) based on 228 surveys from 2010-2016 (pers. comm. Ivor Williams, NOAA). The number of typed loci was 200 which was determined after the final number of SNPs was resolved. The genotype of each offspring was then compared to each candidate parent and a random individual in the population to calculate a likelihood ratio. This ratio is presented as a LOD score, the natural logarithm of calculated likelihood ratio. A positive LOD score indicates that a candidate parent is more likely to be the true parent, whereas a negative LOD score indicates the candidate parent is unlikely to be the true parent. Parent-offspring assignments were accepted at a 95% confidence level. Dispersal distances were estimated using the distance calculator tool from sea-seek.com (https://www.sea-seek.com/tools/tools.php).

RESULTS

SNP analysis

After initial trimming, filtering and demultiplexing, we retained a total of 80,955 loci. Following the second filtering step which accounted for coverage, minimum allele frequency and presence among the individuals included in the dataset, we identified 399 loci that met all the criteria for downstream analyses. When individual libraries were analyzed, they showed patterns consistent with the analyses of the concatenated dataset. In other words, parent-offspring assignments were the same when analyzed as individual libraries and when using the concatenated dataset. However, the concatenated dataset included a few more individuals due to the strict filtering process; therefore, the results present here are only for the individual library analyses.

Parental assignment

Of the 607 juveniles screened for DNA parentage analysis, we assigned 68 juveniles back to a parent (Table 4.2, Fig. 4.1), and the geographic distribution of assignments was highly uneven. No assignments were detected on the north shore of Oahu. Along the western side only one location, Kahe (KAH in Fig. 4.1), had offspring recovered in which all the adults were collected in Maunalua Bay (MB in Fig. 4.1). Along the south shore, the only assigned juvenile was a case of self-recruitment at China Walls (CW in Fig. 4.1). The largest concentration of assigned individuals was found along the eastern side, particulary within Kāneʻohe Bay, accounting for 94% of the assignments in this study (Fig. 4.2). The juveniles recovered along the eastern shore mostly originated from locations on the east side of the island with a few individuals originated from the south shore and one instance of dispersal from Kahe on the west. There were several instances of self-recruitment in addition to the one at China Walls; one at Kailua (KAI in Fig. 4.1), and five within Kāneʻohe Bay.

Distance between parent and detected offspring ranged from 0.25 km between Reef 14 and 16 in South Kāneʻohe Bay, to 78 km between Kahe and Kailua. The average distance between spawning and settlement was 27 km. The highest proportions of juveniles were found to have dispersed 10-15 km (27%) and between 25-30 km (23%). These trends can be attributed to the exportation of juveniles from Lāʻie and Kailua into Kāneʻohe Bay.

DISCUSSION

This study assigned 68 (11.2%) sampled juveniles back to a parent. This is a remarkably high recover rate considering this species has potential to remain in the planktonic phase for nearly two months. For comparison, Christie (2010) sampled approximately 1,100 adults and juveniles of another surgeonfish, the yellow tang (*Zebrasoma flavescens*), along the windward coast of Hawaiʻi Island and recovered four (0.36%) parent-offspring pairs. However, the low assignment may be atttributed to sampling a smaller proportion of the adult population. The population of yellow tang around Hawaiʻi Island is estimated to be 4.2 million individuals, four times the estimated population size of manini around Oʻahu. In studies where the population sizes are much lower, a higher assignment rate is expected (Christie *et al.* 2017). Parentage analyses conducted on clownfishes (*Amphiprion polymnus*, *A. percula*) in Papua New Guinea assigned ~20% and 64% of sampled juveniles back to their parents (Saenz-Agudelo *et al.* 2009; Berumen *et al.* 2012). However, studies of butterflyfish (*Chaetodon vagabundus*) and groupers (*Plectropomus areolatus*) in the same region had a recovery rate of 8% and 10%, respectively (Berumen *et al.* 2012; Almany *et al.* 2013). Along the Great Barrier Reef of Australia, Harrison *et al.* (2012) had a recovery rate of 12% for a grouper (*Plectropomus maculatus*) and 16% for a snapper (*Lutjanus carponotatus*).

Bernardi *et al.* (2012) demonstrated that planktonic larval fish from a single spawning event may remain in close proximity, perhaps using shared sensory and behavioral mechanisms (Dixson *et al.* 2008). Despite the potential for these sophisticated behaviors, our initial screen revealed that no two individuals shared the same parent, providing no evidence of siblings at any of our 23 sample sites.

As exhibited above, the ability to assign juveniles back to their parent is highly variable and is influenced by many factors including life history strategies, physical processes of the surrounding environment, and the proportions of the adult population sampled. In the case of the clownfish and Great Barrier Reef studies, the adult population was heavily sampled, increasing the success of assigning a juvenile to a parent. Additionally, clownfish are demersal spawners with a relatively short planktonic larval phase of ~11 days (Almany *et al.* 2007).

The distance between spawning and settlement of juvenile fishes also varies. On Hawai‘i Island, Christie *et al.* (2010) detected dispersal distances as high as 184 km which is attributed to a combination of passive transport and active behavioral mechanisms. No evidence of self-recruitment was observed in that study. In contrast, clownfish exhibit high levels of self-recruitment as well as shorter disperal distance (35 km) (Planes *et al.* 2009). In the current study, we assigned juveniles to parents that were separated by as little as ~0.25 km, to locations as far as 79 km apart (Kahe to Kailua; Table. 4.2). However, the majority of offspring were recovered within 30 km of their spawning location. The general patterns of limited dispersal we observed in *manini* are similar to many dispersal kernels obtained for marine fishes, which show a high proportion of recruitment close to spawning site that tapers down as distance increases (Jones 2015). In one of the most thorough dispersal kernal studies, D'Aloia *et al.* (2015) detected a mean dispersal of only 1.7 km in Belizean gobies (*Elacatinus lori*), with no dispersal event detected <16.4 km.

The dispersal patterns of *manini* around O‘ahu are quite complex and cannot be explained by any single factor. *Manini* are known to spawn in pairs as well as large groups (Robertson 1983). Subtidal habitat and marine physical processes vary around the island, both of which may influence dispersal patterns. Additionally, larval behavior will influence settlement, and larval *manini* can delay metamorphosis as needed to recruit to appropriate habitat (Randall 1961; McCormick 1999). Below we discuss the general patterns of disperal along each coast of O‘ahu, and discuss the potential mechanisms influencing dispersal.

North, west, and south Oʻahu

The assignment of parent-offspring pairs on the north and western side of Oʻahu is strikingly low when compared to other areas of the island. There is only one instance of dispersal from Kahe, located on the southwestern side of Oʻahu, to Kailua, and another instance from Maunalua Bay to Kahe. No additional parent-offspring assignments were detected along the entire western and northern coasts. There are several possible reasons for this trend. First, sampling effort along the western and northern side of the island are lower compared to other regions (Table 4.1). Collection efforts along the northern coast were constrained by higher wave energy with winter swells often > 7 m in height (Fletcher *et al.* 2008) , making many potential sites inaccessible. When collecting was possible, few juveniles were located. The number of juveniles collected from both western and northern coasts account for only 12% of the total juvenile collection. As an effort was made to collect both adults and juveniles at each collection location, the ratio of adults to juveniles may reflect the biological reality of the presence and absence of each size class. However, to verify this, a more systematic survey of *manini* adults and juveniles would be required.

The low recovey on the northern and western side may also be attributed to the currents surrounding Oʻahu that drive dispersal in a westerly direction. The North Hawaiian Ridge Current (NHRC) flows in a west-northwesterly direction adjacent to the northern coast of Oʻahu (Firing 1996). On the southern coast of Oʻahu, the Hawaii Lee Current (HLC) flows northwest following the Hawaiian Ridge from Maui to Kauaʻi (Lumpkin 1998). Therefore, propagules of *manini* orginating on the west or north coasts may be carried west towards Kauai. Notably, planktonic species that are typically found nearshore (within 1 km) on the eastern side of Oahu are more common offshore along the western coast of Oʻahu (Hassett & Boehlert 1999).

The dispersal observed from Maunalua Bay to Kahe is consistent with the flow of the HLC. However the dispersal from Kahe, and all locations along the south shore, to the eastern side of Oʻahu is against the HLC. The maximum flow of the HLC reaches 20 cm/s, although there is some interannual fluctation in the strength of the current (Lumpkin 1998). Nonetheless, the HLC would be predicted to be major barrier to dispersal in an easterly direction which makes us speculate that other physical or biological mechanisms are facilitating dispersal towards the eastern side of Oʻahu.

East Oʻahu and Kāneʻohe Bay

On the eastern side of Oʻahu, the tide floods to the southeast and ebbs to the northwest. Smaller scale circulation features are also established by headlands. Hence some of the fine scale coastal processes support the settlement of juveniles in both a north and south direction, as well as importation of larva into Kāneʻohe Bay. The successful assignments in this study are overwhelmingly concentrated on the eastern side of Oʻahu, primarily into Kāneʻohe Bay, accounting for 94% of the successfully assigned juveniles.

Kāneʻohe Bay, located on the northeast coast of Oʻahu, is a semi-enclosed estuarine system characterized by shallow patch reefs and an average depth of 10 m (Jokiel 1991). It is bounded by a barrier reef on the seaward (northeastern) side with two major channels out to the ocean. The bay has an extensive history of anthropogenic modifications including dredging, filling and increased sedimentation from runoff, all which which have severely altered the natural configuration, bathymetry, and even the currents that exist in the bay (Bahr *et al.* 2015).

In a partner study, Jerolmon (2016) modeled *manini* larval settlement along the eastern coast and within Kāneʻohe Bay. The overall patterns of simulated connectivity were dominated by settlement and retention within Kāneʻohe Bay. Propagules that originated within the bay or entered the bay had a high chance of being retained. This pattern is consistent with the highest assignment of juveniles occurring within Kāneʻohe Bay.

The circulation patterns are highly variable between northern and southern reaches of Kāneʻohe Bay (Bathen 1968; Lowe *et al.* 2009), with water residence times ranging from <1 day on the outer reef to >1 month at the semi-enclosed southern part of the bay (Bathen 1968; Ostrander *et al.* 2008; Lowe *et al.* 2009). The northern half of the bay has a much more active circulation pattern with high levels of exchange between the bay and offshore waters. The southern part of the bay is characterized by reduced circulation due to flow restrictions which are absent in the northern part of the bay. Hence, the South Bay has been identified as a potential hotspot for retention and self-recruitment due to the high-water residence time (Lowe et al. 2009). Indeed, South Bay had the highest rates of parental assignments, accounting for > 50% of all the recovered offspring matches found in this study. Additionally, the highest rates of self-recruitment were in the South Bay. These patterns are consistent with the model predictions of Jerolmon (2016).

There are two instances of dispersal outside of the bay, both of which followed a northern trajectory towards Hauʻula and Lāʻie (HAU and LAIE in Fig. 4.1). These individuals originated at the northernmost collection site within Kāneʻohe Bay which is subjected to more oceanic conditions and where water residence time can be <1 day (Lowe *et al.* 2009). Unlike the southern part of the bay, physical processes in this northernmost part of the bay appear to reduce larval retention, a finding which is also consistent with Jerolmon (2016).

Fishery implications

Despite high assignment of juveniles within Kāneʻohe Bay, we observed that the size-class distribution of the manini population there appears to be skewed toward juvenile size-classes, which is reflected in the adult to juvenile sampling ratio (Table 4.1). This reflects trends from personal observations and conversations with local fishers, in which heavy fishing pressure on adult and subadult *manini* throughout the bay is likely to have reduced adult fish numbers and skewed size-class ratios within the population. Many Hawaiian coastal fishes, including *manini*, are harvested at rates that may not be sustainable (Smith 1993; Friedlander 2004; Friedlander *et al.* 2018). In the Main Hawaiian Islands, it is estimated that biomass of reef-associated catches is nearly 1.2 million kg per year. For *manini*, legal size limits are below the average size at maturity meaning females can be removed from the population before they can contribute offspring (Schemmel & Friedlander 2017).

One of the motivations for this study is to inform management efforts at the community level to ensure that subsistence fisheries for *manini* persist sustainably into the future. Inherent in this motivation is knowing which populations are currently at risk of overfishing. Although there were a few instances of self-recruitment inside Kāneʻohe Bay, the major source of recruitment originates outside the bay. This may be a result of heavy fishing pressure; however, an investigation of the abundance of adult *manini* inside the bay would need to be conducted to clarify these patterns. Nonetheless, in the context of fisheries and ensuring long-term sustainability, the population of *manini* inside Kāneʻohe Bay seems to be largely sourced by adjacent areas outside of the Bay. Accordingly, management efforts would need to ensure healthy population levels to the north and south of Kāneʻohe Bay, in order to accommodate heavy fishing pressure inside the bay. These findings provide a geographic scale at which both communities and agencies may cooperate to target management efforts to promote sustainability in subsistence and recreational fisheries.

Patterns observed elsewhere for Manini

Manini are a ubiquitous feature of reefs from the East Pacific to the Western Indian Ocean, and several previous studies have provided genetic assessments of dispersal. Lessiosand Robertson (2006) reported very limited genetic connectivity on the scale of eastern versus central Pacific (mtDNA Φ_{ST} =0.355). Planes *et al.* (1996) reported a pattern of isolation by distance between proximal islands in French Polynesia. These authors concluded that most dispersal is between adjacent regions, and that long-distance dispersal is rare or sporadic. More directly pertinent to this study is the allozyme analysis of *manini* within the lagoon at New Caledonia, which revealed significant population structure (F_{ST}= 0.049) on a scale of a few hundred kms, unusual for a reef fish (Planes *et al.* 1998a). Planes *et al.* (1998b) reached a similar finding in Taiaro Lagoon in French Polynesia (F_{ST}= 0.055 between lagoon and ocean), concluding that *manini* could close their life cycle within the lagoon (an area of 6 km^2), which has no regular connection to the ocean. These results are in substantial agreement with our finding of limited larval dispersal on the scale of eastern and southern O‘ahu. Collectively, these studies reinforce the conclusion that a long pelagic larval duration does not invariably translate into extensive dispersal (Weersing & Toonen 2009; Selkoe & Toonen 2011).

CONCLUSIONS

Understanding the early life history, ecology and dynamics of *manini* is critical in projecting the success of adult populations and thus strategizing a method to ensure their sustainability. We hope that by illuminating some of the pathways of dispersal and settlement around O‘ahu, we have provided one of the necessary components to properly inform conservation and management strategies. This study indicates that local recruitment is low along the northern and western shores of Oahu, which are subject to westerly currents, but is much higher in the protected waters of Kāne‘ohe Bay on the eastern side. Kāne‘ohe Bay acts as a sink for propagules from reefs as far as 60 km away. However, it is also a source of recruitment to regions along the eastern shore. Therefore, the community-based subsistence fishing areas (CBSFAs), a return to *moku* traditional Hawaiian management strategies, would be most effective on the eastern and southern coasts of Oahu. Indeed, given the scale of *manini* dispersal observed in previous studies, *moku* management seems a good fit to *manini* fisheries in general. The possible exceptions are the *manini* on the western and northern shores, where currents may disperse propagules beyond the coastal waters of Oahu.

Finally, we note that when demographic composition was skewed towards adults in our study sites, we found very low larval retention. When skewed towards juveniles, we found very high larval retention. This may be an artifact of fishing pressure, but also may provide a simple observational test that can indicate areas of productivity (in terms of high recruitment) without lethal sampling and expensive lab work.

Figure 4.1. Map of O‘ahu collection sites and dispersal pathways. Lines and arrows indicate the pathway of dispersal from parent to offspring. Dashed lines are a single dispersal event. Solid lines indicate dispersal paths shared by two or more larvae, and line thickness is proportional to the number of individuals that followed a given path. Red sqares indicated self recruitment events. Collection site codes are provided in Table 4.1.

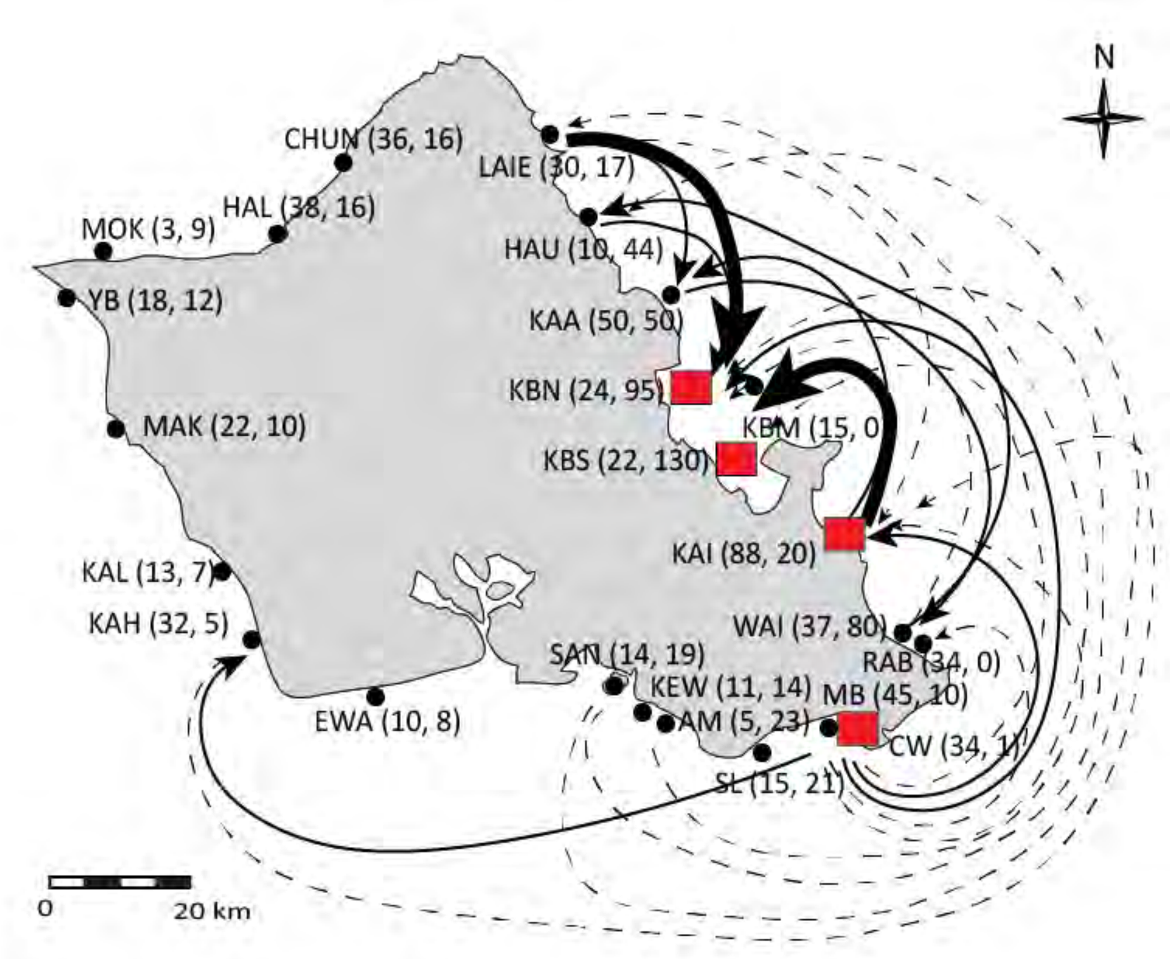

Figure 4.2. Map of Kāneʻohe Bay colletion sites. Black dots indicate sampled reefs. Reefs IDs are based on nomenclature of Roy (1970). Only reefs where parents or offspring were recovered are listed, however dots denote the location where collections occurred. Lines and arrows indicate the pathway of dispersal from parent to offspring. Dashed lines indicated a single dispersal event.

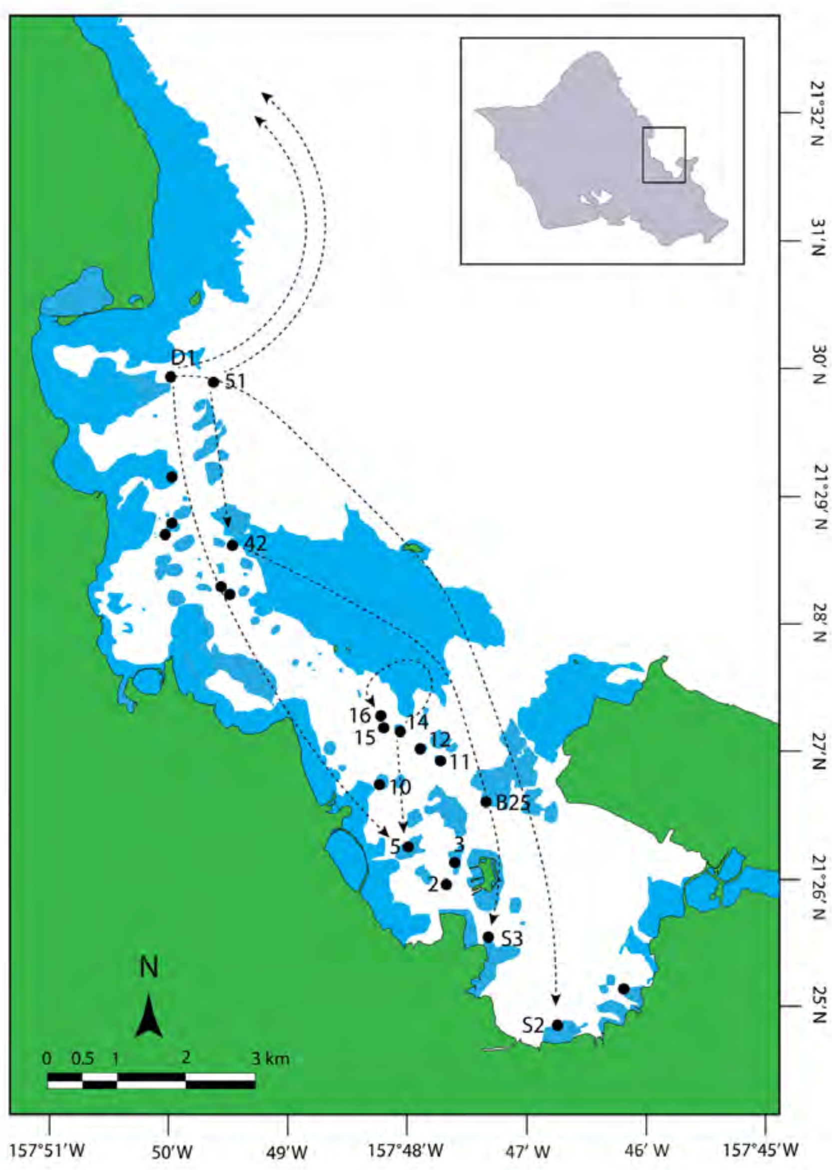

Table 4.1. Locations where *Acanthurus triostegus* was collected around O‘ahu, Hawai‘i. Collection numbers are separated by adults and juveniles. The locations and number of assigned juveniles that were collected at each location is noted, as well as number of self-recruiting events.

Sampling Location	Site code	# of adults	# of juveniles	# assigned to location	# Self recruiting
North					
Mokulē‘ia	MOK	3	9		
Hale‘iwa	HAL	38	16		
Chuns	CHUN	36	16		
East					
Lā‘ie	LAIE	30	17	2	
Hau‘ula	HAU	10	44	5	
Ka‘a‘awa	KAA	50	50	7	
Mouth of Kāne‘ohe Bay	KBM	15	0		
Kāne‘ohe Bay, North	KBN	24	95	1	1
Kāne‘ohe Bay, South	KBS	22	130	35	4
Kailua	KAI	88	20	6	1
Waimānalo	WAI	37	80	2	
Rabbit Island	RAB	34	0		
South					
China Walls	CW	34	1		1
Maunalua Bay	MB	45	10		
Shangri La	SL	15	21		
Ala Moana	AM	5	23		
Kewalo	KEW	11	14		
Sand Island	SAN	14	19		
Ewa	EWA	10	8		
West					
Kahe	KAH	32	5	3	
Kalanianaole	KAL	13	7		
Mākaha	MAK	22	10		
Yokohama Bay	YB	18	12		
Total		606	607	61	7

Table 4.2. Pathways and distances of dispersal between collection sites. Abbreviations: KBS, Kāneʻohe Bay, South; KBN, Kāneʻohe Bay, North; * denotes self-recruitment, in addition to self-recruitment events in north and south Kåne'hoe Bay.

Location of parent-offspring pairs			
Parent	Offspring	# of occurrences	Dispersal Distance (km)
Lāʻie	Kaʻaʻawa	3	12.5
Lāʻie	KBN, Reef 42	1	23.0
Lāʻie	KBS Reef S2	1	30.0
Lāʻie	KBS, Reef B25	6	26.7
Lāʻie	KBS, Reef 11	2	25.6
Lāʻie	KBS, Reef 14	3	25.9
Lāʻie	KBS, Reef 15	1	25.9
Lāʻie	Kailua	1	35.2
Kaʻaʻawa	KBS, Reef 14	1	14.2
Kaʻaʻawa	Waimānalo	2	30.6
KBN, Reef D1	KBS Reef S2	1	10.2
KBN, Reef D1	KBS, Reef 5	1	6.8
KBN, Reef D1	Hauʻula	2	13.4
KBN, Reef 42	KBS, Reef S3	1	6.1
KBN, Reef 51	KBN, Reef 42	1	1.9
KBN, Reef 51	Lāʻie	1	23.0
KBS, Reef 14	KBS, Reef 5	1	1.4
KBS, Reef 16	KBS, Reef 14	1	0.2
Kailua	Kailua	1	*
Kailua	Kaʻaʻawa	3	23.2
Kailua	KBS	1	16.8
Kailua	KBS, Reef S3	1	17.9
Kailua	KBS, Reef 10	1	15.0
Kailua	KBS, Reef 14	4	14.0
Kailua	KBS, Reef 15	8	14.3
Waimānalo	KBS, Reef 15	1	23.0
Waimānalo	Hauʻula	2	35.6
Rabbit Island	Kaʻaʻawa	1	33.2
China Walls	Lāʻie	1	58.3
China Walls	KBS Reef 2	1	40.4
China Walls	KBS, Reef 5	1	38.9
China Walls	Kailua	2	25.6

China Walls	China Walls	1	*
Maunalua Bay	KBS, Reef 10	1	38.7
Maunalua Bay	Kailua	1	26.5
Maunalua Bay	Kahe	3	51.9
Ala Moana	Kailua	1	42.8
Sand Island	Hau‘ula	1	70.9
Sand Island	KBS Reef 2	1	59.6
Kahe	Kailua	1	78.0

CHAPTER 5 CONCLUSIONS

The overall aim of my dissertation was to use molecular methods to gain a better understanding of connectivity in reef fishes. By assessing connectivity across wide-ranges to fine scales I aimed to contribute to our growing knowledge regarding the mechanisms that influence dispersal and connectivity in coral reef fishes and how these patterns promote biodiversity in both an evolutionary and a contemporary framework. In utilizing phylogeographic, traditional population genetic, and parentage analyses for my research, I was able to bring further attention to the insight that can be obtained by conducting theses analyses.

Insights from range-wide phylogeographic analyses

By assessing phylogeographic patterns across an entire species range, many studies have recovered highly diverged populations and cryptic diversity (Gaither *et al.* 2011a; Szabo *et al.* 2014; Fernandez-Silva *et al.* 2015; Dudoit *et al.* 2018). My research was set apart from other studies due to evaluating genetic patterns for a member of a monotypic genus. The regal angelfish, *Pygoplites diacanthus*, is the sole species in the genus *Pygoplites*. Phylogenetic analyses of the family Pomacanthidae (marine angelfishes), which is comprised of seven genera, estimated the age of *Pygoplites* to be 10 million years old (Alva-Campbell *et al.* 2010). The ability for a species to persist for millions of years without the pressure to diversify initiated the question as to the evolutionary or ecological traits that promoted species cohesion across time.

A range-wide genetic evaluation of *P. diacanthus* revealed cryptic diversity that was previously unknown. First, diverged populations were recovered that indicated isolation between the Red Sea, the Indian Ocean, and the Pacific Ocean. These genetic breaks coincided with previously identified barriers to gene flow that have been observed across a variety of taxa and are recognized as major biogeographic barriers (Rocha *et al.* 2007; Toonen *et al.* 2016). Second, we endorsed sub-species status for the Indian Ocean and Red Sea populations based on shallow diagnostic distinctions based on genetics and morphology, raising the name to *P. d. flavescens,* while the Pacific Ocean population retained the name *P. d. diacanthus*. Furthermore, we provided evidence indicating hybridization between the different sub-species at the Christmas Island which was eventually recognized as a hybridization hotspot (Hobbs & Allen 2014).

Although my results corroborated previously identified patterns, new insights were also recovered. The phylogenetic progression showed the Red Sea population diverging from the Pacific Ocean and then two dispersal events from the Red Sea into the Indian Ocean leading to separate lineages. The two cryptic Indian Ocean lineages do not show evidence of admixture and it is unclear what mechanisms are facilitating the isolation between the lineages. A thorough study of the ecology and reproductive strategies within these lineages would need to be conduct to identify the mechanism promoting isolation despite occupying sympatric ranges. Further evidence of isolated was observed within the Pacific Ocean lineage where the French Polynesian population (Moorea) was found to be genetically differentiated from all other Pacific populations. An analysis of the circulation pattern in the region indicated that the westward flow of the Southern Equatorial Current and eddies created in the wake of Tahiti contributed to the formation of a strong counterclockwise flow around the island promoting the local retention of larvae while inhibiting emigration from other islands.

Range-wide phylogeographic studies contribute to our understanding into the mechanisms that lead to divergence within species. An insight that may otherwise not be apparent if sampling was limited to a smaller part of the species range. These patterns may corroborate previously findings, as well as identify patterns that have not be documented elsewhere leading to further analyses of connectivity within these regions and identifying the processes promoting and inhibiting diversification.

Archipelago-wide connectivity and the efficacy of genomic sequencing

An archipelago-wide genetic assessment provided insight into how the use of genetic markers can lead to interpreting patterns of gene flow in a historical or contemporary framework. Assessing connectivity patterns of *Acanthurus triostegus* (*manini*) and *Ctenochaetus strigosus* (*kole*) provides the first archipelago wide population genetics analyses based on genomic sequencing. Previous studies used a targeted loci approach based on single *mt*DNA markers or a combination of *mt*DNA and selected *n*DNA or microsatellites. This research also provides the first report of island-by-island isolation for a reef fish (*kole*) across the archipelago, which counters connectivity patterns based on mtDNA (Eble *et al.* 2009). Using an mtDNA marker, *kole* was shown to have genetic homogeneity across most of the archipelago with an isolated population between Maro Reef and Pearl and Hermes Atoll in the northwest end of the archipelago. By conducting a genomics based genetic assessment, which utilizes hundreds to thousands of loci, we showed that population structure was much more fine scale. The results of our genomic-based connectivity study highlights the efficacy of genomic sequencing to characterize contemporary connectivity.

A comparison between connectivity patterns of *kole* and *manini* also provided insight into the dispersal potential for presumably low and high dispersing species. *Kole* is a Hawaiian endemic and it is hypothesized that Hawaiian endemics are descendants of low dispersers who colonized Hawaiʻi but were unable to maintain sufficient connectivity with the rest of the Pacific population. This hypothesis is supported by the high levels of population structure exhibited by Hawaiian endemic species when compared to species that are wide ranging who often show no structure across most of the archipelago. *Manini* has a Indo-Pacific distribution and the sole study investigating connectivity of *manini* within Hawai‘i showed structure between Hawai‘i Island and O‘ahu (Planes & Fauvelot 2002). However, connectivity studies in *manini* have shown that they have enigmatic dispersal potential. An assessement across a large portion of their range showed connectivity across thousands of kilometers (Planes & Fauvelot 2002); however, structure was observed between neighboring islands (Planes *et al.* 1998b), and even within a lagoon (Planes *et al.* 1998a). In the Hawaiian Archipelago manini was found to exhibit a combination of these traits where *manini* showed population structure between each of the Main Hawaiian Islands (MHI), but showed genetic homogeneity across most of the remaing 2/3 of the archipelago in the Northwestern Hawaiian Islands (NWHI) and Johnston Atoll.

By assessing connectivity across the entire archipelago I was able to provide insight into the different patterns that can be recovered depending on the scope of connectivity being assessed, as well as how endemic and wide-ranging species can differ in dispersal potential. The different patterns based on genomic sequencing compared to mtDNA suggest genomic sequencing is a much powerful tool to assess contemporary levels of connectivity and suggests it would be worthwhile to revist to past connectivity studies which used targeted loci and reassess them in a genomics framework. Comparing dispersal potential between endemic and wide-ranging species showed that endemic species are much more limited in their disperal ability. These findings provide insight into our understanding of how endemic species evolve in isolation.

Fine scale connectivity

Assessing connectivity of *manini* across Oʻahu is the first study to evaluate connectivity using a parentage analysis at the island scale for a reef fish, and provides valuable insight to our understanding of dispersal as well as assisting to inform management strategies. The signal for genetic differentation is not fine scale enough for a traditional population genetics approach; however a parentage analysis provides a means to characterize dispersal and connectivity at the island scale. Although, genetic connectiity of *manini* was found to be structured island-by-island in the MHI, the parentage analysis shows that even within an island connectivity is not homogenous between different regions of the island.

An island scale connectivity assessment resulted in identifying several patterns. First, dispersal in *manini* is not consistent in terms of direction and distance. We assigned juveniles to less than 250 meters from their presumed spawning location, up to as far away as 78 km on the opposite end of the island. The direction of dispersal coincided with known ciruclation patterns, however, several instances were discovered that counterd the direction of known physical processes suggesting unknown biological, ecological, and phyiscal processes have a greater influence on dispersal and settlement.

Second, despite a high diseprsal potential, *manini* larvae do not travel far from their natal reef. This is a trait common among many reef fishes (Jones 2015) and may explain why each island in the MHI are isolated from one another. The windward side of Oʻahu in particular is a region of local retention and the final destination for many *manini* larvae, particulalry within Kāneʻohe Bay. Within Kāneʻohe Bay local retention is attributed to phyiscal processes within the bay which inhibit dispersal out of the bay. However, while some of the patterns of dispersal into the bay coincide with prediction made by biophyiscal models (Lai et al., unpublished), other patterns are unclear and require further investigation.

Finally, the identifying dispersal patterns are directly relevant to establishing a competent community-based management strategy. The motivations for section of my research was to inform management efforts of at the community level to ensure adequate Kāneʻohe Bay and east coast populations of *manini* persist for future generations. We identified that the population of *manini* inside Kāneʻohe Bay seems to be largely sourced by populations outsides of the bay. Based on these findings, I suggest that management efforts would need to coordinate with communities all around Oʻahu to ensure they retain healthy population levels which in turn would seed into Kāneʻohe Bay.

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REPORT

Depth-dependent indicators of algal turf herbivory throughout the Main Hawaiian Islands

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Abstract Herbivorous fish are key to maintaining a balance between coral and algae on reefs, where reefs with greater herbivore biomass often show lower algal cover. For reefs worldwide, algal turf cover is expanding and is increasingly used as an indicator of disturbance. Water depth affects reef fish composition; thus, it may be expected that herbivory could also differ by depth. We examined relationships between algal turf cover and biomass (g m^{-2}), density (# m^{-2}) and size (cm) of herbivore groups (grazers, browsers and scrapers) across shallow (< 6 m), mid (6–18 m) and deep (18–30 m) coral reefs in the Main Hawaiian Islands. We find that across all depth classes, algal turf cover decreased with increasing grazer and scraper density, with steeper relationships observed at mid and deep reefs than in shallow reefs. In contrast, algal turf cover slightly increased with increasing grazer and browser biomass at deep reefs. Considering fish size, algal turf cover increased with larger grazer and scrapers at mid and deep reefs. The results indicate that herbivorous fish density, rather than biomass, is a better indicator of reductions in algal turf cover and resulting coral-algal balance on Hawaiian reefs, where smaller fish exert greater top-down control on cover than larger fish. Despite significant differences in herbivorous fish compositions, length-frequency distributions and fishing intensities across depth, algal turf cover remains similar across depths. Increases in fishing would have a disproportionately negative impact in deep than shallow reefs due to a lower overall fish density, where grazing functions in deep reefs are maintained by significantly fewer and smaller grazers and browsers, and larger scrapers, than in shallow reefs. Developing an understanding of patterns of algal turf herbivory by depth is important to understanding the spatial scale at which herbivory and regime shifts operate.

Keywords Herbivore · Coral reefs · Hawaii · Phase shifts · Algal turf · Size spectra

Introduction

A central goal in preserving and improving reef resiliency is the maintenance of a coral-dominated state after disturbance and avoiding regime-level shifts from coral to algal cover (Hughes 1994; Pandolfi et al. 2003). Various algal forms such as fleshy macroalgae (frondose, structurally complex algae) and turf algae (a diverse assemblage including mixed species of filamentous algae clumps, cyanobacteria, and diminutive forms of various macroalgal species less than 2 cm in height (Connell et al. 2014; Williams et al. 2019)) can overgrow live coral, inhibit coral growth, impact coral juvenile settlement and recruitment and cause coral mortality (Rasher and Hay 2010; Rasher et al. 2012; Couch et al. 2014). Algal turfs are important primary producers on coral reefs (Carpenter 1990), are a common food source for herbivorous fishes (Wilson et al. 2003), and can be an intermediary stage between bare substrate and macroalgae (McClanahan 1997). Although degrading coral reefs are often characterised by high fleshy macroalgal cover, increases in algal turf can be just as detrimental through the overgrowth and reduction in photochemical efficiency of neighbouring corals (Sandin et al.

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2008; Vermeij et al. 2010). In okina, for example, the majority of algal cover is composed of algal turf species, where 50% of reefs are dominated by algal turf (Jouffray et al. 2015; Harris et al. 2015; Gove et al. 2019). Algal turf cover is expanding globally and increasingly used as an indicator of anthropogenic disturbance (Airoldi et al. 2008), largely due to the ability of algal turf to outcompete corals via high growth rates under nutrient enrichment (Diaz-Pulido and McCook 2004; Birrell 2008; Vermeij et al. 2010).

Herbivorous fishes are key to sustaining and regaining coral dominance after disturbances, and reefs with higher herbivore biomass and density, a proxy for herbivory intensity (Graham et al. 2015), often show lower levels of algal cover (Wismer et al. 2009; Rasher et al. 2012; Heenan and Williams 2013). Herbivorous fishes include grazers, scrapers and browsers, which differentially affect the pattern and rate of algal community succession (Hixon and Brostoff 1996; Ceccarelli et al. 2005) and are critical to controlling algal assemblages (Green and Bellwood 2009; Arnold et al. 2010). Grazers feed on a combination of epilithic algal turf and sediment, maintaining algal turf in a closely cropped state (Hughes et al. 2007), primarily represented by surgeonfishes from the genus *Acanthurus* in okina (Table S1). Scrapers feed on epilithic algal turf and underlying substrate, often removing some reef carbonate as they feed, contributing to bioerosion (Green and Bellwood 2009) and in the Hawaiian Islands primarily consist of parrotfish species from the *Scarus* and *Chlorurus* genera. Browsers primarily feed on macroalgae, removing fleshy macroalgae from the substrate (Hoey and Bellwood 2008), mainly represented by species of unicornfishes and parrotfishes in this dataset (Table S1). Herbivore management is a strategy proposed to prevent algal overgrowth and boost coral resilience, key to maintaining reef health and restoring of degraded reefs (McClanahan et al. 2012; Graham et al. 2013; Williams et al. 2019).

Herbivorous reef fish abundance and size differ between shallow and deep reefs (Pereira et al. 2018; Cooper et al. 2019). Previous work has shown that herbivores decline with depth (Feitoza et al. 2005) likely due to changes in algal abundance and growth rates (Itzkowitz et al. 1991; Liddell and Avery 2000; Aponte and Ballantine 2001). Depth-specific habitat limits also occur where younger and smaller animals cannot exploit specific habitats due to predation risk (Schreer and Kovacs 1997; McCormick 1998), where some coral reef fish move to deeper habitats as they age and grow. Additionally, deeper reefs are often less susceptible to disturbance and overfishing in comparison with shallower reefs (Tyler et al. 2009; Pereira et al. 2018), further contributing to changes in herbivorous fish communities along a depth gradient. Meta-analyses and reviews have indicated that top-down impacts, i.e. herbivore grazing, exert the dominant control on algal blooms (Mumby and Steneck 2008), where declines in herbivorous fishes at depth have led to benthic coral-algal phase shifts of mesophotic communities (Lesser and Slattery 2011). Therefore, variation in herbivorous fish composition with depth would be expected to lead to variation in algal herbivory with depth.

Deeper habitats also experience light attenuation, lower temperatures, changes in nutrients, and decreased turbulent flow (Lesser et al. 2009), which could affect the balance between algal growth and consumption across depth. Algal turf growth rates and productivity correlate with light availability, and therefore decrease with depth (Leichter et al. 2008; Brokovich et al 2010). Overall, as algal growth and fish distributions vary across depth, assuming that herbivory is equal across depths may misrepresent reef resiliency. An understanding of whether relationships between algal turf and herbivorous fish varies with depth would provide greater insight into how future reef trajectories may vary spatially.

We investigated relationships between algal turf cover and herbivorous fish density and biomass at different depths to reveal potential depth-dependent, top-down processes in algal turf control in the Main Hawaiian Islands (MHI). The aim of our investigation was to: (1) Determine how benthic cover and the biomass and density of herbivore groups (grazers, browsers, scrapers) differ by depth; (2) Investigate length-frequency distributions across depth and size spectra as an indicator of fishing impacts across depth; and (3) Explore how herbivore biomass, density and size associate with algal turf cover at shallow, mid and deep reefs. Developing an understanding of patterns of algal turf herbivory across depth is central to understanding the spatial scale at which ecological processes and regime shifts occur.

Materials and methods

Fish and benthic surveys

Data were obtained from the National Oceanic and Atmospheric Administration (NOAA) Coral Reef Ecosystem Program (NOAA PIFSC 2020). The dataset includes 1476 surveys across the MHI collected in 2010, 2012, 2013, 2015, 2016 and 2019, where fish biomass (g per m^2) and density (individuals per m^2), as well as benthic data were collected within the same site, month and year (Fig. 1). Survey sites were chosen via a randomised depth-stratified design, with 30–50 surveys conducted per island (okina, Kahoʻolawe, Kauaʻi, Lānaʻi, Maui, Molokaʻi, Niʻhau, Oʻahu) per survey year, i.e. survey locations within

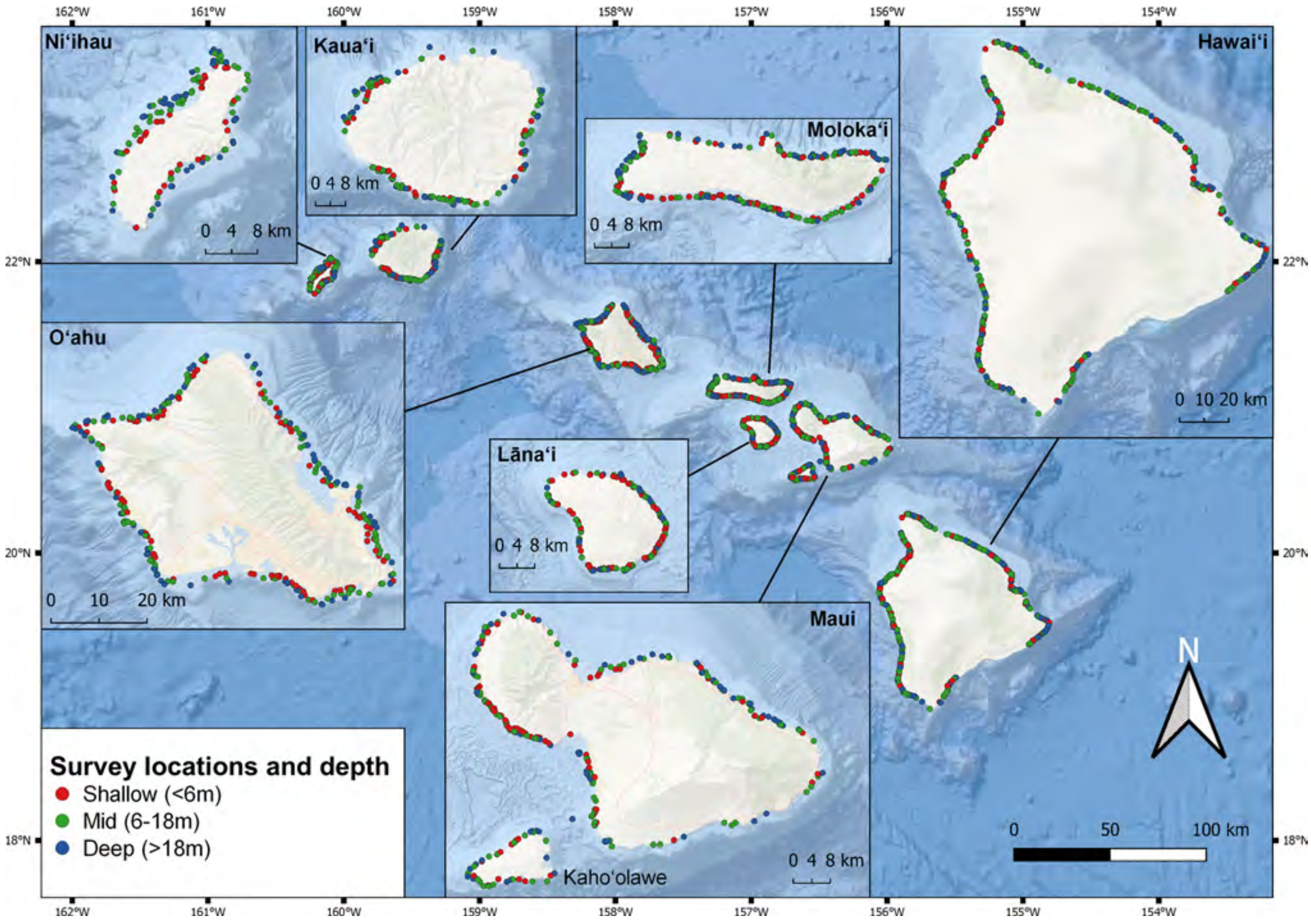

Fig. 1 Spatial distribution of survey locations around the main Hawaiian Islands coloured by depth class. 1476 surveys were collected across 2010, 2012, 2013, 2015, 2016 and 2019

each island were different every year. Full survey methods are described in Heenan et al. (2017).

Briefly, fish surveys were conducted as stationary point counts in which a pair of divers counted and sized all fish to the nearest centimetre at each site, within adjacent, predefined 15 m diameter cylindrical areas, estimated by laying out a 30 m transect line, with markings at the 7.5, 15 and 22.5 m points to allow divers to locate the edges of their cylinders (Ayotte et al. 2015). Site-level estimates were calculated by taking the mean of the adjacent diver-level counts. All fish were classified into functional groups, with herbivores further subdivided into scrapers, grazers and browsers, based on trophic classifications and diet information from Heenan et al. (2016). Only herbivorous fish were considered in the analyses with herbivore group indicated in Table S1. Two species of fishes were classified as detritivores and included with the grazer group for the analysis. Benthic surveys were conducted using photo-quadrats at 1-m intervals along the entire 30-m transect line (Ayotte et al. 2015). Photo-quadrats were analysed using Coral Point Count with Excel extensions (CPCe; Kohler and Gill 2006) and CoralNet (Beijbom et al. 2015) to produce site-level, relative abundance estimates of benthic cover (reported as percentage cover).

Sites at various depths were randomly distributed around each island, and therefore horizontal differences in wave exposure or other biogeographical drivers among depth categories were therefore considered minimal. Vertical differences in these conditions are likely to exist; however, as depth-specific oceanographic data is not available for these surveys, the top-down controls on algal turf cover: herbivorous fish biomass, density and size, were the only factors considered in our analysis.

Data analysis

Sites were classified into three depth classes: shallow (0–6 m, $n = 414$), mid (6–18 m, $n = 650$) and deep (18–30 m, $n = 412$), where 30 m represents the depth limits of these surveys (Fig. 1). Per site, the total herbivorous fish biomass and density per m^2 were calculated. To assess whether fish biomass, density and benthic community composition differed across depth classes, we used bootstrapping with 10,000 iterations of site-level observations to generate 95% confidence intervals (CI) for mean herbivorous fish biomass and density, and percentage benthic cover in each depth class. Non-overlapping 95% CIs was an indication that means were significantly different between depths (Smith 1997; Cumming and Finch 2005). This process was repeated for each herbivorous group, i.e. grazers, browsers and scrapers, as well as total herbivores as a group.

Kernel density estimates were used to visualise fish length distributions across depth classes, with Kolmogorov–Smirnov two sample tests used to compare the length-frequency distributions across depth for each herbivore group (Siegel and Castellan 1988). Here, all numbers of herbivorous fish recorded across surveys were plotted, visualised separately for each herbivore group and depth.

Size spectra, which show the relationship between fish abundance and size, can be used as ecosystem indicators, where steeper size spectra slopes are often attributed to greater fishing intensity and exploitation due to reduction in the abundance of larger fish and dominance of small fish (Rice and Gislason 1996; Graham et al. 2005; Robinson et al. 2017). Previous studies estimating size spectra use linear regression for binned abundance data, here we used logarithmic binning with normalisation (Blanchard et al. 2005; Roy et al. 2011; Edwards et al. 2017) estimating size spectra via:

$$\begin{aligned}&\log_{10}(\text{normalised biomass, } g)\\&\quad = a \times \log_{10}(\text{midpoint of bin}) + b\end{aligned}$$

where a = slope and b = intercept, determined by a linear regression model fit to the size spectra (Dulvy et al. 2004; Graham et al. 2005). Fish were assigned to $\log_2$ bin sizes: 2–4, 4–8, 8–16, 16–32, 32–64, 64–128, 128–256, 256–512, 512–102, 1024–2048, 2048–4096 and 4096–8192 g. Total biomass within each bin was divided by the respective bin width to normalise data, g, with biomass size spectra then fit separately for each herbivore group across depth. To focus on the part of the size spectrum that can be estimated by a linear slope, only fish above a certain threshold were included in the analysis. To determine the threshold, we first excluded fish < 5 cm in length, and then used the modal mass of fish > 5 cm as the lower size threshold (Ackerman et al. 2004; Treblico et al. 2015), calculated separately for grazers (32 g), browsers (256 g) and scrapers (64 g). To assess the influence of depth on the slopes of the size spectra, multiple linear regression with depth class as an interacting factor with size was carried out with Tukey post hoc contrasts.

Since there were differing patterns of herbivorous fish biomass, density and size across depth, the effects of each of these metrics and their respective interactions with depth on algal turf cover were assessed for grazers, browsers and scrapers using generalised linear mixed models (GLMMs, Zuur et al. 2009) from the glmmTMB package (Magnusson et al. 2016) in R version 4.0.2, with separate models for biomass, density and size and herbivore group. For models, individual data points were represented by site-level observations, where total biomass per m^2, total density per m^2 and mean size (cm) of each herbivore group were considered with their respective site-level algal turf cover. The glmmTMB function fits models using maximum-likelihood estimation with random effects integrated using the Laplace approximation, with the package giving more flexibility regarding zero-inflation and overdispersion of nonzero data (Brooks et al. 2017). Algal turf cover was represented as a proportion bounded between 0 and 1, and data were fitted with beta error structure and logit link GLMM models, suitable for proportional data for which observations are limited to the interval (0, 1) (Kieschnick and McCullough 2003; Smithson and Verkuilen 2006). Further, herbivorous fish biomass and density data were inspected for outliers, where site-level observations that were more than 99% of the IQR were capped at the 99% value (Smith et al. 2011). GLMMs conducted in R require a reference level for categorical values, where the model contrasts all levels of that variable to the reference level, in this case, shallow reefs. Differences in survey location and date were accounted for by including “year” and “island” as random effects in the models. Comparisons of algal turf cover by fish biomass, density and size between pairs of depths were conducted using pairwise comparison post hoc tests with the ‘emtrends’ function in the R ‘emmeans’ package (Lenth et al. 2021). We assessed model fits by visual inspection of *Q*–*Q* plots for normality and residual plots for homogeneity, all of which were satisfactory.

Results

Variation in benthic cover across depth

Bootstrapped estimates of confidence intervals for benthic cover show that algal turf cover was similar between all depth classes (means of 70, 67 and 69% for shallow, mid and deep reefs, respectively, Fig. 2). Macroalgal cover was the smallest component of benthic cover in the MHI, on average, less than 3% of cover across all depths (Fig. 2). There was significantly higher crustose coralline algal cover (CCA) in shallow reefs than in mid and deep reefs; however, CCA cover was still less than 5% across all depths (Fig. 2). The highest coral cover occurred at mid-depths (15.4%), significantly higher than at shallow reefs (11.8%). Shallow and deep reefs had a similar amount of coral cover (11.8 and 12.3%, respectively).

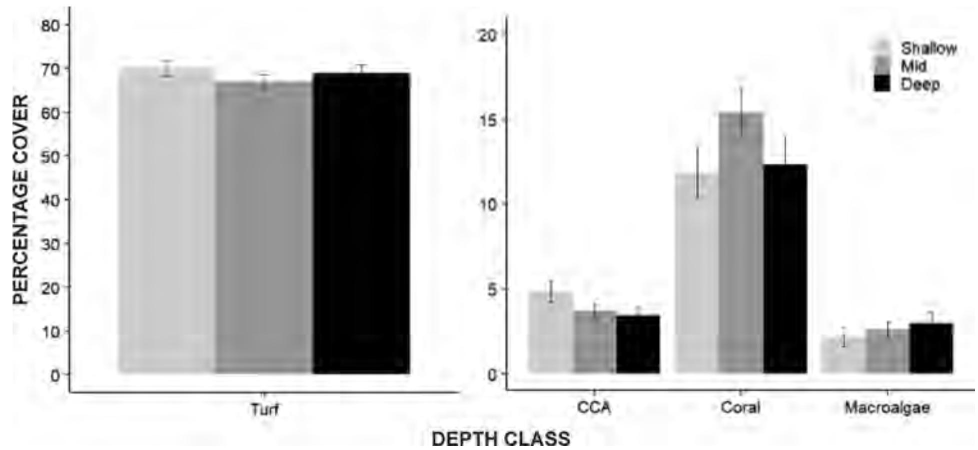

Fig. 2 Patterns of benthic cover by depth class. The left panel indicates mean percentage cover of algal turf with 95% confidence intervals. The right panel provides mean percentage cover of crustose coralline algae, coral and macroalgae with 95% confidence intervals

Herbivorous fish community compositions across depth

Overlapping confidence intervals indicate that total herbivorous fish biomass was not significantly different across depth classes, with a mean biomass range of 11.8 (deep reefs) to 14.9 (shallow reefs) g m^{-2} across depths (Fig. 3). Total herbivorous fish density was significantly lower on deep reefs (mean of 0.14 individuals m^{-2}) in comparison with both shallow (mean of 0.20 individuals m^{-2}) and mid (mean 0.19 individuals m^{-2}) reefs (Fig. 2).

The majority of herbivorous fish were composed of grazers, representing a mean of 71% of herbivorous fish biomass and 86% of herbivorous fish density across all depths (Figure S1). Grazer biomass did not significantly differ across depths (mean range of 7.4–8.1 g m^{-2} from shallow to deep reefs), but browser biomass was significantly lower at deep (mean of 1.2 g m^{-2}) in comparison with both shallow (mean of 4.6 g m^{-2}) and mid (mean of 2.5 g m^{-2}) reefs. Scraper biomass was significantly higher at deep (mean of 3.3 g m^{-2}) compared to shallow (mean of 2.0 g m^{-2}) reefs (Fig. 3).

Grazers had significantly fewer fish in deep (mean of 0.12 individuals m^{-2}) reefs in comparison with both shallow (mean of 0.17 individuals m^{-2}) and mid (mean of 0.16 individuals m^{-2}) reefs (Fig. 3). Similarly, there were significantly fewer browsers on deep (mean of 0.006 individuals m^{-2}) reefs in comparison with both shallow (mean of 0.014 individuals m^{-2}) and mid (mean of 0.010 individuals m^{-2}) reefs. Scraper density decreased slightly with depth; however, the trend was not statistically significant.

Size structure of herbivore groups across depth

Density plots revealed significant differences in length-frequency distributions across all depths within each herbivore group (Fig. 4). Shallow reef grazers had a mean length of 12.2 cm, with a higher proportion of larger grazers than at mid (mean length of 10.8 cm, Kolmogorov–Smirnov $D = 0.313$, $p < 0.000$) and deep reefs (mean length of 10.3 cm, $D = 0.385$, $p < 0.000$). Mid and deep reef grazers also had significantly different length-frequency distributions ($D = 0.089$, $p < 0.000$). For browsers, shallow reefs had larger proportions of large fish (mean of 22.6 cm) in comparison with mid reefs (mean of 20.6 cm, $D = 0.156$, $p < 0.000$) and deep reefs (mean of 17.8 cm, $D = 0.291$, $p < 0.000$). Mid and deep reefs had significantly different size distributions ($D = 0.175$, $p < 0.000$) with deep reefs having the most right skewed distribution. In contrast to other herbivore groups, scrapers had a significantly larger proportion of large fish at deep depths (mean of 20.0 cm) in comparison with mid (mean of 18.3 cm, $D = 0.142$, $p < 0.000$) and shallow (mean of 16.2 cm, $D = 0.171$, $p < 0.000$) reefs. Shallow and mid reefs had significantly different size distributions ($D = 0.082$, $p < 0.000$), with shallow reefs having the highest proportion of smaller scrapers (Fig. 4).

Size spectra were negative for all herbivore groups and across all depths with the steepest size spectra slopes seen for browsers (Fig. 5). Although not significantly different between depths, the steepest slopes were seen in shallow reefs across all herbivore groups, with the least steep slopes in deep reefs (Fig. 5).

Relationships between algal turf cover and herbivorous fish across depth

For grazers, greater algal turf cover was associated with a higher biomass at deep reefs only (Fig. 6, Tables S2, S3). A negative relationship between algal turf cover and grazer density was observed across all depths, although this was significantly steeper for mid and deep reefs in comparison with shallow reefs (Fig. 6, Tables S2, S3). Positive relationships between algal turf cover and grazer size were observed at mid and deep reefs, significantly different to

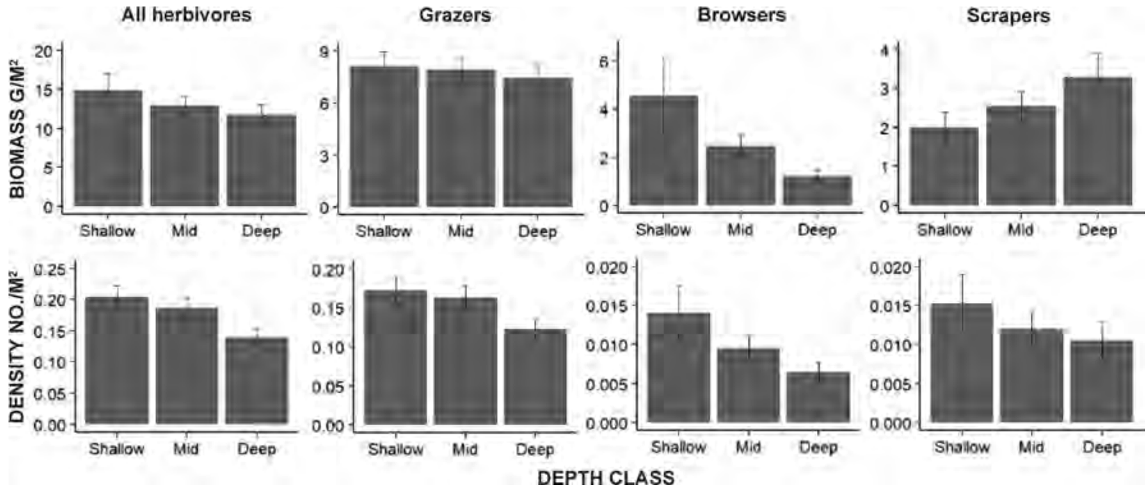

Fig. 3 Patterns of herbivores and herbivore groups across depth. Results are separated for all herbivores and individual herbivore groups: grazers, browsers and scrapers. The top panels show mean biomass in g m^{-2} with 95% confidence intervals across each depth class. The bottom panels show mean fish density in individual's m^{-2} with 95% confidence intervals across each depth class

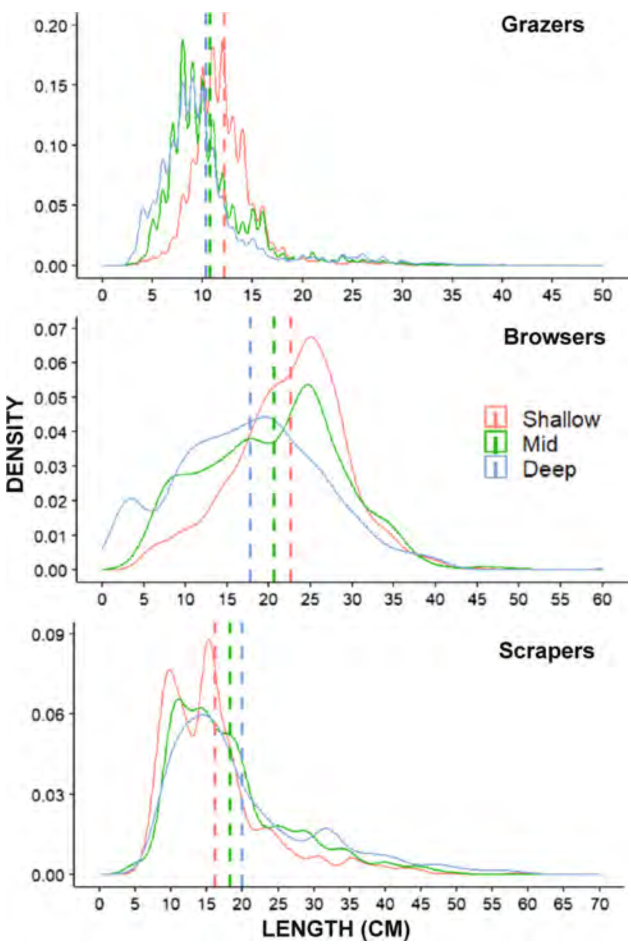

Fig. 4 Length frequencies, expressed as kernel density distributions. Distributions are separated for individual herbivore groups: grazers, browsers and scrapers, and across each depth class: shallow, mid and deep. Dashed lines denote location of the mean length of each distribution

the almost flat relationship between algal turf cover and grazer size at shallow depths (Fig. 6, Tables S2, S3).

Browser biomass showed a positive relationship with algal turf cover in deep reefs, significantly different to both mid and shallow reefs. There were no significant relationships between algal turf cover and browser density or size (Fig. 6, Tables S2, S3).

For scrapers, there were no relationships between algal turf cover and biomass. Significantly steeper negative relationship between algal turf cover and scraper density were observed for mid and deep reefs in comparison with shallow reefs (Fig. 6, Tables S2, S3). There were positive relationships between algal turf cover and scraper size in mid and deep reefs, significantly different to the flatter relationship seen in shallow reefs.

Discussion

Different compositions of herbivorous fish across depth

Total herbivorous fish biomass decreased with depth, with significantly fewer fish on deep reefs in comparison with shallow reefs. Grouping fish into different herbivore types allowed for the investigation of changes in different algal feeding strategies with depth. Grazers showed a slight decrease in biomass with depth, although this was not significant. This was likely driven by both the higher densities of grazers on shallow versus deep reefs and larger mean grazer size at shallower depth. Browser biomass decreased significantly with depth, driven by the lower density and size with increasing depth. Scrapers showed the opposite pattern, with increasing biomass with depth

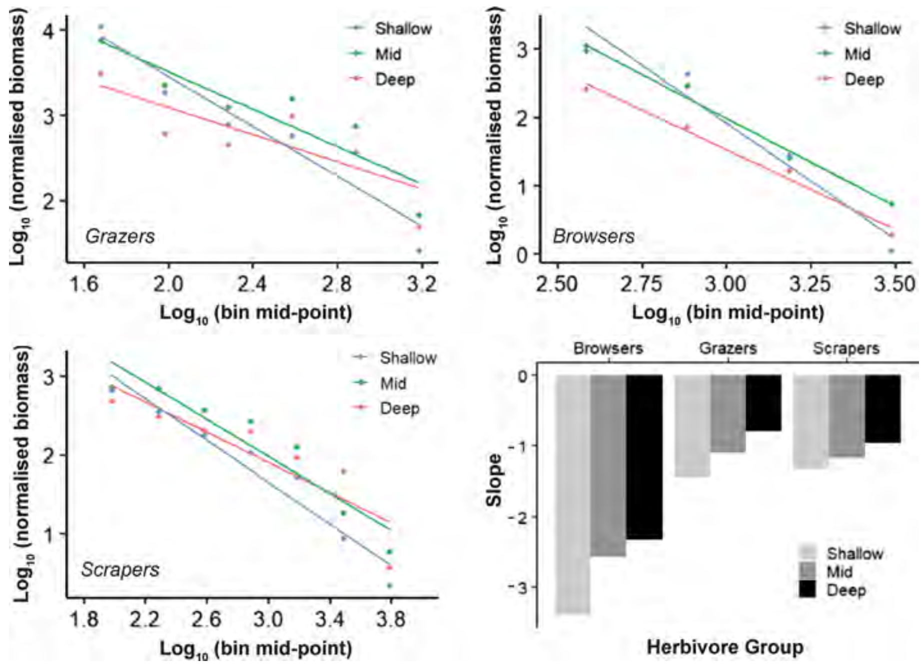

Fig. 5 Biomass size spectra for herbivore groups across depth. Size spectra are displayed for each herbivore group: grazers, browsers and scrapers, and across each depth class: shallow, mid and deep. The bottom right panel contrasts the slopes of each size spectra

but lower densities with increasing depth, although not significant. The increased biomass in deep reefs is driven by the larger scrapers found in deep reefs in comparison with shallow reefs. Declines in herbivorous fish density with depth agree with previous findings (e.g. Brokovich et al. 2010; Bejarano et al. 2014), where decreases in herbivores with depth can occur due to reductions in food source and declines in coral cover (Ferreira and Goncalves 2006; Rotjan and Lewis 2006; Nemeth and Appeldoorn 2009).

Size spectra analyses were negative for all herbivore groups across all depths, with the steepest slopes observed in shallow reefs for all herbivore groups. Steeper size spectra are attributed to greater fishing intensity and utilisation (Rice and Gislason 1996; Graham et al. 2005; Robinson et al. 2017), where our results suggest that shallow reefs in the MHI are the most exploited. In the MHI, this unequal fishing pressure by depth could be due to differences in reef accessibility and gear types used to catch fish (McCoy et al. 2018), contributing to the different compositions of herbivores observed by depth. For example, the SCUBA spear fishing ban approved by the State of Hawaii Board of Land and Natural Resources in 2013 has likely reduced pressure on scrapers (i.e. parrotfishes) at deeper depths. Additionally, deeper reefs are often less susceptible to disturbance and overfishing in comparison with shallower reefs (Pereira et al. 2018), reflected here in our results with the least steep spectra observed at deep reefs across all herbivore groups.

Apart from differences in fishing impacts by depth, differences in herbivore composition with depth could be driven by changes in algal growth rates (Itzkowitz et al. 1991; Liddell and Avery 2000; Aponte and Ballantine 2001), which correlate with light availability that decreases with depth (Leichter et al. 2008). This may cause fish to preferentially feed at shallower depths, where reductions in surgeonfishes and parrotfishes across small depth gradients (3–15 m) have been correlated with changes in light penetration and algal productivity (Nemeth and Appeldoorn 2009). Macroalgal production, which also decreases with depth (Bejarano et al. 2014), is likely to influence the large decrease in browser biomass and density observed here, where macroalgae is the dominant food source of this group. The change in herbivore composition across depth could also be driven by ontogenetic habitat shifts, where previous work in the Caribbean found that striped parrotfish move from shallower to deeper reefs as they mature from juveniles to adults (Cocheret de la Morinière et al. 2002), supporting our findings of larger body lengths of scrapers at increased depth. These larger roaming reef species also move to greater depths where they are less susceptible to predation, but also where there is reduced reef structural complexity and more exposure (Werner et al. 1983).

Herbivorous fish density rather than biomass more related to algal turf cover

Across all depths, we found that lower algal turf cover was related to higher grazer and scraper density. On the other hand, increasing algal turf cover corresponded to increased grazer and browser biomass for deep reefs. Greater algal

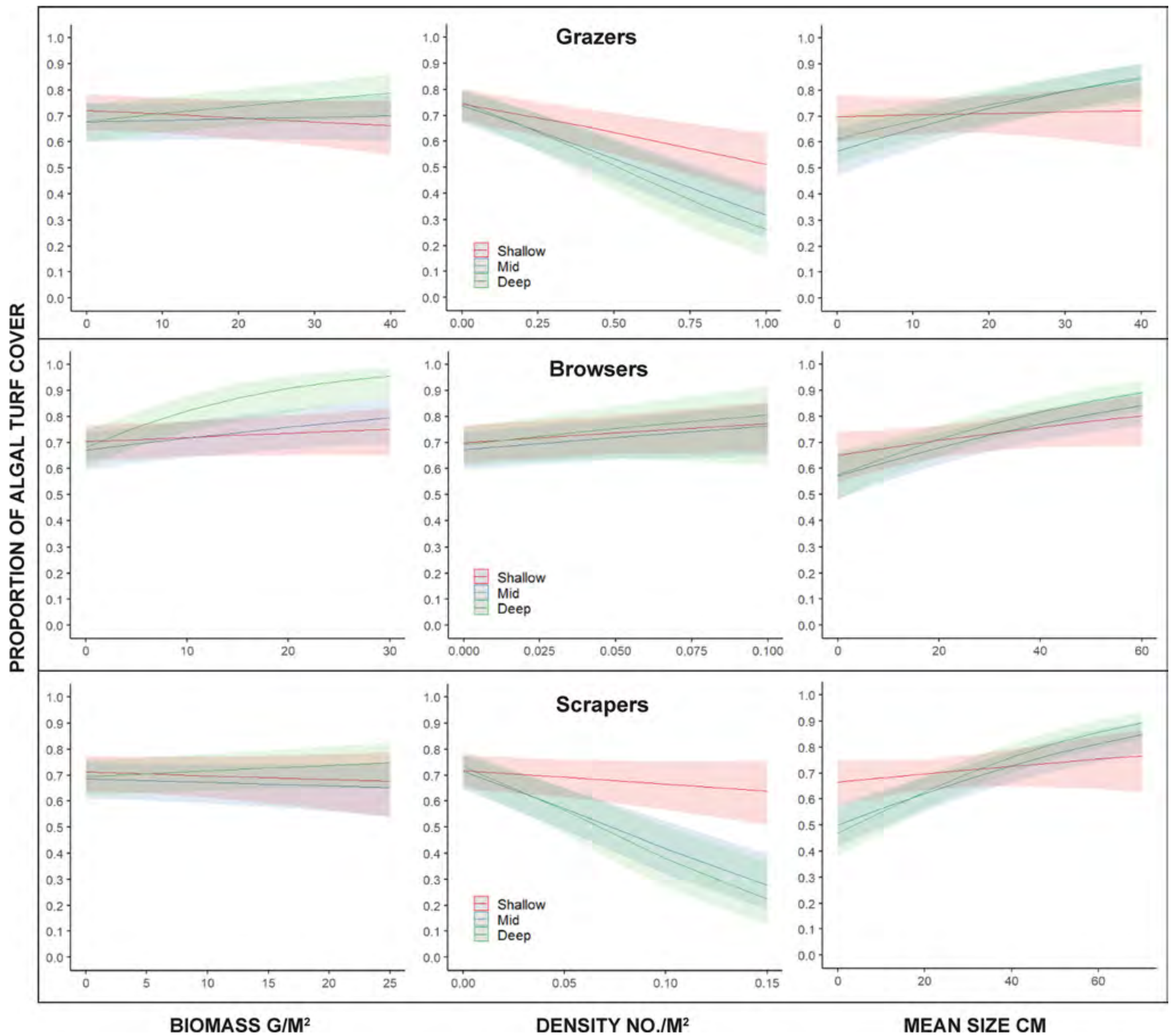

Fig. 6 Impacts of herbivorous fish groups on algal turf cover across depth. The results of the generalised linear mixed models are displayed separately for each herbivore group. The left panels show modelled relationships between algal turf cover and biomass (g m^{-2}) with 95% confidence intervals. The middle panels show modelled relationships between algal turf cover and density (individuals m^{-2}) with 95% confidence intervals. The right panels show modelled relationships between algal turf cover and mean survey size (cm) with 95% confidence intervals

turf cover was also associated with larger grazers and scrapers, indicating that size structure must also be considered to better understand grazing pressure. Previous research shows that for a given level of biomass, communities dominated by smaller fishes had higher grazing potential than larger fishes (Bellwood et al. 2012; Robinson et al. 2017). Here, decreases in density did not necessarily lead to decreases in biomass, and in fact for scrapers, biomass and density showed the opposite pattern across depth. These results suggest that herbivorous fish density, rather than biomass or size, is more indicative of herbivory because it better distinguishes the differences in herbivorous fish compositions. The significant relationships between algal turf cover and size found here show that not all fish graze equally—therefore considering fish density helps to uncover more of that variation than biomass. Many studies consider herbivore biomass as an indicator of coral reef resilience (e.g. Graham et al. 2015; Jouffray et al. 2015; Donovan et al. 2018); however, also considering fish density and size, as we have done here, may provide further insight into spatial and temporal changes in coral reef dynamics.

Different controls over algal turf cover by depth

We demonstrate depth-dependent relationships of algal turf cover and herbivorous fish on coral reefs of the MHI. Although compositions and sizes of herbivorous fish differed by depth, algal turf cover was similar across all depth classes, suggesting that there are different mechanisms of herbivory operating at different depths. Top-down control may not exert equal impact at all depths, where environmental factors are likely to play a large role in algal turf dynamics.

At shallow depths, the higher density of grazers compared to other depths may result in intense grazing and rapid turnover of algal turf (Rogers and Salesky 1981; Klumpp and McKinnon 1989). This is especially important on shallow reefs, where higher light levels drive increased photosynthesis and enhanced rates of productivity in algal turf (Adey and Steneck 1985; Carpenter and Williams 2007), and where higher herbivore densities are likely compensating for this increased productivity. Additionally, positive relationships observed between algal turf cover and increasing grazer and scraper size at mid and deep reefs, indicate that larger fish are less effective at controlling algal turf cover. The importance of smaller-bodied fish in preventing algal accumulation has been observed on reefs in the Indian Ocean (Cernohorsky et al. 2015) and on Indo-Pacific reefs (Robinson et al. 2020). Due to higher mass-specific metabolic rates, small fish more intensively graze than larger fish (Gillooly et al. 2001; Lange et al. 2020; Robinson et al. 2020), reflecting the results seen here.

On mid and deep reefs, there was a significantly steeper negative relationship between grazer and scraper density and algal turf cover in comparison with shallow reefs, suggesting top-down pressure on algal turf is stronger in these deeper reefs. This increased reliance on herbivory at depth may help compensate for weaker bottom-up effects (e.g. weaker wave energy) at these depths, although decreased light intensity with depth is confounded with grazing intensity. Deep reefs have a disproportionate contribution of herbivores to algal turf control, rendering the coral-algal relationship more vulnerable to fishing than it is on shallow reefs, where abiotic influences are stronger. Although fishing impacts are lower on deeper reefs than on shallow reefs, if fishing were to increase on deep reefs, it would have a more dramatic effect due to lower overall fish density there.

The less pronounced relationship of algal turf cover and herbivorous fish observed on shallow reefs in comparison with mid and deep reefs suggest that other factors contribute to top-down algal control on shallow reefs. Algae on shallow reefs is more productive than mid or deep reefs, due to higher light levels and hydrodynamic factors (Carpenter 1985). Algal turf productivity does not necessarily equal cover, where herbivores may just be cropping turf rather than impacting cover. Algal turf height is the first to respond to grazing pressure in the short term rather than lateral expansion or an increase in cover (Harris 2015). Changes in algal turf cover may be underrepresented due to grazing fish heavily cropping turf rather than reducing cover. Consequently, considering algal turf biomass and height rather than turf cover could reveal more direct relationships of algal consumption.

Future studies should examine direct feeding rates and algal turf growth by depth, and measure abiotic variables (e.g. wave energy, light levels, sedimentation, pollution, bleaching history) by depth which would reveal direct mechanisms driving differences in top-down control across depth and resolve the vertical differences in these conditions across depth. As coral reef managers set targets to enhance algal herbivory, it will be imperative to consider algal turf height as a key benthic monitoring variable, especially when not directly estimating grazing rates.

Conclusions

Our analyses reveal that top-down control of algal turf cover differs by depth, and herbivorous fish density, rather than biomass, is better correlated with algal turf cover in the MHI. Steeper relationships between algal turf cover and both grazer and scraper density occurred at increasing depths. On deep reefs, grazing functions are performed by fewer individuals—fewer and smaller grazers and browsers, and larger scrapers—than on shallow reefs. Since different mechanisms of top-down control of algal turf cover occur at different depths, we can expect differences in reef vulnerability, resiliency and recovery across depths as well. Herbivore management has the potential to benefit coral reefs. Here we reveal the scales at which herbivore management can be effective—deep reefs which rely on fewer, larger-bodied fish to graze algal turf may require more intensive monitoring and management. Due to the lower fish density on deeper reefs, if increases in fishing pressure were to occur in this region, it would have a disproportionately negative impact compared to shallow reefs. A management strategy that focuses on these depth differences will be required to maximise the resilience of reefs as a whole and increase the likelihood of recovery after disturbance.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00338-021-02162-2.

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Data availability Data are publicly available at https://doi.org/10.7289/v59c6vr5.

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Abundances of Aquarium-collected Coral Reef Fishes in Protected and Open-access Areas of Oahu, Hawaii[1]

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Abstract

Since the 1930's, the collection and trade in marine ornamental fish has expanded to become an international industry with the potential for overexploitation and negative effects on coral reefs. The Main Hawaiian Islands are major exporters of ornamental reef fish and yet, outside of the well-managed Kona coastline of the Big Island, there are no published studies on the effects of ornamental collection on reef fish populations. On the island of Oahu, for example, there are few collection limits and less than 1% of its coastline is protected. Oahu does however maintain fish collection records and has one long-term well-protected no-take zone, Hanauma Bay, which has been closed to collection since 1967. Here we report on the abundance of aquarium-collected fish species from Oahu by comparing fish abundances in open collection areas to two protected locations within Hanauma Bay. Sixteen species were surveyed, including five endemics, using the visual belt-transect search method. Six species of reef fish – *Acanthurus triostegus*, *Chaetodon lunula*, *Ctenochaetus strigosus*, *Naso lituratus*, *Zanclus cornutus*, and *Zebrasoma flavescens* – exhibited significantly lower populations in collection areas. Decreases were observed in the four most heavily-collected species, three of which are not taken as food fish, suggesting that ornamental collection is primarily responsible for the differences in abundance. These findings indicate that the creation of additional protected areas on Oahu could both improve the status of reef fish populations and sustainability of the aquarium fishery.

Coral reef fish communities face various anthropogenic challenges, including climate change, acidification, pollution, invasive species, destructive fishing practices, and over-exploitation (Hoegh-Guldberg and Bruno 2010, Burke et al. 2011, Muthukrishnan and Fong 2014). There is an increasing understanding of how the loss of reef fish impacts reef condition, and conversely, how degraded reefs undermine coral reef fish populations. (Hay 1981,1985, Jones et al. 2004, Berumen and Pratchett 2005, Beger and Possingham 2008, Bozec et al. 2016, Plass-Johnson et al. 2016). One cause of reef fish exploitation is the trade in marine ornamental fish (Livengood and Chapman 2007, Jones et al. 2008, Rhyne et al. 2009, Rhyne and Tlusty 2012, Rhyne et al. 2012, Murray and Watson 2014). This trade began in the 1930's in Sri Lanka, spread to the Philippines and Hawaii in the 1950's, and eventually matured into a global industry (Tomey 1996, Wood 2001, Bruckner 2001, 2005, Wabnitz et al. 2003, Livengood and Chapman 2007). The U.S. is the single largest importer of ornamental fish in the world, importing approximately 64% of the total coral reef species in numbers of specimens (Tissot et al. 2010). Most fish are collected from the wild when they are small and pre-reproductive since these demographics are generally preferred by hobbyists (Stevenson et al. 2011). And whereas most freshwater ornamental fish are bred in captivity, nearly all (>99%) marine ornamental fishes are caught in the wild (Wood 2001, Tissot and Hallacher 2003). In 2005, for example, the trade led to the removal of over five million ornamental fish belonging to 1,050 species from the Philippines alone (Rhyne et al. 2012). Likewise, from 2013 to 2014 around the Big Island of Hawaii, 33% of Achilles tangs (*Acanthurus achilles*; 7,073 fish) and 17% of yellow tangs (*Zebrasoma flavescens*; 273,778 fish) were collected for aquaria (DLNR Report to the Legislature 2015). Despite these numbers, we know surprisingly little about the effects of ornamental reef fisheries on population resilience or coral reef health (Kolm and Berglund 2003, Tissot and Hallacher 2003, Lunn and Moreau 2004, Rhyne et al. 2012).

One cause of uncertainty regarding collection impacts is a lack of baseline data describing natural ornamental species abundances. This is due, in part, to collection beginning prior to development of standard fish-counting techniques (Walsh et al. 2004). When baseline data do exist, it can be difficult to discern the volume of fish taken and collection effects often concomitantly occur with changes in the surrounding environment, confounding analyses. Yet despite this uncertainty there are compelling examples of population declines driven by the ornamental fish trade, in for instance Banggai cardinalfish, butterflyfish, anemonefish, mandarinfish, yellow tang, and seahorses (reviewed in Thornhill 2012). In the well-monitored ornamental fishery of Hawaii's Big Island, long-term closure of areas previously open to collection led to a 64.5% increase in abundance for the most heavily-collected species (Walsh 2014).

The Main Hawaiian Island archipelago is a relatively small area (2,536 km^2) that produces most ornamental fish of U.S. origin (Tissot & Hallacher 2003, Walsh et al. 2004, Bruckner 2005). Rough comparisons of export volumes and catch reports suggest that Hawaii is the world's third largest producer of marine ornamental fish (Friedlander 2004, Rhyne et al. 2012). In 2010, 712,553 reef fish were reported collected in Hawaii, 217,627 (31%) of which came from Oahu (Dept. of Land and Natural Resources Division of Aquatic Resources 2010 catch reports); these catch reports may be underestimated (Ceasar 2002, Walsh et al. 2004). The two most collected fish are *Z. flavescens* and *Ctenochaetus strigosus*; together these species encompass over 75% of the total catch (Friedlander 2004, Claisse et al. 2009, Walsh 2014, DAR data). Protective measures are in place for certain areas of Hawaii. In West Hawaii there is an official "white list" of 40 fish species that are permissible for collection and 35.5% of the coastline is off limits. Conversely, on nearby Oahu, all but three species of butterflyfish can be collected and <1% of the coastline is protected (Friedlander et al. 2005, Walsh 2014). Collection of ornamental reef fish has been ongoing on Oahu longer than elsewhere in the Hawaiian Islands, but surprisingly little is known about its effects.

Here we determine the abundance of 16 aquarium-collected fish species, including 5 endemics, at unprotected and protected sites around the island of Oahu. This work is the first study to focus on aquarium-collected fish from the island of Oahu. Our results indicate a correlation between collection effort and the abundance of ornamental reef fish, suggesting collection-driven population decreases. Oahu's long history of moderate to heavy ornamental fish collection along with its limited management and protected areas make it a useful system for assessing the long-term impacts of collection on ornamental fish populations.

Materials and Methods

We used a control-impact research design to assess the effect of aquarium collectors on reef-fish abundance throughout the island of Oahu. The magnitude of the effect was determined by comparing fish abundance at 15 unprotected collection sites to 2 sampling locations within Oahu's only well-protected Marine Life Conservation District, Hanauma Bay (Table 1, Fig. 1). Currently less than 1% of Oahu's shoreline is protected from aquarium fish collection through three Marine Life Conservation Districts (MLCDs), yet in two of these – Pupukea and Waikiki – enforcement is weak and poaching is suspected, making them unsuitable controls (Grabowsky, personal observation). Thus, sampling locations within Hanauma Bay were used as unfished control locations. Hanauma Bay has been closed to all take since 1967, longer than other

MLCDs. It is an enclosed bay that is heavily visited by beach goers and dive tours and is observed by City and County lifeguards. Any boating or fishing within the Bay is clearly visible.

A total of fifteen unprotected study sites were also examined (Fig. 1, Table 1). All of the study sites included in this study share common Benthic Zones, Geomorphological Structures, and Biological Cover profiles according to habitat type analysis using NOAA's Center for Coastal Monitoring and Assessment Maps (Shallow Water Benthic Maps of the Main Hawaiian Islands; http://ccma.nos.noaa.gov/products/biogeography/hawaii_cd_07/maps/maps_oahu.aspx) (Table 1). Locations with habitat characteristics dissimilar to Hanauma Bay were avoided.

<< Table 1 and Fig. 1 near here>>

The visual belt-transect search method was used to determine fish abundances at each site (Sale and Douglas 1981). To survey fish, a 100 m transect line was laid at 2-10 m depths. The transect line was soaked for 15 min without swimmers present before commencing the count. Sites were surveyed between 10:00 AM and 2:00 PM between June 30th and July 20th of 2009, 2010, and 2011. When conducting the fish counts, three swimmers swam side-by-side down the transect, with the center person swimming directly over the line and the two others on either side. Fish were counted in a corridor 3 m wide and extending to the surface.

A total of 16 species of fish were counted by each person over the entire area of the belt transect. The targeted species were originally intended to compare the abundances of 11 aquarium collected fish and 5 non-collected fish (following Tissot and Hallacher 2003). However, changes in the aquarium trade made this comparison unfeasible. The 11 species initially considered to be aquarium fish were: *Acanthurus achilles, Chaetodon lunula, C. multicinctus, C. ornatissimus, C. quadrimaculatus, Ctenochaetus strigosus*, *Dascyllus albisella,* *Forcipger* spp., *Naso lituratus, Zanclus cornutus*, and *Zebrasoma flavescens*. Due to uncertainty in species identification of longnose butterflyfish, species we pooled *Forcipger longirostris* and *F. flavissimus* as *Forcipiger* spp. (following Tissot and Hallacher 2003). The five species initially considered to be non-collected species were: *Abudefduf* spp.*, Acanthurus nigrofuscus, A. nigroris, A. triostegus* and *Thalassoma duperrey* (following Tissot and Hallacher 2003, with the addition of *A. abdominalis*). *Abudefduf abdominalis* and *A. vaigiensis* were recorded as *Abudefduf* spp. because these two abundant species are difficult to distinguish and may hybridize (K. Stender pers. comm.). When this study was initiated in 2009, all five of Tissot and Hallachers' (2003) "non-collected species" were available for purchase as aquarium fish, limiting the ability to make inferences about the effects of collection vs. other factors on reef fish abundances. Thus, we considered all 16 species as subjected to the aquarium trade.

The data from each fish counter were recorded and the average taken for each species. All counts were kept to 15 to 20 min duration. When visibility was less than 5 m or the deepest depth on the transect the count was aborted and redone under better conditions. Data were recorded on underwater paper with photographs and names of all 16 fish species. Data were collected by lead investigator Grabowsky and Pacific Island student interns. Students were trained in species identification and standardized survey methodology (Hallacher and Tissot 1999) before practicing taking data in the field for three weeks in June prior to the official counts. Grabowsky participated in all counts. Fish densities were compared in protected Hanauma Bay and in unprotected locations via T-tests using the analytical software JMP version 8 (SAS Institute Inc., Cary, NC, U.S.).

Results

Fourteen of the sixteen targeted species were numerically more abundant inside Hanauma Bay compared to unprotected areas (Fig. 2). Exceptions to this trend were *A. nigrofuscus* and *A. nigroris*, which are uncommonly sold as aquarium fish and unfavored as food fish in Hawaii. Six species exhibited statistically-significant differences between protected and unprotected sites, according to T-tests (Fig. 2). These included *A. triostegus* (p = 0.040), *C. lunula* (p = 0.014), *C. strigosus* (p = 0.004), *N. lituratus* (p < 0.0001), *Z. cornutus* (p = 0.028), and *Z. flavescens* (p = 0.011). Three of these are exclusively collected for the aquarium trade (*C. lunula, Z. cornutus* and *Z. flavescens*), whereas the others are taken both for aquaria and as food (*A. triostegus*, *C. strigosus* and *N. lituratus*).

<< Fig. 2 near here >>

Discussion

The results of our benthic surveys suggest collection-driven population declines in six species of coral reef fish. Marine ornamental fish have been gathered from Oahu since the 1950's. Based on the State of Hawaii's voluntary collection records, four of the species exhibiting significant declines at unprotected sites were also the most-collected ornamentals from Oahu (Commercial Aquarium Harvest by Species Oahu Areas reports, 2000-2010). Because three of these – *Z. flavescens, Z. cornutus,* and *C. lunula* – are not taken as food fish, it is likely that their decreased abundances at unprotected sites are due to the aquarium fishery. Such results are consistent with earlier investigations from other Hawaiian Islands that demonstrated collection impacts on aquarium fish abundances (Tissot and Hallacher 2003; Tissot et al. 2004, Walsh and Williams 2008, Walsh 2014). For example, Williams and Walsh (2007) found that at Honaunau on the Big Island of Hawaii: "of the 20 most collected aquarium species, 18 declined in abundance ($p<0.001$) with the species facing the heaviest fishing pressure typically showing the greatest declines."

Hawaiian reef fish may be jeopardized by collection due to Hawaii's high rate of marine endemism (Wood 1985; Walsh et al. 2004). Twenty-five percent of shallow-water (< 30 m) marine life in Hawaii is endemic; the highest level known (Randall 1998, 2007, Friedlander et al. 2008). Endemism further increases in deep-water habitats (Kane et al. 2014). Because of their limited range and concomitantly small population sizes, endemic species inherently face increased chances of overexploitation (Gaston 1996, Hawkins et al. 2000, Eble et al. 2009). Five of the species we surveyed are Hawaiian endemics: *A. vaigiensis*, *C. multicinctus*, *C. strigosus*, *D. albisella*, and *T. duperrey*. *Zebrasoma flavescens* occurs elsewhere in the Pacific but is only abundant in Hawaii (Hoover 2008). *Ctenochaetus strigosus* and *Z. flavescens* are therefore at greater risk if overexploited in Hawaii.

Additionally, many of the fish that are collected by Hawaiian aquarium fisheries are herbivores, which provide important ecosystem services by controlling algal abundance (Hay 1981, 1985, Lewis and Wainwright 1985, Lewis 1986; Hixon and Brostoff 1996, McCook 1996, Hughs et al. 1999, Aronson and Precht 2000). Herbivore removal therefore increases the likelihood of shifting reef ecosystems from coral-dominated to macro-algae dominated states (Smith et al. 2001, Ceccarelli et al. 2005, Rasher et al. 2012, Muthukrishnan and Fong 2014).

The research reported here was limited by several factors, including lack of baseline data, shifting trends in the aquarium trade, and poaching. To the best of our knowledge, no reliable baseline data on fish abundances are available for Oahu prior to the onset of collection (Walsh et al. 2004). For instance, the pioneering work of Brock (1954) – which used a quite different methodology from the current study to catalog fish abundance – noted that reef fish populations were already in decline as early as 1900 as a result of changing human activities. Our original experimental design mirrored that of Tissot and Hallacher (2003), wherein non-aquarium targeted species were used as controls. This design proved unfeasible for our study as previously untargeted species began being sold by aquarium fish vendors (Grabowsky pers. obs.). In addition, a comprehensive search of past dissertations conducted on Oahu on species studied here found no examples wherein fish were counted in a comparable fashion or on comparable substrates. Finally, the sample size of protected sites was limited by frequent poaching in all Marine Life Conservation Districts besides Hanauma Bay. Collectors were observed within Marine Life Conservation Districts, undermining the reliability of these sites as protected controls. It is therefore unsurprising that we did not find differences between open areas and the putatively protected sites, excluding Hanauma Bay (results not shown). Even Hanauma Bay is not pristine. Although we do not suspect aquarium fish collection occurs in this sheltered bay, the site is an extremely popular tourist destination, hosting over 800,000 visitors each year (Grabowsky 2016). These various unavoidable limitations constrained the scope and implications of our study. Nevertheless, the statistically-significant results, which are consistent with both collection volume data and analogous studies from other Hawaiian Islands (e.g., Tissot and Hallacher 2003), make a convincing case for collection-driven declines in reef fish abundances.

Given the potential for negative impacts to both fish populations and coral reef condition in this time of escalating anthropogenic threats, it seems pertinent to increase protective measures to safeguard fish populations from overexploitation. Less than 1% of Oahu’s coastline is currently protected from take (Friedlander et al. 2005, Walsh 2015). Considering that Oahu produces over 30% of Hawaii’s ornamental fish catch, this level of protection seems inadequate.

For comparison, the Big Island of Hawaii has protected approximately 35% of the Kona Coastline (where most aquarium fish collection occurs) through a system of Fish Replenishment Areas (FRAs). The Kona FRA system has led to increased fish abundance within the reserves and replenishment of adjacent areas (Walsh 2014). Creation of an analogous system for Oahu would likely both improve the status of reef fish populations and help to improve the sustainability of the aquarium fishery.

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Figure Legends:

Figure 1: Map of Oahu highlighting survey locations of 15 open access or unprotected sites (black stars) and 2 protected Hanauma Bay sites (white star). For clarity, proximate locations are demarcated by a single star. Coordinates and habitat characteristics of the survey locations are listed in Table 1.

Figure 2: Densities of the 16 target species of ornamental reef fish in the 15 unprotected sites (white bars) and 2 protected sites in Hanauma Bay (gray bars). Data presented as mean numbers of fish per 100 m^2 (± SE). Asterisks indicate significant differences between protected and unprotected locations according to T tests.

Table 1: Name, protection status, geographic coordinates, and habitat characteristics of the seventeen survey locations.

Name	Status[a]	Latitude	Longitude	Zone[b]	Geomorphological structure types[b]	Biological cover types[b]
Ala Moana 1	U	21.284581	157.849731	Fore Reef	Pavement + Spur & Groove	Uncolonized + Turf 50%-<90% + Coral 10%-<50%
Ala Moana 2	U	21.286622	157.848875	Reef Flat	Pavement	Macroalgae 50%-<90%
Ala Moana 3	U	21.289486	157.857486	Reef Flat	Pavement	Macroalgae 50%-<90%
Diamond Head	U	21.255083	157.815128	Reef Flat + Reef Crest + Channel	Pavement + Aggregate Reef	Coralline Algae 50%-<90% + Macroalgae 10%-<50%
Kaena Point	U	21.571044	158.274336	Bank/Shelf	Rock/Boulder	Coralline Algae 10%-<50% + Turf 50%-<90%
Makaha	U	21.550675	158.245925	Bank/Shelf	Pavement	Turf 50%-<90% + Uncolonized 90%-100%
Mokuleia 1	U	21.580967	158.214958	Reef Crest + Reef Flat	Pavement + spur and Groove	Macroalgae 10%-<50%
Mokuleia 2	U	21.580583	158.217400	Fore Reef + Bank/Shelf	Aggregate Reef + Spur and Groove	Turf 10%-<50%
Mokuleia 3	U	21.580544	158.235203	Bank + Reef Flat	Pavement	Macroalgae 10%-<50%
Nanakuli	U	21.372719	158.142422	Bank/Shelf	Pavement	Turf 50%-90%
Pupukea	U	21.635194	158.070808	Bank/Shelf	Rock/Boulder + Pavement	Macroalgae 10%-<50% + Turf 50%-<90%
Waikiki 1	U	21.261261	157.822836	Reef Flat + Reef Crest	Pavement	Macroalgae 10%-<50% + Macroalgae 50%-<90%+ Turf 50%-90%
Waikiki 2	U	21.277894	157.838556	Reef Flat + Reef Crest	Pavement	Macroalgae 10%-<50% + Coral 10%-<50%
Waikiki 3	U	21.279914	157.841789	Reef Flat + Reef Crest + Fore Reef	Pavement + Spur & Groove	Coral 10%-<50% + Macroalgae 10%-<50%+ Macroalgae 50%-<90%
Waimanalo	U	21.321094	157.669917	Reef Flat	Pavement + Scattered Coral/Rock	Turf 50%-<90% + Macroalgae 10%-<50%
Hanauma Bay Left Side	P	21.271439	157.693011	Bank/Shelf	Pavement + Rock/Boulder	Coral 10%-50%
Hanauma Bay Right Side	P	21.268331	157.695717	Fore Reef + Bank/Shelf	Pavement + Aggregate Reef	Coralline Algae 50%-<90% + Coral 10%-<50%

[a]: U = unprotected or protected with indications of poaching; P = fully protected

[b]: Following the National Center for Coastal Monitoring and Assessment Maps, available at http://ccma.nos.noaa.gov/products/biogeography/hawaii_cd_07/maps/maps_oahu.aspx

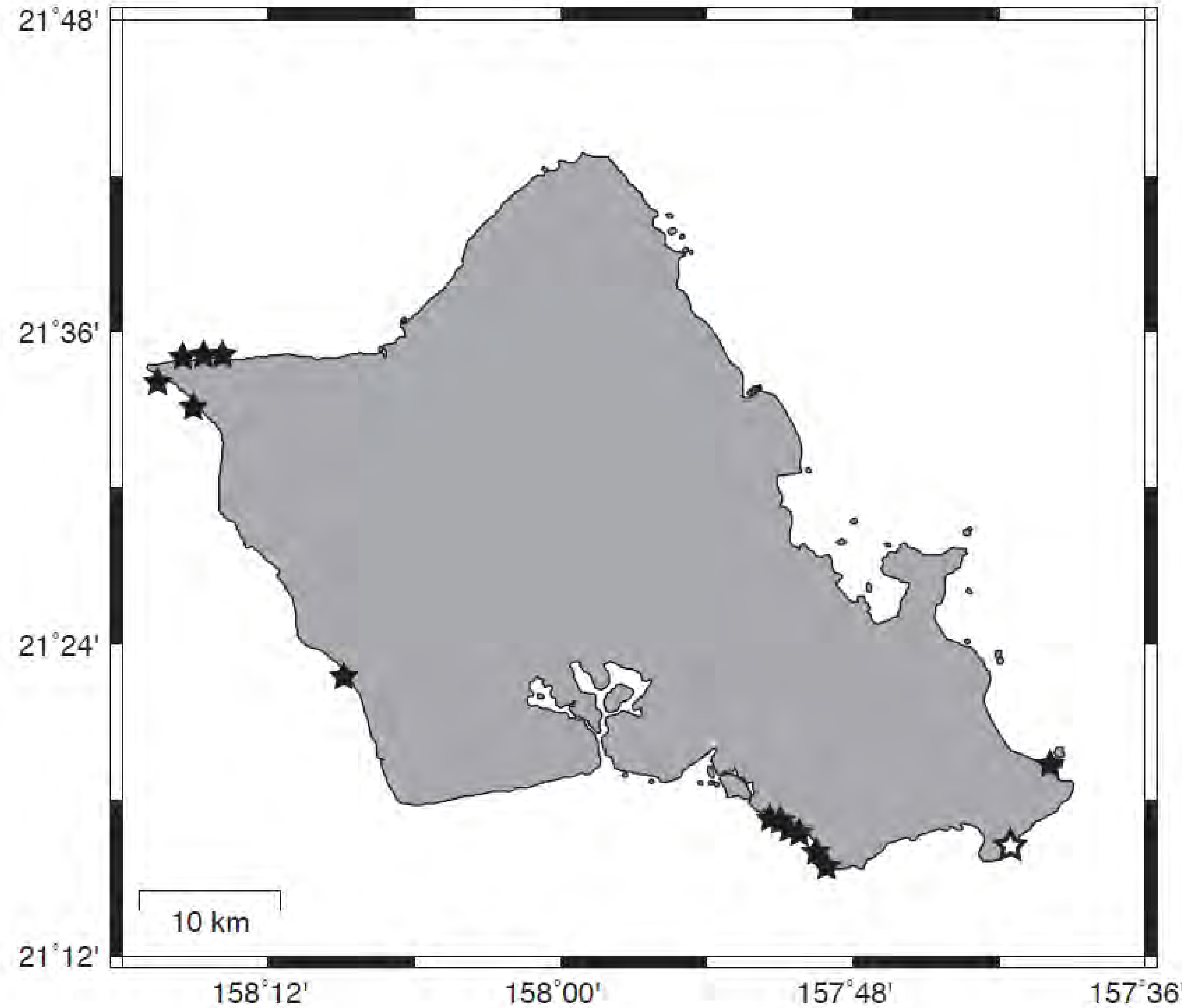
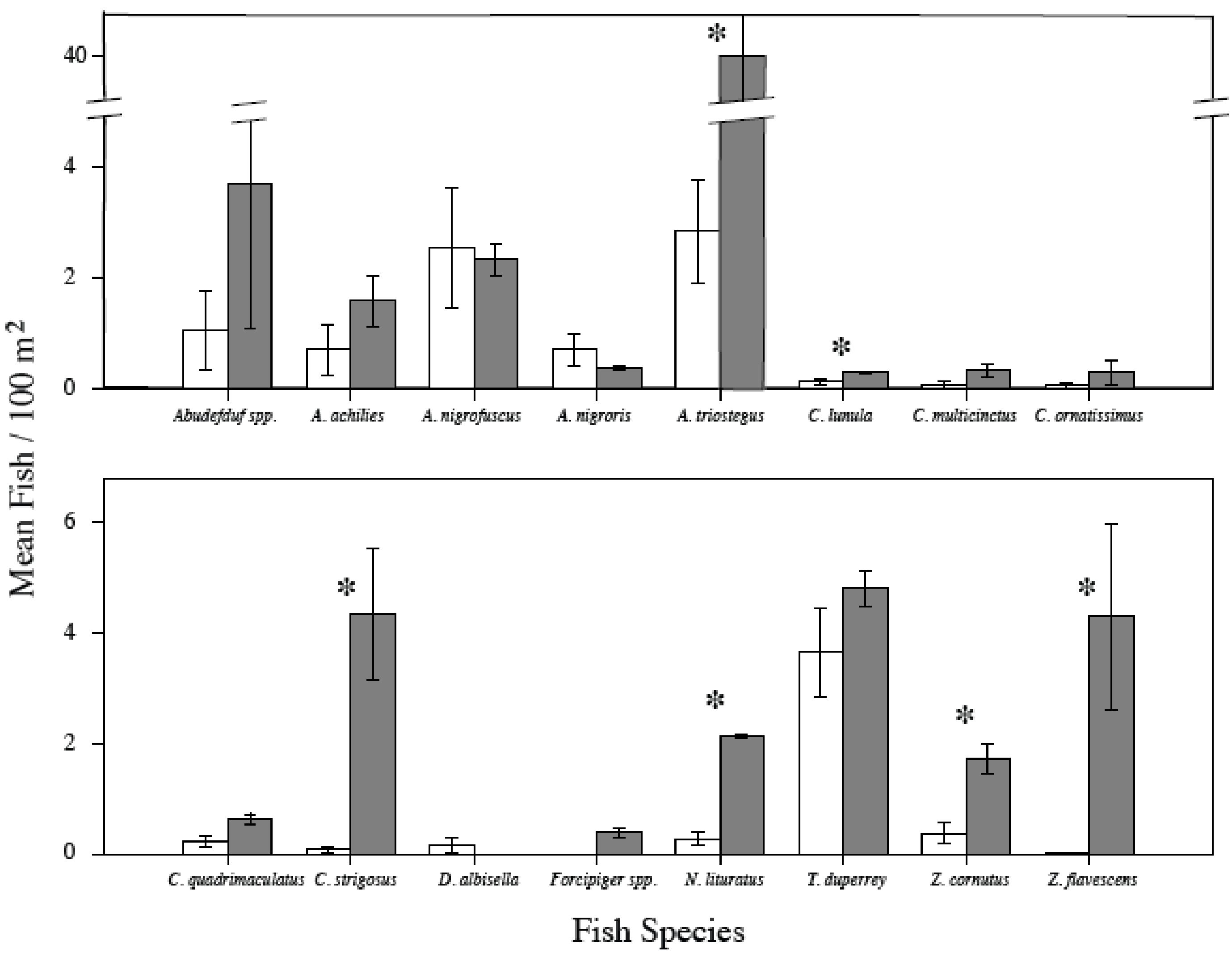


Figure 1.



Mean Fish / 100 m2
40
4
2
0
*
*
Abudefduf spp.
A. achilies
A. nigrofuscus
A. nigroris
A. triostegus
C. lunula
C. multicinctus
C. ornatissimus
6
4
2
0
*
*
*
*
C. quadrimaculatus
C. strigosus
D. albisella
Forcipiger spp.
N. lituratus
T. duperrey
Z. cornutus
Z. flavescens
Fish Species

446 Figure 2.

PIFSC-ESD Data, 2019

		Oahu	Hawaii_East	Hawaii_West	Oahu	Hawaii_East	Hawaii_West
Area (Hardbottom < 30m, Ha)		25,119	8,995	5,727			
SURVEY DENSITY	N Surveys	58	36	37	RULE OF THUMB - 95% CONFIDENCE INTERVALS ARE APPROX +/- 2*SE		
TAXON	SPECIES CODE	MEAN ABUNDANCE (/100m2)			STANDARD ERROR (/100 m2)		
Acanthurus achilles	ACAC	0.03	0.21	0.05	0.02	0.06	0.03
Acanthurus dussumieri	ACDU	0.10	0.41	0.09	0.04	0.08	0.04
Acanthurus nigricans	ACNC	0.00	0.02	0.12	0.00	0.02	0.10
Acanthurus nigrofuscus	ACNF	4.19	4.20	7.57	0.71	0.63	1.35
Acanthurus olivaceus	ACOL	0.61	0.98	0.48	0.14	0.20	0.15
Acanthurus thompsoni	ACTH	0.06	0.34	0.35	0.06	0.34	0.19
Anampses chrysocephalus	ANCH	0.03	0.01	0.01	0.01	0.01	0.01
Canthigaster jactator	CAJA	1.00	0.49	0.67	0.11	0.08	0.14
Cephalopholis argus	CEAR	0.06	0.19	0.49	0.02	0.04	0.07
Centropyge fisheri	CEFI	0.05	0.01	0.47	0.02	0.01	0.31
Centropyge potteri	CEPO	0.20	0.26	0.76	0.09	0.08	0.16
Chaetodon kleinii	CHKL	0.29	0.43	0.08	0.15	0.37	0.08
Chaetodon miliaris	CHMI	0.58	0.55	0.03	0.37	0.39	0.02
Chaetodon multicinctus	CHMU	0.17	0.36	1.40	0.05	0.09	0.26
Chaetodon quadrimaculatus	CHQU	0.23	0.42	0.22	0.07	0.07	0.06
Chaetodon tinkeri	CHTI	-	-	-	-	-	-
Cirrhitops fasciatus	CIFA	0.30	0.18	0.02	0.06	0.05	0.01
Cirrhilabrus jordani	CIJO	-	-	-	-	-	-
Coris gaimard	COGA	0.16	0.13	0.26	0.04	0.05	0.09
Ctenochaetus hawaiiensis	CTHA	0.00	0.12	0.55	0.00	0.07	0.13
Ctenochaetus strigosus	CTST	0.67	1.48	11.62	0.18	0.30	1.26
Dascyllus albisella	DAAL	0.36	0.03	0.15	0.12	0.03	0.08
Forcipiger flavissimus	FOFL	0.14	0.28	0.37	0.05	0.07	0.07
Gomphosus varius	GOVA	0.23	0.22	0.73	0.07	0.07	0.16
Halichoeres ornatissimus	HAOR	0.85	1.00	0.79	0.31	0.18	0.22
Hemitaurichthys polylepis	HEPO	0.09	-	-	0.09	-	-
Lutjanus kasmira	LUKA	0.68	1.70	0.31	0.32	0.40	0.09
Macropharyngodon geoffroy	MAGE	0.19	0.05	0.08	0.05	0.02	0.05
Melichthys niger	MENI	0.15	0.57	1.90	0.06	0.17	0.78
Naso lituratus	NALI	0.33	0.53	0.90	0.15	0.09	0.12
Ostracion meleagris	OSME	0.04	0.06	0.02	0.02	0.02	0.01
Paracirrhites forsteri	PAFO	0.12	0.17	0.14	0.04	0.05	0.04
Pseudojuloides cerasinus	PSCE	0.33	0.02	0.15	0.09	0.01	0.07
Pseudanthias hawaiiensis	PSHW	-	-	-	-	-	-
Pseudocheilinus octotaenia	PSOC	0.02	0.14	0.44	0.02	0.05	0.11
Pseudocheilinus tetrataenia	PSTE	0.05	0.13	0.16	0.03	0.06	0.05
Sufflamen bursa	SUBU	0.85	0.76	0.64	0.12	0.08	0.09

	Oahu	Hawaii_East	Hawaii_West
	COEFFICIENT OF VARIATION (SE/Mean).		
	Color coding to give some sense of data quality: green is pretty good to OK (~<20%), yellow is OK to marginal (~20-30%), orange is weak (~30-50%), red is terrible (~>50%).		
Acanthurus achilles	68%	30%	64%
Acanthurus dussumieri	39%	21%	42%
Acanthurus nigricans	100%	100%	81%
Acanthurus nigrofuscus	17%	15%	18%
Acanthurus olivaceus	23%	21%	31%
Acanthurus thompsoni	100%	100%	54%
Anampses chrysocephalus	46%	100%	69%
Canthigaster jactator	11%	16%	21%
Cephalopholis argus	32%	21%	13%
Centropyge fisheri	46%	100%	66%
Centropyge potteri	43%	31%	22%
Chaetodon kleinii	51%	86%	100%
Chaetodon miliaris	64%	72%	70%
Chaetodon multicinctus	30%	24%	18%
Chaetodon quadrimaculatus	29%	17%	29%
Chaetodon tinkeri	#DIV/0!	#DIV/0!	#DIV/0!
Cirrhitops fasciatus	21%	30%	59%
Cirrhilabrus jordani	#DIV/0!	#DIV/0!	#DIV/0!
Coris gaimard	27%	39%	35%
Ctenochaetus hawaiiensis	100%	55%	23%
Ctenochaetus strigosus	26%	20%	11%
Dascyllus albisella	32%	100%	53%
Forcipiger flavissimus	37%	25%	20%
Gomphosus varius	29%	32%	22%
Halichoeres ornatissimus	37%	18%	28%
Hemitaurichthys polylepis	100%	#DIV/0!	#DIV/0!
Lutjanus kasmira	47%	24%	30%
Macropharyngodon geoffroy	28%	49%	62%
Melichthys niger	37%	30%	41%
Naso lituratus	45%	17%	13%
Ostracion meleagris	37%	39%	46%
Paracirrhites forsteri	30%	31%	33%
Pseudojuloides cerasinus	27%	71%	46%
Pseudanthias hawaiiensis	#DIV/0!	#DIV/0!	#DIV/0!
Pseudocheilinus octotaenia	63%	37%	26%
Pseudocheilinus tetrataenia	56%	48%	32%
Sufflamen bursa	14%	10%	15%

PIFSC-ESD Data, 2019

TAXON	SPECIES CODE	MEAN ABUNDANCE (/100m2) Oahu	Hawaii_East	Hawaii_West	STANDARD ERROR (/100 m2) Oahu	Hawaii_East	Hawaii_West
Thalassoma duperrey	THDU	7.03	3.69	4.49	0.57	0.44	0.72
Xanthichthys auromarginatus	XAAU	0.06	-	0.12	0.03	-	0.07
Zebrasoma flavescens	ZEFL	0.29	0.37	10.63	0.16	0.10	1.65
Canthigaster coronata	CACO	0.13	0.01	0.06	0.03	0.01	0.06
Pseudanthias bicolor	PSBI	0.03	-	-	0.02	-	-
Zanclus cornutus	ZACO	0.10	0.76	0.31	0.02	0.11	0.08
Desmoholocanthus arcuatus	APAR	-	0.01	-	-	0.01	-
Chaetodon Auriga	CHAU	0.01	0.10	0.02	0.01	0.04	0.01
Chaetodon lunula	CHLU	0.08	0.32	0.30	0.03	0.08	0.09
Cirrhilabrus jordani	CIJO	-	-	-	-	-	-
Gymnothorax meleagris	GYME	0.02	0.01	0.06	0.01	0.01	0.03
Gymnothorax melatremus	GYMT	0.00	-	-	0.00	-	-
Gymnothorax zebra	GYZE	0.00	-	-	0.00	-	-
Heniochus diphreutes	HEDI	0.12	-	-	0.08	-	-
Novaculichthys taeniourus	NOTA	0.02	0.02	0.04	0.01	0.01	0.02
Xanthichthys mento	XAME	-	-	-	-	-	-

Color coding to give some sense of data quality: green is pretty good to OK (~<20%), yellow is OK to marginal (~20-30%), orange is weak (~30-50%), red is terrible (~>50%).

	Oahu	Hawaii_East	Hawaii_West
Thalassoma duperrey	8%	12%	16%
Xanthichthys auromarginatus	52%	#DIV/0!	57%
Zebrasoma flavescens	56%	27%	16%
Canthigaster coronata	26%	100%	100%
Pseudanthias bicolor	89%	#DIV/0!	#DIV/0!
Zanclus cornutus	24%	14%	25%
Desmoholocanthus arcuatus	#DIV/0!	71%	#DIV/0!
Chaetodon Auriga	55%	46%	76%
Chaetodon lunula	36%	24%	30%
Cirrhilabrus jordani	#DIV/0!	#DIV/0!	#DIV/0!
Gymnothorax meleagris	45%	71%	48%
Gymnothorax melatremus	100%	#DIV/0!	#DIV/0!
Gymnothorax zebra	100%	#DIV/0!	#DIV/0!
Heniochus diphreutes	66%	#DIV/0!	#DIV/0!
Novaculichthys taeniourus	48%	54%	58%
Xanthichthys mento	#DIV/0!	#DIV/0!	#DIV/0!

ESTIMATED POPULATION SIZE (# INDIVIDUALS IN SURVEYED REEF AREAS - I.E. HARDBOTTOM IN <30M PER ISLAND)

		Oahu	Hawaii_East	Hawaii_West	Oahu	Hawaii_East	Hawaii_West
TAXON	SPECIES CODE	ESTIMATED POPULATION SIZE			STANDARD ERROR (#/INDIVIDUALS)		
Acanthurus achilles	ACAC	73,299	185,259	27,392	50,178	56,147	17,475
Acanthurus dussumieri	ACDU	247,336	365,994	49,219	95,976	75,043	20,657
Acanthurus nigricans	ACNC	11,501	21,495	70,723	11,497	21,484	57,423
Acanthurus nigrofuscus	ACNF	10,523,860	3,777,626	4,336,269	1,787,736	566,169	773,888
Acanthurus olivaceus	ACOL	1,534,094	885,926	276,512	356,188	183,733	85,370
Acanthurus thompsoni	ACTH	147,584	302,538	201,230	147,475	302,396	108,968
Anampses chrysocephalus	ANCH	69,693	6,976	5,813	32,306	6,972	4,011
Canthigaster jactator	CAJA	2,513,096	443,961	381,051	287,002	69,692	81,277
Cephalopholis argus	CEAR	156,057	172,341	279,962	49,582	35,856	37,426
Centropyge fisheri	CEFI	117,920	11,697	268,363	54,763	11,689	176,627
Centropyge potteri	CEPO	512,697	236,771	437,617	221,787	73,421	94,399
Chaetodon kleinii	CHKL	728,984	387,141	43,768	369,546	333,058	43,746
Chaetodon miliaris	CHMI	1,452,891	493,360	14,533	923,022	353,235	10,245
Chaetodon multicinctus	CHMU	415,710	320,777	800,686	126,185	77,159	147,913
Chaetodon quadrimaculatus	CHQU	577,780	378,603	126,564	166,778	63,942	36,143
Chaetodon tinkeri	CHTI	-	-	-	-	-	-
Cirrhitops fasciatus	CIFA	744,687	162,539	11,626	159,466	47,958	6,836
Cirrhilabrus jordani	CIJO	-	-	-	-	-	-
Coris gaimard	COGA	397,004	118,139	146,227	107,938	46,360	51,284
Ctenochaetus hawaiiensis	CTHA	2,426	110,361	315,065	2,423	60,234	73,166
Ctenochaetus strigosus	CTST	1,690,372	1,331,404	6,655,072	443,277	272,762	722,332
Dascyllus albisella	DAAL	913,456	22,690	87,254	290,190	22,680	46,552
Forcipiger flavissimus	FOFL	345,009	251,206	210,290	128,116	61,696	42,167
Gomphosus varius	GOVA	580,100	196,231	420,492	167,217	61,968	92,012
Halichoeres ornatissimus	HAOR	2,137,281	898,641	451,108	784,336	164,325	125,015
Hemitaurichthys polylepis	HEPO	226,614	-	-	226,568	-	-
Lutjanus kasmira	LUKA	1,709,426	1,525,714	174,851	799,792	362,181	51,810
Macropharyngodon geoffroy	MAGE	481,899	44,480	48,099	137,057	22,003	29,716
Melichthys niger	MENI	376,349	514,378	1,087,628	140,993	156,261	449,113
Naso lituratus	NALI	837,112	478,551	512,857	373,966	79,326	66,242
Ostracion meleagris	OSME	104,861	51,632	11,626	38,757	20,200	5,396
Paracirrhites forsteri	PAFO	313,317	149,287	77,476	93,793	46,668	25,715
Pseudojuloides cerasinus	PSCE	829,120	14,314	87,423	227,997	10,120	40,546
Pseudanthias hawaiiensis	PSHW	-	-	-	-	-	-
Pseudocheilinus octotaenia	PSOC	59,945	127,551	249,438	37,969	47,535	64,267
Pseudocheilinus tetrataenia	PSTE	134,617	114,627	91,698	75,685	54,494	28,971
Sufflamen bursa	SUBU	2,128,863	685,297	365,354	295,723	67,774	53,347
Thalassoma duperrey	THDU	17,655,664	3,319,375	2,569,788	1,438,473	398,538	414,420
Xanthichthys auromarginatus	XAAU	162,831	-	69,871	85,324	-	39,603
Zebrasoma flavescens	ZEFL	728,777	329,557	6,087,924	405,795	87,794	946,888

		Oahu	Hawaii_East	Hawaii_West	Oahu	Hawaii_East	Hawaii_West
TAXON	SPECIES CODE	ESTIMATED POPULATION SIZE			STANDARD ERROR (#/INDIVIDUALS)		
Canthigaster coronata	CACO	319,076	7,338	34,879	83,687	7,335	34,836
Pseudanthias bicolor	PSBI	69,760	-	-	62,342	-	-
Zanclus cornutus	ZACO	251,451	681,905	176,954	61,060	94,747	43,358
Desmoholocanthus arcuatus	APAR	-	13,186	-	-	9,379	-
Chaetodon Auriga	CHAU	31,081	87,153	9,336	17,221	40,191	7,051
Chaetodon lunula	CHLU	201,288	290,142	170,637	72,049	68,465	50,532
Cirrhilabrus jordani	CIJO	-	-	-	-	-	-
Gymnothorax meleagris	GYME	58,821	12,824	35,551	26,580	9,098	16,983
Gymnothorax melatremus	GYMT	4,761	-	-	4,757	-	-
Gymnothorax zebra	GYZE	11,501	-	-	11,497	-	-
Heniochus diphreutes	HEDI	301,466	-	-	198,150	-	-
Novaculichthys taeniourus	NOTA	54,784	22,465	20,962	26,267	12,052	12,094
Xanthichthys mento	XAME	-	-	-	-	-	-

PIFSC-ESD Data, 2010-2016 Averages

	Area (Hardbottom < 30m, Ha)	16,840	18,127	3,004	9,678	12,730	9,266	24,776	5,727								
SURVEY DENSITY	N Surveys	257	113	115	172	170	103	227	138	RULE OF THUMB - 95% CONFIDENCE INTERVALS ARE APPROX +/- 2*SE							
		Hawaii	Kauai	Lanai	Maui	Molokai	Niihau	Oahu	HAW_KONA	Hawaii	Kauai	Lanai	Maui	Molokai	Niihau	Oahu	HAW_KONA
TAXON	SPECIES CODE	MEAN ABUNDANCE (/100m2)								STANDARD ERROR (/100 m2)							
Acanthurus achilles	ACAC	0.14	0.01	0.06	0.02	0.02	0.10	0.00	0.09	0.04	0.01	0.03	0.02	0.01	0.05	0.00	0.02
Acanthurus dussumieri	ACDU	0.34	0.06	0.13	0.22	0.18	0.19	0.13	0.06	0.04	0.01	0.03	0.04	0.03	0.03	0.04	0.02
Acanthurus nigricans	ACNC	0.06	-	0.03	0.01	0.02	-	0.00	0.06	0.03	-	0.02	0.01	0.01	-	0.00	0.02
Acanthurus nigrofuscus	ACNF	8.57	2.97	5.62	9.09	6.27	4.01	4.33	11.30	0.49	0.42	0.51	0.98	0.75	0.41	0.48	0.84
Acanthurus olivaceus	ACOL	0.78	0.90	0.33	0.51	0.46	1.25	0.56	0.36	0.11	0.13	0.05	0.11	0.07	0.13	0.06	0.06
Acanthurus thompsoni	ACTH	0.24	0.09	0.81	0.04	0.09	0.14	0.04	0.67	0.06	0.06	0.27	0.02	0.03	0.06	0.02	0.18
Anampses chrysocephalus	ANCH	0.02	0.06	0.07	0.07	0.08	0.39	0.06	0.01	0.01	0.02	0.04	0.03	0.02	0.17	0.01	0.00
Canthigaster jactator	CAJA	0.41	0.57	0.57	0.66	0.73	0.28	0.76	0.32	0.04	0.06	0.05	0.04	0.07	0.04	0.05	0.04
Cephalopholis argus	CEAR	0.28	0.10	0.34	0.15	0.25	0.36	0.05	0.29	0.02	0.02	0.04	0.02	0.03	0.04	0.01	0.03
Centropyge fisheri	CEFI	0.40	0.18	0.07	0.03	0.02	0.07	0.08	0.43	0.09	0.13	0.05	0.02	0.01	0.03	0.05	0.10
Centropyge potteri	CEPO	0.65	0.29	0.20	0.33	0.17	0.24	0.12	0.91	0.08	0.06	0.03	0.07	0.02	0.05	0.02	0.11
Chaetodon kleinii	CHKL	0.08	0.36	0.19	0.89	0.16	0.21	0.54	0.09	0.02	0.09	0.05	0.54	0.03	0.07	0.12	0.02
Chaetodon miliaris	CHMI	0.07	0.26	0.06	0.14	0.21	0.34	0.24	0.02	0.02	0.10	0.02	0.10	0.05	0.16	0.08	0.01
Chaetodon multicinctus	CHMU	1.06	0.36	0.51	0.60	0.48	0.30	0.33	1.85	0.06	0.05	0.07	0.06	0.06	0.04	0.04	0.13
Chaetodon quadrimaculatus	CHQU	0.47	0.13	0.11	0.16	0.19	0.17	0.17	0.45	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.06
Chaetodon tinkeri	CHTI	0.01	-	-	-	-	-	-	0.00	0.01	-	-	-	-	-	-	0.00
Cirrhitops fasciatus	CIFA	0.14	0.23	0.01	0.20	0.12	0.15	0.22	0.02	0.02	0.05	0.01	0.04	0.03	0.03	0.03	0.01
Cirrhilabrus jordani	CIJO	-	0.01	0.02	0.01	0.00	-	0.00	-	-	0.01	0.02	0.01	0.00	-	0.00	-
Coris gaimard	COGA	0.23	0.10	0.12	0.13	0.18	0.23	0.16	0.21	0.02	0.02	0.03	0.03	0.05	0.04	0.02	0.02
Ctenochaetus hawaiiensis	CTHA	0.33	-	0.00	0.01	0.00	0.00	0.00	0.79	0.06	-	0.00	0.00	0.00	0.00	0.00	0.17
Ctenochaetus strigosus	CTST	6.95	0.28	2.90	3.18	3.04	1.44	0.46	12.20	0.65	0.06	0.42	0.35	0.36	0.38	0.11	0.86
Dascyllus albisella	DAAL	0.13	0.73	0.46	0.53	0.38	0.67	0.26	0.36	0.04	0.15	0.15	0.17	0.07	0.22	0.05	0.12
Forcipiger flavissimus	FOFL	0.26	0.06	0.09	0.12	0.11	0.12	0.08	0.44	0.02	0.02	0.02	0.02	0.02	0.03	0.01	0.04
Gomphosus varius	GOVA	0.52	0.09	0.49	0.45	0.72	0.09	0.16	0.94	0.06	0.03	0.08	0.09	0.13	0.03	0.04	0.11
Halichoeres ornatissimus	HAOR	0.97	0.33	0.36	0.63	0.48	0.70	0.27	0.61	0.07	0.05	0.05	0.07	0.12	0.09	0.03	0.06
Hemitaurichthys polylepis	HEPO	0.01	0.00	0.08	-	0.00	0.03	0.00	0.04	0.01	0.00	0.05	-	0.00	0.02	0.00	0.02
Lutjanus kasmira	LUKA	4.21	2.12	0.32	0.14	0.70	3.67	1.13	0.99	2.23	0.92	0.24	0.06	0.19	1.16	0.70	0.62
Macropharyngodon geoffroy	MAGE	0.18	0.31	0.20	0.31	0.23	1.16	0.30	0.06	0.05	0.07	0.06	0.06	0.05	0.28	0.04	0.02
Melichthys niger	MENI	0.80	0.19	0.19	0.20	0.20	0.12	0.09	1.11	0.11	0.10	0.05	0.05	0.10	0.04	0.03	0.24
Naso lituratus	NALI	0.53	0.13	0.46	0.63	0.44	0.59	0.38	0.81	0.04	0.04	0.09	0.06	0.07	0.07	0.06	0.06
Ostracion meleagris	OSME	0.06	0.01	0.03	0.05	0.03	0.02	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Paracirrhites forsteri	PAFO	0.15	0.11	0.10	0.07	0.11	0.14	0.05	0.16	0.01	0.03	0.02	0.01	0.02	0.02	0.01	0.02
Pseudojuloides cerasinus	PSCE	0.10	0.38	0.19	0.19	0.16	0.44	0.44	0.10	0.03	0.08	0.07	0.06	0.05	0.11	0.06	0.04
Pseudanthias hawaiiensis	PSHW	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	0.00	-
Pseudocheilinus octotaenia	PSOC	0.41	0.09	0.19	0.16	0.18	0.03	0.08	0.72	0.05	0.03	0.04	0.03	0.04	0.01	0.02	0.08
Pseudocheilinus tetrataenia	PSTE	0.74	0.13	0.20	0.09	0.14	0.08	0.07	0.61	0.14	0.03	0.03	0.02	0.03	0.02	0.01	0.10
Sufflamen bursa	SUBU	0.77	0.58	0.24	0.61	0.39	0.75	0.85	0.74	0.04	0.04	0.02	0.04	0.03	0.05	0.06	0.05
Thalassoma duperrey	THDU	3.80	3.71	5.78	4.43	4.79	5.89	4.83	3.26	0.19	0.34	0.70	0.28	0.37	0.47	0.53	0.23
Xanthichthys auromarginatus	XAAU	0.08	0.01	0.01	0.00	-	-	0.06	0.13	0.01	0.01	0.01	0.00	-	-	0.03	0.03
Zebrasoma flavescens	ZEFL	4.91	0.06	1.79	0.68	0.75	0.12	0.09	10.52	0.43	0.02	0.27	0.09	0.10	0.03	0.02	0.99
Canthigaster coronata	CACO	0.01	0.09	0.01	0.03	0.06	0.03	0.12	0.01	0.00	0.02	0.00	0.01	0.01	0.01	0.01	0.00
Pseudanthias bicolor	PSBI	0.01	0.06	0.00	0.02	0.05	0.04	0.12	0.00	0.01	0.03	0.00	0.01	0.02	0.02	0.06	0.00
Zanclus cornutus	ZACO	0.32	0.16	0.14	0.12	0.10	0.13	0.09	0.24	0.03	0.04	0.03	0.02	0.02	0.03	0.01	0.03

PIFSC-ESD Data, 2010-2016 Averages

COEFFICIENT OF VARIATION (SE/Mean).

Color coding to give some sense of data quality: green pretty good, yellow (~<20%) is OK, orange is marginal, red is pretty weak (~>50%) or terrible.

	Hawaii	Kauai	Lanai	Maui	Molokai	Niihau	Oahu	HAW_KONA
Acanthurus achilles	26%	46%	52%	74%	46%	51%	70%	26%
Acanthurus dussumieri	12%	25%	26%	20%	17%	18%	33%	28%
Acanthurus nigricans	46%	#DIV/0!	73%	88%	69%	#DIV/0!	100%	34%
Acanthurus nigrofuscus	6%	14%	9%	11%	12%	10%	11%	7%
Acanthurus olivaceus	14%	14%	16%	21%	15%	10%	11%	17%
Acanthurus thompsoni	25%	62%	33%	64%	37%	47%	47%	26%
Anampses chrysocephalus	36%	36%	57%	38%	28%	43%	24%	49%
Canthigaster jactator	9%	10%	10%	6%	10%	13%	6%	11%
Cephalopholis argus	8%	20%	11%	15%	14%	12%	23%	10%
Centropyge fisheri	22%	68%	66%	55%	40%	37%	61%	23%
Centropyge potteri	12%	20%	16%	22%	14%	20%	19%	13%
Chaetodon kleinii	30%	25%	28%	61%	20%	33%	22%	25%
Chaetodon miliaris	22%	38%	34%	70%	24%	45%	32%	73%
Chaetodon multicinctus	5%	15%	13%	9%	13%	15%	12%	7%
Chaetodon quadrimaculatus	8%	20%	20%	17%	17%	17%	15%	14%
Chaetodon tinkeri	55%	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	100%
Cirrhitops fasciatus	15%	24%	55%	20%	24%	21%	12%	31%
Cirrhilabrus jordani	#DIV/0!	100%	100%	100%	73%	#DIV/0!	75%	#DIV/0!
Coris gaimard	9%	19%	21%	19%	26%	19%	11%	11%
Ctenochaetus hawaiiensis	18%	#DIV/0!	69%	55%	43%	100%	71%	21%
Ctenochaetus strigosus	9%	22%	15%	11%	12%	26%	24%	7%
Dascyllus albisella	30%	20%	32%	32%	18%	33%	20%	33%
Forcipiger flavissimus	8%	35%	21%	18%	16%	21%	18%	9%
Gomphosus varius	11%	35%	16%	19%	18%	37%	23%	12%
Halichoeres ornatissimus	7%	16%	14%	11%	24%	13%	11%	10%
Hemitaurichthys polylepis	50%	100%	69%	#DIV/0!	100%	83%	100%	50%
Lutjanus kasmira	53%	44%	74%	41%	27%	32%	62%	62%
Macropharyngodon geoffroy	25%	24%	29%	20%	20%	25%	13%	33%
Melichthys niger	14%	54%	26%	25%	52%	37%	31%	22%
Naso lituratus	8%	28%	20%	10%	15%	11%	16%	7%
Ostracion meleagris	21%	37%	41%	22%	26%	37%	30%	22%
Paracirrhites forsteri	9%	25%	23%	17%	17%	18%	24%	12%
Pseudojuloides cerasinus	27%	21%	38%	32%	34%	24%	13%	40%
Pseudanthias hawaiiensis	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	100%	#DIV/0!
Pseudocheilinus octotaenia	11%	31%	20%	16%	21%	37%	25%	11%
Pseudocheilinus tetrataenia	18%	21%	16%	21%	22%	25%	20%	16%
Sufflamen bursa	5%	8%	9%	6%	9%	7%	7%	6%
Thalassoma duperrey	5%	9%	12%	6%	8%	8%	11%	7%
Xanthichthys auromarginatus	19%	100%	64%	100%	#DIV/0!	#DIV/0!	50%	22%
Zebrasoma flavescens	9%	33%	15%	14%	14%	27%	22%	9%
Canthigaster coronata	37%	27%	50%	29%	22%	31%	12%	65%
Pseudanthias bicolor	56%	50%	99%	69%	43%	53%	50%	100%
Zanclus cornutus	9%	23%	22%	17%	20%	26%	16%	11%

PIFSC-ESD Data, 2010-2016 Averages

ESTIMATED POPULATION SIZE (# INDIVIDUALS IN SURVEYED REEF AREAS - I.E. HARDBOTTOM IN <30M PER ISLAND)

		Hawaii	Kauai	Lanai	Maui	Molokai	Niihau	Oahu	HAW_KONA	Hawaii	Kauai	Lanai	Maui	Molokai	Niihau	Oahu	HAW_KONA
TAXON	SPECIES CODE	ESTIMATED POPULATION SIZE								STANDRD ERROR (#/INDIVIDUALS)							
Acanthurus achilles	ACAC	231,377	25,881	18,506	20,661	20,729	96,822	5,750	49,142	59,892	12,018	9,557	15,274	9,524	48,932	4,003	12,839
Acanthurus dussumieri	ACDU	578,835	102,321	40,143	216,660	225,765	176,031	322,676	35,415	71,701	25,595	10,308	42,818	37,802	30,906	105,958	9,923
Acanthurus nigricans	ACNC	97,924	-	8,994	6,818	19,159	-	2,875	31,953	44,718	-	6,587	5,978	13,252	-	2,872	10,918
Acanthurus nigrofuscus	ACNF	14,439,543	5,378,880	1,688,092	8,797,459	7,983,065	3,714,777	10,726,239	6,474,819	826,091	766,786	154,580	950,389	950,483	378,256	1,182,007	481,070
Acanthurus olivaceus	ACOL	1,319,924	1,637,879	100,191	494,424	589,586	1,158,300	1,380,451	207,351	182,462	229,580	15,716	103,634	85,673	119,041	148,018	35,157
Acanthurus thompsoni	ACTH	405,776	171,854	242,904	34,964	111,511	125,099	108,032	382,850	102,112	106,270	81,009	22,376	41,327	58,922	51,223	100,835
Anampses chrysocephalus	ANCH	36,770	102,992	20,129	68,439	98,455	360,145	146,521	4,311	13,338	36,959	11,476	25,742	27,992	155,230	35,691	2,126
Canthigaster jactator	CAJA	685,517	1,040,252	172,094	641,584	926,210	260,057	1,888,605	182,867	60,826	99,928	16,505	39,296	92,681	34,732	117,075	20,950
Cephalopholis argus	CEAR	476,556	172,487	103,293	147,066	317,647	331,384	111,882	166,186	39,429	34,897	11,432	21,353	44,263	40,408	26,036	16,404
Centropyge fisheri	CEFI	666,209	333,200	20,781	30,842	25,678	63,067	192,591	244,919	144,612	227,129	13,705	17,044	10,393	23,244	117,283	57,022
Centropyge potteri	CEPO	1,087,709	530,321	61,380	321,023	210,894	220,676	297,372	520,769	133,437	107,805	10,006	70,942	29,067	44,674	56,821	65,260
Chaetodon kleinii	CHKL	131,260	657,236	57,998	861,801	199,401	198,646	1,326,735	54,114	39,565	165,998	16,273	522,459	40,190	65,716	296,664	13,415
Chaetodon miliaris	CHMI	122,588	479,022	18,793	131,441	266,973	318,925	603,563	8,654	27,029	182,567	6,401	92,514	64,225	144,409	192,470	6,309
Chaetodon multicinctus	CHMU	1,788,604	652,207	153,063	585,136	616,100	273,504	806,937	1,061,149	95,235	95,394	19,911	54,249	78,382	39,862	95,279	73,399
Chaetodon quadrimaculatus	CHQU	797,673	233,327	33,825	153,652	238,333	160,244	423,205	260,405	60,885	46,494	6,694	26,410	39,395	26,842	64,190	35,331
Chaetodon tinkeri	CHTI	18,475	-	-	-	-	-	-	2,188	10,220	-	-	-	-	-	-	2,181
Cirrhitops fasciatus	CIFA	231,580	417,317	3,616	194,106	155,291	139,531	554,451	13,306	33,761	99,605	2,002	38,739	37,242	29,048	66,584	4,145
Cirrhilabrus jordani	CIJO	-	18,591	6,182	5,045	3,786	-	5,683	-	-	18,574	6,160	5,020	2,773	-	4,240	-
Coris gaimard	COGA	391,507	172,518	36,653	128,168	224,467	208,491	395,152	119,260	37,157	32,614	7,673	24,366	58,857	40,593	42,579	13,018
Ctenochaetus hawaiiensis	CTHA	549,462	-	767	7,084	4,798	2,643	5,938	450,464	98,942	-	530	3,904	2,082	2,639	4,194	94,847
Ctenochaetus strigosus	CTST	11,697,561	499,042	869,873	3,080,180	3,873,657	1,335,258	1,144,130	6,986,664	1,096,730	108,764	127,495	340,535	462,263	351,516	271,327	490,330
Dascyllus albisella	DAAL	225,153	1,319,267	137,729	515,707	483,025	618,030	653,097	204,753	68,310	265,926	44,436	166,516	87,082	203,671	129,623	67,649
Forcipiger flavissimus	FOFL	435,954	105,352	28,478	118,670	134,233	112,597	192,505	254,592	35,417	37,016	5,912	21,426	21,846	23,779	34,618	22,866
Gomphosus varius	GOVA	877,224	168,465	148,463	437,493	913,888	85,597	396,658	535,858	97,494	59,193	23,386	84,990	168,772	31,453	93,098	63,846
Halichoeres ornatissimus	HAOR	1,630,224	603,125	109,561	612,443	614,833	652,001	668,852	350,687	115,846	98,508	15,260	69,117	147,585	87,814	75,594	33,777
Hemitaurichthys polylepis	HEPO	23,217	7,437	22,574	-	4,272	25,662	1,874	23,217	11,560	7,429	15,665	-	4,255	21,242	1,871	11,560
Lutjanus kasmira	LUKA	7,092,851	3,840,820	97,446	138,375	887,359	3,398,002	2,805,838	567,687	3,754,382	1,674,506	71,881	56,881	239,310	1,077,503	1,727,788	354,037
Macropharyngodon geoffroy	MAGE	307,032	568,448	61,518	301,142	287,203	1,070,321	746,227	31,513	76,517	134,271	17,563	60,711	58,308	263,240	96,747	10,457
Melichthys niger	MENI	1,354,454	341,215	55,646	192,999	250,682	111,591	224,700	637,515	185,408	185,453	14,658	47,565	129,727	41,278	69,955	139,551
Naso lituratus	NALI	897,085	227,631	136,786	611,554	553,864	547,441	950,505	465,745	70,463	64,061	27,357	62,038	84,474	60,634	151,293	33,079
Ostracion meleagris	OSME	94,937	24,729	9,359	49,750	40,874	20,340	57,436	23,080	19,981	9,090	3,855	10,946	10,617	7,473	17,308	4,973
Paracirrhites forsteri	PAFO	246,727	193,772	31,250	68,710	141,940	125,457	125,912	90,049	23,056	48,524	7,264	11,746	23,704	22,831	30,488	11,181
Pseudojuloides cerasinus	PSCE	169,025	695,507	56,187	188,522	204,001	408,416	1,091,806	56,437	45,669	146,132	21,322	60,155	69,609	99,299	146,586	22,688
Pseudanthias hawaiiensis	PSHW	-	-	-	-	-	-	10,415	-	-	-	-	-	-	-	10,411	-
Pseudocheilinus octotaenia	PSOC	689,221	163,852	57,843	153,561	231,226	25,114	206,014	410,760	78,378	50,589	11,648	24,736	49,496	9,323	52,479	45,471
Pseudocheilinus tetrataenia	PSTE	1,253,164	238,335	59,273	88,705	181,191	70,449	177,710	350,409	231,802	50,882	9,516	19,041	40,123	17,937	35,788	57,813
Sufflamen bursa	SUBU	1,299,027	1,051,109	72,929	588,640	493,167	690,445	2,108,418	426,110	59,522	80,168	6,619	38,016	44,044	49,885	149,564	26,066
Thalassoma duperrey	THDU	6,396,052	6,731,755	1,735,608	4,285,011	6,101,605	5,459,530	11,959,153	1,868,224	325,891	611,529	208,832	267,657	466,584	431,958	1,321,536	134,078
Xanthichthys auromarginatus	XAAU	129,089	11,155	4,438	3,101	-	-	156,921	75,769	24,965	11,144	2,840	3,097	-	-	78,933	17,011
Zebrasoma flavescens	ZEFL	8,262,144	116,356	539,080	658,687	955,987	108,718	216,524	6,022,548	720,841	38,661	80,318	91,052	129,075	28,868	48,322	567,988
Canthigaster coronata	CACO	15,827	157,495	1,998	29,376	76,157	29,936	285,677	3,747	5,865	42,963	1,006	8,499	17,117	9,412	32,964	2,430
Pseudanthias bicolor	PSBI	15,285	106,472	410	15,289	61,750	38,728	300,208	1,094	8,552	53,398	407	10,626	26,308	20,420	150,391	1,091
Zanclus cornutus	ZACO	534,568	296,353	41,459	112,411	131,601	117,940	221,573	135,669	46,429	68,157	9,233	19,315	25,833	30,142	35,873	14,844

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The future for Hawai‘i’s marine aquarium fishery: A cost benefit analysis compared to an environmental impact assessment

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A B S T R A C T

Conflict has surrounded Hawai‘i’s commercial marine aquarium fishery since its inception in the late 1940s. In 2019, the Hawai‘i Supreme Court requested that an environmental impact statement (EIS) analysing the ecological and cultural impacts of Hawai‘i’s marine aquarium fishery be completed for Hawai‘i Island (Big Island) and O‘ahu. The costs and benefits associated with the fishery and their distribution across stakeholder groups was however not addressed in the EIS. This paper presents a cost-benefit based analysis of four policy scenarios using existing secondary data for Hawai‘i’s marine aquarium fishery. From the analysis, a state-wide collection ban was the option that yielded positive annual net benefits and negatively impacted the fewest stakeholders. In contrast, the EIS recommends ten permits for fishing off the coast of Big Island be issued.

1. Introduction

Some view the marine aquarium fish trade as a path to expanding the conservation of reef environments based on the assumption that owning aquarium fishes cultivates awareness and interest in the conservation of their source habitats [46,6,31,47]. While conservation groups have promoted the aquarium trade as a means of enhancing livelihoods in developing countries, others are concerned that the profit motive of commercial fishers serves as an incentive to overharvest species commonly found in marine aquariums [37,39,59]. If marine aquarium fisheries are not properly regulated and the regulations are not promulgated, a common-pool resource dilemma will result in economic profitability prevailing over long-term sustainability – a tragedy of the commons scenario [43].

Hawai‘i’s commercial marine aquarium fishery has been a source of debate among various stakeholder groups including aquarium fishers and hobbyists, marine scientists, Native Hawaiians (Kānaka Maoli), resource managers, policy makers and community members [2,36,46]. The fishery’s costs and benefits are distributed differently among these stakeholders, resulting in years of conflict. As has been observed in many fisheries around the world, fishers in Hawai‘i under report their catches and mortality rates [23,48,52,56], which further exacerbates conflicts. The fishery is comprised of two geographically distinct zones. The first is the West Hawai‘i Regional Fishery Management Area (WHRFMA) that extends the length of the west coast of Hawai‘i Island (Big Island) from Ka Lae, Ka‘u¯ (South Point) to ‘Upolu Point. The second encompasses North Kohala, and the main Hawaiian Islands excluding all zones that are designated as Marine Protected Areas (MPAs) [57].

Residents and Native Hawaiian cultural practitioners have pushed to ban aquarium fishing in Hawai‘i citing the lack of sustainable and humane harvesting methods, inadequate enforcement, inaccurate catch reporting and poor alignment with Kānaka Maoli ideals of resource management [23]. In 2017, the Hawai‘i Supreme Court placed a moratorium on aquarium fishery permits, citing a need for a Hawai‘i Environmental Policy Act (HEPA) review [15–17]. The court concluded that the permitted use of fine mesh nets involves the public’s use of state land and therefore requires discretionary approval from the state [15–17]. The court’s request in 2019 for an environmental impact statement (EIS) analysing the ecological and cultural impacts of the marine aquarium fishery came after Environmental Assessments (EA) for Big Island and O‘ahu were submitted by the Pet Industry Joint Advisory Council (PIJAC) and deemed insufficient by the State’s Department of Land and Natural Resources (DLNR) Chair Suzanne D. Case [15–17]. The final environmental impact statement (EIS) funded by PIJAC and conducted by a consulting firm, which concluded that DLNR should issue permits to ten commercial aquarium fishers in the WHRFMA, was unanimously rejected by the Board of Land and Natural Resources (BLNR) after concluding that the EIS did not adequately disclose the potential environmental impacts of the proposed action [14]. PIJAC appealed BLNR’s decision to the Environmental Council who affirmed BLNR’s rejection of

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Table 1
Description of policy scenarios analysed in CBA.

Scenario	Characteristics
A. Status quo (2019)	AQ Permits void and fishery continues without use of fine mesh nets on O'ahu, Big Island and no collecting in WHRFMA Voluntary catch report data Majority of catch is exported Unknown impacts to other fisheries, the environment, cultural resources and on-reef tourism State funds monitoring and management of fishery Potential for non-compliance Provides industry income Provides tax and fee revenue to state
B. Permitting system (2016)	Administrative rules and bag limits apply across the State Voluntary catch report data Majority of catch is exported Unknown impacts to other fisheries, the environment, cultural resources and on-reef tourism State funds monitoring and management of fishery Potential for non-compliance Provides industry income Provides tax and fee revenue to state
C. State-wide collecting ban	No aquarium species from Hawaiʻi state waters can be collected Collection exemptions possible for research, educational institutions and managers Wild-captured aquarium exports banned No impacts on other fisheries, the environment, cultural resources or on-reef tourism State avoids costs associated with managing the fishery Potential for non-compliance Loss of industry income Loss of tax and fees revenues to state
D. Captive breeding collection	Permits issued to fishers with facilities for captive breeding Opportunity to export from Hawaiʻi Unknown impacts on other fisheries, cultural resources, the environment and on-reef tourism State funds monitoring and management of fishery Potential for non-compliance Provides income opportunity for industry Provides tax and fee revenue to state

the EIS [27].

The 2019 state-wide moratorium allows commercial aquarium fishing to continue without commercial aquarium permits, as long as fine-mesh net equipment is not used and fishers possess a commercial marine license (CML), whereas, all collection has been outlawed regardless of gear-type for the WHRFMA [20]. A November 2020 order from Hawaiʻi's First Circuit Court requires environmental review for issuance of new or renewed annual CMLs to be used for aquarium fishing purposes, allowing aquarium collecting by CML holders to continue until their CML expire one year after issuance [18,21]. A January 2021 order from the same court further strengthened the November 2020 order by issuing an injunction to halt aquarium collection under existing CMLs, completely banning commercial aquarium fishing in the State of Hawaiʻi pending environmental review by the industry [13].

Many U. S. government agencies use cost benefit analysis (CBA) in addition to or in place of environmental impact assessment to assist in management decision-making. The U.S. Environmental Protection Agency [54] concluded that cost benefit analyses used to determine environmental regulations increased net benefits to society and "provide the balance required in complex regulatory decisions." International non-profit organizations also rely on CBAs in managing natural resources. Verdone [55] used CBA to analyse landscape forest restoration in Rwanda for the International Union for Conservation of Nature and Natural Resources.

This paper presents a cost benefit (CBA) based analysis using published information and existing data to provide evidence to assist decision makers considering the future of this fishery. Four policy scenarios were developed, the relevant costs and benefits for each scenario are described and/or estimated and their distribution across stakeholder groups are assessed. The CBA results are compared to the EIS recommendations and conclusions in order to determine how the two differ and which one provides a more accurate appraisal of maintaining the aquarium fishery.

2. Methods

Four past, current or proposed scenarios for managing this fishery are described (Table 1) in order to identify the associated costs and benefits, along with stakeholders impacted. Scenarios A and B assume that the aquarium fishery continues, though the number of fishers in the industry is not mandated in either one. Scenario A involves maintaining the 2019 status quo that restricts the use of fine mesh nets and no collecting in the WHRFMA. Scenario B assumes that the 2016 bag limits would be applied across the State. These were considered here because they both attempt to limit the catch. Scenario C involves a state-wide ban, which has been suggested by many stakeholders who do not benefit from the fishery. Scenario D allows the fishery to continue only to facilitate the establishment of captive breeding operations. This option is considered as one that protects wild fish in the long run, while also encouraging an industry that cultivates awareness and interest in the conservation of their source habitats by producing aquarium fish. The environmental impact statement (EIS) funded by PIJAC recommends limiting the number of permits, rather than limiting the catch.

The stakeholder groups who were identified in each scenario are described (Table 2) and the acronym used for the group throughout the

Table 2
Codes and descriptions for stakeholder groups.

Code	Stakeholder Group Description
S1	Native Hawaiians
S2	Residents of Hawaiʻi
S3	Tourists
S4	Collectors and wholesalers from Oʻahu
S5	Collectors and wholesalers from Hawaiʻi Island excluding the WHRFMA
S6	Collectors and wholesalers from the WHRFMA
S7	All collectors and wholesaler in the State
S8	State government agencies

paper is identified. Previous research [2,23,36,46], various media reports, hearings and litigation surrounding the ongoing conflict in this fishery provided details about the stakeholder groups. A description of the methods used to estimate or describe each cost/benefit and their expected sign follow. While CBA normally involves discounting to ensure that net present value of costs and benefits are calculated, annual point estimates are used in this CBA. Since the estimates do not vary over time, discounting adds nothing to the analysis.

2.1. Cost and benefit estimates and descriptions

2.1.1. State management costs

Since both Scenarios A and B involve limiting the industry's catch and require voluntary reporting, the State will have to enforce these regulations. Therefore, to estimate this cost, DAR personnel in DLNR were contacted and asked to estimate DAR's 2019 management cost for Hawaiʻi's marine aquarium fishery including salaries of employees who work directly with the fishery, aquarium fish surveys and any other costs associated with the fishery that DAR funds. DAR officials provided a low estimate of USD 300,000 annually covering the time spent by 20 or more individuals in the aquarium fishery along with their supplies and equipment. Their high estimate of USD 500,000 annually includes costs, such as fringe benefits that are not included DAR's annual 2019 budget, but are found in DLNR's overall budget. For Scenario C, these management costs should be eliminated overtime. Scenario D would likely involve management costs, which could be reduced as the policies and regulations that support this scenario are refined.

2.1.2. Tourism value

According to the Hawaiʻi Tourism Authority [29], the State's economy relied on tourism for its largest source of private capital. Spalding et al. [50], estimated the "on-reef" tourism value for the entire state of Hawaiʻi at USD 550.8 million per year. Spalding was contacted and estimated, using the existing data base the annual "on-reef" values for Oʻahu and Hawaiʻi Island to be approximately USD 442,496,000 and USD 16,921,000 respectively, for an annual upper bound of USD 459, 417,000. This was inflated to 2019 USD for a total annual value of USD 478,891,356.77. Cesar and Beukering [7] estimated the value of tourism to be USD 304 million and inflating this value to 2019 USD yields a low estimate of approximately USD 442.1 million.

This estimated tourism value between USD 478,891,356.77 and 442,100,000 USD represents the direct and indirect market value of on-reef tourism to the State in 2019. Maintaining this value over time is partially contingent on maintaining the health and beauty of Hawaiʻi's reefs. The aquarium fishery may reduce this over time as fish are removed from the reefs in Scenarios A and B because the limits are not calculated based on the productivity of the fishery and are difficult to enforce. Evidence also suggests that catches are underreported. Therefore, if the fishery continues, overharvesting of this public resource will likely occur and as a result, the value of tourism will decrease. Uncertainty exists as to how quickly this decline will occur. Researchers predict that unmitigated bleaching events could lead to the loss of shallow coral cover in Hawaiʻi by the year 2050 [35], which indicates that a 30 year time frame could be considered in making marine resource management decisions and would result in an extremely large total cost of continuing this aquarium fishery by 2050.

2.1.3. Industry income

In order to determine the market value of the aquarium fishery in Hawaiʻi, the methods used by Dierking [22] were updated with recent data to conservatively estimate 2019 gross revenue for the industry. Unpublished 2019 catch report summary information, unpublished 2019 dealer purchase information, unpublished 2019 individual catch reports, and unpublished permit lists from 2015 to 2018 were obtained from DAR. The 2019 price and cost information from dealer websites, retail price lists on websites, and industry structure information provided the data used for the estimation. The lower bound for total revenue accruing to fishers was calculated by multiplying the "diver price" for each species by the number sold to estimate annual revenue of USD 1,676,982 in 2019.

Wholesale revenue could not be estimated due to the lack of price information among local fishers who are also wholesalers. In order to estimate the upper bounds, the 2016 catch report data for "number sold" was used with retail prices on the website of a Hawaiʻi based fisher retailing fish. The "number sold" on the 2016 catch report for each of 12 species was multiplied by the 2019 retail price listed by the primary collector/retailer. The total revenue across all the species represents the upper bounds of USD 8,343,896, which includes the value of the fish after they were exported.

2.1.4. License fees

The State does collect license fees for the aquarium fishery. Commercial aquarium permits are USD 50 and recreational aquarium permits have no cost [20]. Commercial aquarium collectors must also purchase USD 100 commercial marine fishing licenses annually from DAR. Scenario A, which represents the status quo in 2019 only accounts for the cost of the commercial marine fishing license since all commercial aquarium permits are void. Scenario D assumes that a permit is required to collect for captive breeding. This scenario explores an option that would raise the permit cost to USD 500 and cap the number of permits issued at 100 state-wide.

2.1.5. Export values

The industry values also include the value of fish exported, which were investigated to determine how much of this value accrues to the State. Catch reports for 2016 are the most recent, complete annual data set and thus are used to estimate exports. Twelve species commonly targeted in Hawaiʻi's marine aquarium fishery (*Table a1*, appendix) were included. The data for six out of the twelve species discussed in this study (*Naso lituratus, Forcipiger flavissimus, Chaetodon multicinctus, Zanclus cornutus, Centropyge potteri, Coris gaimard)* indicated that the fish sales on initial catch reports by licensed fishers was lower than numbers of fish reportedly purchased by licensed dealers from licensed fishers on dealer sales and export reports. This suggests that a percentage of the catch was not reported on catch reports or was sold to dealers by fishers who do not report their catch to the state.

Dierking [22], reported that roughly 95% of the aquarium fish caught from the West Hawaiʻi fishery were exported. Two criteria were used to identify retailers from which price information was obtained. The first criteria requires that the species' primary and sole collection origin had to be Hawaiʻi, and the second requires the species be one of the 12 species described in this study, not including captive bred fish. Retail prices for 2019 were collected from 11 online aquaria retailers with 10 on mainland U.S.A. and one from Hawaiʻi. Species name, price, retailer name, city of operation and website information were used to generate an average out-of-state retail price for each of the 12 species and were compared to online retail prices offered by the local aquarium fishers/retailer. Retail price differences were 1.5–5.1 times higher in mainland markets compared to the local market.

The profits made on the mainland and the taxes on the value added accrues to the area in which the fish is retailed. Since these profits and taxes occur from the sale of a Hawaiʻi public resource, a negative impact occurs in comparison to keeping the fish in the reef to ensure that the State's tourism sector and/or residents continue to benefit from these fish. This is consistent with a 2019 decision by the Hawaiʻi Supreme Court that "all public natural resources are held in trust by the State for the common benefit of Hawaiʻi's people and the generations to come" ([8], p. 1150).

2.1.6. Environmental costs

Hawaiʻi's marine aquarium fishery almost exclusively targets herbivores and corallivores. The development of a State Coral Bleaching

Table 3
Cost and benefits associated with each scenario.

Scenario	Impacted Stakeholder Groups	Annual Estimates (USD)	
		Low	High
A. Status Quo (2019)			
- State management costs	S8	-300,000.00	-500,000.00
- Tourism value	S2, S3, S8	-442,105,806.46	-478,891,356.77
+ Industry income	S4, S5	1,784,936.43	8,343,896.00
+ License fees	S8	17,400.00	17,400.00
Total valued net benefit		-440,603,470.03	-471,030,060.77
Costs/benefits not valued			
- Losses from exports	S2, S8		
- Environmental costs	S1, S2, S3, S7, S8		
- Social costs	S1, S2, S8		
- Other fisheries' indirect costs	S1, S2, S7, S8		
- Captive breeding costs	S4, S5		
B. Permitting System (2016)			
- State management costs	S8	-300,000.00	-500,000.00
- Tourism value	S2, S3, S8	-442,105,806.46	-478,891,356.77
+ Industry income	S7	1,784,936.43	8,343,896.00
+ License fees	S8	26,100.00	26,100.00
Total valued net benefit		-440,594,770.03	-471,021,360.77
Costs/benefits not valued			
- Losses from exports	S2, S8		
- Environmental costs	S1, S2, S3, S7, S8		
- Social costs	S1, S2, S8		
- Other fisheries' indirect costs	S1, S2, S7, S8		
- Captive breeding costs	S7		
C. Statewide AQ Collection Ban			
+ Tourism value	S2, S3, S8	442,105,806.46	478,891,356.77
- Industry income	S7	-1,784,936.43	-8,343,896.00
- License fees	S8	-26,100.00	-26,100.00
Total valued net benefit		440,294,770.03	470,521,360.77
Costs/benefits not valued			
+ Environmental costs	S1, S2, S3, S7, S8		
+ Social costs	S1, S2, S7, S8		
+ Other fisheries' Indirect costs	S1, S2, S8		
D. Captive Breeding Collection			
- State management costs	S8	-300,000.00	-500,000.00
- Tourism value	S2, S3, S8	-442,105,806.45	-478,891,356.77
+ Industry income	S7	1,784,936.43	8,343,896.00
+ License fees	S8	50,000.00	50,000.00
Total valued net benefit		-440,570,870.03	-470,997,460.77
Costs/benefits not valued			
- Losses from exports	S2, S8		
- Environmental costs	S1, S2, S3, S7, S8		
- Social costs	S1, S2, S7, S8		
- Other fisheries' indirect costs	S1, S2, S8		
- Captive breeding costs	S7		

Recovery Plan, in collaboration with the National Oceanic and Atmospheric Association (NOAA), DLNR, and DAR concluded that the establishment of a combination of Marine Protected Areas (MPAs) and Herbivore Fishery Management Areas (HFMAs) across the main Hawaiian Islands ranked among the most preferred actions to address the State's coral reef recovery from climate change induced bleaching events [19]. The State's decision to employ spatial herbivore management, highlights the importance of herbivores as a critical tool for reef recovery and resiliency, thus increasing their value and importance in Hawaiʻi's coral reef ecosystems.

Past studies have indicated that climate change impacts coupled with local, human-induced stressors can retard coral reef resilience, resulting in regime shifts from coral to algal turf dominated systems if left unchecked [1,8,9,26,30]. Herbivores have been found to play critical roles in resisting these regime shifts [26]. While the long-term impact of the aquarium fishery on herbivore management is uncertain, the potential exists for the fishery to prevent the State from realizing its reef recovery goals.

2.1.7. *Social costs*

A 2017 survey of Hawaiʻi residents concluded that 90% of respondents support further regulation of Hawaiʻi's marine aquarium fishery, and that 83% of respondents support ending the trade altogether [4]. From the fishers' perspective, Stevenson et al. [51] found that 20.7% of all fishers disliked the bureaucracy and 17.2% disliked the poor reputation of the West Hawaiʻi aquarium fishery.

No secondary information about the overall social impacts is available. However, the Pet Industry Joint Advisory Council [44] did summarize several interviews in a Cultural Impact Statement found in Appendix A that describes the contentious nature of the fishery and its lack of alignment with Native Hawaiian values and fishing/management views/traditions [44].

While the impact of the fishery on the long-term social well-being of State's residents is uncertain, the majority appears to conclude that continuing to operate this fishery reduces their social well-being.

2.1.8. *Indirect costs for other fisheries*

While some studies have indicated that fish populations have increased in open areas and Fish Replenishment Areas (FRAs) where no aquarium collecting occurs, other studies have argued that many marine aquarium fish stocks in Hawaiʻi are still relatively data poor [41]. The Hawaiʻi Supreme Court has adopted a precautionary principle associated with the public trust with a ruling concluding that "where (scientific) uncertainty exists, a trustee's duty to protect the resource mitigates in favour of choosing presumptions that also protect the resource" ([32], p. 466)).

Overfishing is the primary driver of reef fish declines across the main Hawaiian Islands and the populations of food-fish species that overlap with some commonly collected aquarium species are particularly affected [24]. Specific concern regarding the sustained abundance of some commonly targeted food-fish species in the West Hawaiʻi aquarium fishery exists due to some species exhibiting declining populations [57]. Concern regarding the aquarium fishery's impact on the commercial and recreational nearshore reef fisheries has arisen due to overlap in target species [46,57]. This concern supports the conclusion that the aquarium fishery is likely to have negative impacts on other fisheries in the long-run.

2.1.9. *Captive breeding costs*

Scenario D involves allowing the aquarium fishery to continue in order to support captive breeding efforts. In order for this scenario not to have negative impacts on Hawaiʻi reefs, a detailed policy and supporting regulations would be required. Descriptions of the costs paid by wholesalers and collectors by Dierking [22] can be used to infer the cost categories associated with local collection and wholesale business operations. Captive breeding and husbandry would result in similar costs

Table 4
A comparison of procedures and recommendations for the CBA to those for the 2020 Hawai'i Island EIS.

Cost Benefit Analysis	Big Island 2020 EIS[a]
Explores four policy alternatives, including a ban.	Rejected considering a ban since it did not meet PIJAC's purpose. Considered three scenarios that involved no permit limits and one with a permit limit.
Provided evidence-based recommendations based on impact estimates, descriptions, and the distribution of them among stakeholder groups.	Provided a recommendation based on direct market benefits of the industry.
Recommends a statewide ban on the collection and export of marine aquaria. Suggests that captive breeding collection might hold potential if properly managed.	Recommends reducing the number of permits to ten across the State.
Completed as a student project using existing secondary data and not funded by any industry, government agency or non-profit organization.	Funded by the PIJAC.

[a] [44]

as wild collection, along with some additional costs to accommodate more technologically advanced equipment required to stimulate spawning [40,58].

Marine ornamental species can be categorized as demersal spawners or pelagic spawners. Most demersal spawners produce clutches of eggs in nests or on substrates and tend to form strong breeding pairs, often displaying parental care which makes them the preferred choice for captive breeding aquarists [40]. The specialized knowledge and equipment required for rearing marine aquarium fish that are pelagic spawners will make them more expensive to produce compared to wild collection [49]. This increase in costs would primarily impact those that purchase these captive bred fish. Currently, nearly all of these people live outside of the State and therefore likely have no particular interest in protecting the public resources of residents. Rhyne [49] also argues that promoting access to breeding information could result in more successful ornamental rearing and help conserve populations of wild aquarium fish.

3. Results and discussion

The results indicate that Scenario C, a state-wide ban on aquarium collecting, is the only scenario that produced positive net benefits (Table 3). Because point estimates in 2019 USD were the only quantitative data presented here, this conclusion is based on one annual estimate of costs and benefits. The stakeholder groups negatively impacted by a state-wide ban include a small group of local fishers, wholesalers, and dealers that comprise Hawai'i industry while benefits accrue to larger populations of stakeholders.

The status quo policy in Scenario A would allow collection to continue with methods other than fine-mesh nets. In the WHRFMA, where all permits are now void, poaching has been observed, resulting in vessel, aquarium gear and fish take seizures [5]. Thus, monitoring costs may increase if this scenario occurs. Scenario B, which represents what took place in 2016 does not put a cap on the issuance of permits, though it does provide for the collection of fees by the State. Overall, market benefits would still accrue only to aquarium collectors and wholesalers, though the distribution of net benefits between these industry members varies between Scenarios A and B because Scenario A excludes fishers in the WHRFMA.

Scenario D allows collection for captive breeding with a permit similar to DAR's Special Activity Permit system which allows research, education or management institutions to collect marine organisms with specific gear restriction exemptions [18,21]. However, all existing permit holders can claim to be engaged in breeding. Further research may be needed to identify potential regulatory and enforcement solutions for Scenario D. Fishers could be required to prove their capacity to captive breed species and stricter live-fish export regulations could be developed. While this would increase costs, the potential indirect and non-market benefits associated with not removing fish from the reefs in the long-run would also increase and provide the positive benefits associated with consumers having access to aquarium fish. Militz et al. [38] found that 90.5% of consumer respondents were willing to pay more for fishes that were certified as harvested in an environmentally sustainable way. This type of certification could be considered for captive bred fish to create a mechanism that convinces the customers to absorb some of the costs associated with switching to a sustainable practice [38]. In addition, captive breeding facilities could become attractions for residents and visitors. If captive breeding attractions included educational content designed to inform people about protecting fish and the surrounding reefs, the carrying capacity of Hawai'i's near shore ecosystems may increase.

A comparison of this CBA with the PIJAC funded EIS found that the procedures and overall recommendations were significantly different (Table 4). Both the CBA and the EIS relied on existing data to complete the analysis and the market benefits of the industry estimated by the CBA and the EIS are similar. The EIS did not consider a ban because it did not meet PIJAC's purpose to continue fishers' livelihoods [44]. The EIS considered three scenarios that involved unlimited permits and one that limited permits on the Big Island to ten. The costs for Native Hawaiians and other stakeholder groups of continuing to operate the fishery were considered negligible and no justification is provided as to why this decision was made [44]. No recommendations on compliance enforcement relative to the proposed bag limits or oversight to prevent poaching were included. No caveat was included that oversight and enforcement expenses might increase if permits were limited [44]. One individual who was allegedly named as one of the proposed permit holders [45] was also cited in a February 2020 poaching incident (R. Umberger, personal communication; [5]) which indicates the need for such a caveat. Overall the EIS puts forth a recommendation that supports the industry.

Because Hawai'i's Supreme Court reaffirmed that all public resource are to benefit Hawai'i's people [32] and that private or commercial use should receive a "high" level of scrutiny, the size of the stakeholder groups is also of interest. The resident population, including Native Hawaiians, was 1,415,872 in 2019 [53] and Pet Industry Joint Advisory Council [44] indicates that their preferred plan would directly benefit ten resident fishers with permits and their employees. Visitors, which numbered 10,424,995 in 2019 [28], will also likely pay a cost if marine aquarium fish are removed from the State's reefs. Tourists can also decide to travel elsewhere should the reefs become degraded, which will result in significant market costs for Hawai'i in the long-term.

4. Conclusion and recommendations

The analysis presented here determined that a state-wide ban on collection is likely to produce impacts of positive annual net benefits. The EIS funded by PIJAC recommended that collection permits be limited to ensure that the fishery remains in existence. Relying on EIS recommendations that aim to support one group of stakeholders at the expense of others to determine policy could be considered biased. CBA is used globally for evidence-based decision-making.

When considering the "sustainability" of any system, distributional and equity issues over a long-time frame must be considered [10]. The CBA presented in this paper explores these distributional issues that this fishery poses to a variety of stakeholder groups and the environment using the available evidence. While modern economic systems often focus on gross domestic product to track economic progress and guide policy, tracking environmental and social indicators has been identified as important to ensure sustainability in certain economic sectors specific to Hawaiʻi [42].

Other fisheries, which pose similar environmental problems [3,11,12,25,33,34], should consider employing CBA in order to inform decision-making. Relying on an EIS funded by an industry stakeholder group is likely to produce a document aimed at justifying the position of the funder. Stakeholders that receive cultural ecosystem services from resources that are also being harvested for market benefits often include relatively large populations of disadvantaged minorities and indigenous populations. Businesses interested in protecting their market benefits likely have an advantage if an EIS is the only source of management recommendations. Sustainable management requires that the costs and benefits accruing to all stakeholder groups be investigated to ensure that policies are equitable.

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CRediT authorship contribution statement

Siena Schaar: Investigation, Formal analysis, Writing - original draft. **Linda J. Cox**: Conceptualization, Methodology, Supervision, Writing - review & editing.

Declaration of Competing Interest

none.

Data availability

The majority of data used for this research came from secondary sources. Relevant pricing data was collected from public websites and catch data was retrieved by UIPA from the Hawaiʻi Department of Aquatic Resources (DAR).

Appendix

See Tables A.1–A.3.

Table A.1
The 12 common marine aquarium species included in this report.

Common Name	Scientific Name	Hawaiian Name
Yellow Tang[b]	*Zebrasoma flavescens*	Lauʻipala, Lauī pala, or Lāʻī pala)
Goldring Surgeonfish[a]	*Ctenochaetus strigosus*	Kole
Achilles Tang[b]	*Acanthurus achilles*	Pakuʻikuʻi
Orangespine Unicornfish[b]	*Naso lituratus*	Umaumalei, Kala, Ume, Mahaha, Pakala, Pakalakala or ʻOhua
Chevron Tang[b]	*Ctenochaetus hawaiiensis*	n/a
Longnose Butterflyfish, (Forcepfish)[b]	*Forcipiger flavissimus*	Lau wiliwili nukunuku ʻoiʻoi
Multiband (Pebbled) Butterflyfish[a]	*Chaetodon multicinctus*	Kikākapu, Kapuhili
Fourspot Butterflyfish[b]	*Chaetodon quadrimaculatus*	Lauhau
Tinker's Butterflyfish[b]	*Chaetodon tinkeri*	n/a
Moorish Idol[b]	*Zanclus cornutus*	Kihikihi
Potter's Angelfish[a]	*Centropyge potteri*	n/a
Yellowtail Coris Wrasse[b]	*Coris gaimard*	Hinalea ʻakilolo

[a] Indicates endemic species
[b] Indicates native species

Table A.2
Average retail prices (U.S Mainland) compared to average retail price (local collector/seller) of 12 common aquarium species, and price difference (%).

Common Name	Scientific Name	Avg. Retail Price (U.S Mainland) n = 10	Avg. Retail Price (Local collector/ seller) n = 1	Mark-up (%)
Yellow Tang	*Zebrasoma flavescens*	$74.41	$16.00	465.1
Goldring Surgeonfish	*Ctenochaetus strigosus*	$71.88	$14.00	513.4
Achilles Tang	*Acanthurus achilles*	$392.32	$150.00	261.5
Orangespine Unicornfish	*Naso lituratus*	$152.71	$37.50	407.2
Chevron Tang	*Ctenochaetus hawaiiensis*	$233.11	$150.00	155.4
Longnose Butterflyfish	*Forcipiger flavissimus*	$46.00	$15.00	306.6
Multiband Pebbled Butterflyfish	*Chaetodon multicinctus*	$35.37	$10.00	353.7
Fourspot Butterflyfish	*Chaetodon quadrimaculatus*	$78.99	$40.00	197.5
Tinker's Butterflyfish	*Chaetodon tinkeri*	$699.99	$350.00	200.0
Moorish Idol	*Zanclus cornutus*	$49.98	$10.00	499.8
Potter's Angelfish	*Centropyge potteri*	$108.06	$30.00	360.2
Yellowtail Coris	*Coris gaimard*	n/a	$30.00	n/a

Table A.3
Comparison of specimens reported sold on licensed aquarium collectors' detailed catch reports (2016) versus specimens reported bought from licensed fishers by licensed dealers, on licensed aquarium dealers' personal sales and export reports (2016).

Common Name	Scientific Name	No. Sold (AQ detailed catch report)	No. Bought (AQ dealer pers. Sale/ export report)	% (no. bought/ no. sold)
Yellow Tang	*Zebrasoma flavescens*	322,651	284,784	88.26
Goldring Surgeonfish	*Ctenochaetus strigosus*	45,765	44,106	96.37
Achilles Tang	*Acanthurus achilles*	6787	5758	84.84
Orangespine Unicornfish[a]	*Naso lituratus*	9966	10,338	103.73
Chevron Tang	*Ctenochaetus hawaiiensis*	5126 (B.I only)	4135	80.67
Longnose Butterflyfish[a]	*Forcipiger flavissimus*	1329	1507	113.39
Multiband Pebbled Butterflyfish[a]	*Chaetodon multicinctus*	314	666	212.10
Fourspot Butterflyfish	*Chaetodon quadrimaculatus*	480	448	93.33
Tinker's Butterflyfish	*Chaetodon tinkeri*	293 (B.I only)	218	74.40
Moorish Idol[a]	*Zanclus cornutus*	805 (B.I only)	970	120.50
Potter's Angelfish[a]	*Centropyge potteri*	6708	8726	130.08
Yellowtail Coris Wrasse[a]	*Coris gaimard*	866	993	114.67

(B.I only) indicates collection and reporting on detailed catch report only from Hawaiʻi island
[a] Indicates sales or export reporting over 100% of what was reported on initial detailed catch report.

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Effects of Aquarium Collectors on Coral Reef Fishes in Kona, Hawaii

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Abstract: *No previous studies have conclusively documented the magnitude of the effect of aquarium collecting on natural populations. In Hawaii concern over the effects on reef fish populations of collecting for the aquarium trade began in the early 1970s, primarily in response to multiple-use conflicts between aquarium-fish collectors and recreational dive-tour operators. In 1997–1998 we used a paired control-impact design to estimate the effect of aquarium collectors. We compared differences in fish abundance along visual belt transects between collection sites, where collecting was known to occur, and control sites, where collecting was prohibited. To test the assumptions of our observational design, we surveyed a combination of species captured by aquarium collectors and those not captured. The extent of bleaching, broken coral, and coral cover was also surveyed. Seven of the 10 aquarium species surveyed were significantly reduced by collecting. The abundance of aquarium fish at collection sites ranged from 38% lower (*Chaetodon multicinctus*) to 75% lower (*C. quadrimaculatus*) than that at control sites. In contrast, only two of the nonaquarium species displayed a significant collection effect. There were no significant differences in damaged coral between control and collection sites to indicate the presence of destructive fishing practices. In addition, there were no increases in the abundance of macroalgae where the abundance of herbivores was reduced by aquarium collecting. Although our results suggest that aquarium collectors have a significant effect on the abundance of targeted aquarium fishes, better knowledge of the intensity and location of collecting activities is required to make a rigorous assessment of the effects of collecting on nearshore fish populations. Several lines of evidence suggest that the current system of catch reporting underestimates actual removals.*

Efectos de Colectores de Acuario sobre los Peces de Arrecifes de Coral en Kona, Hawai

Resumen: *La magnitud del efecto de la recolección para acuarios sobre poblaciones naturales no ha sido documentada concluyentemente en ningún estudio previo. La preocupación por los efectos de la recolección para el comercio de acuarios sobre las poblaciones de peces de arrecifes comenzó a principios de los años 70 en Hawai principalmente en respuesta a los conflictos de uso-múltiple entre colectores de peces para acuarios y operadores de viajes de buceo recreativo. En 1997–1998 utilizamos un diseño apareado de control de impacto para estimar el efecto de colectores de acuario. Comparamos diferencias en la abundancia de peces a lo largo de transectos visuales en sitios de recolección, donde se sabía que ocurría recolección, en relación con sitios control en los que la recolección estaba prohibida. Para probar los sopuestos de nuestro diseño observativo examinamos una combinación de especies capturadas por los colectores de acuario y otra de especies no capturadas. Se examinó también la extensión de blanqueo, coral roto y cobertura de coral. Siete de las 10 especies de acuario examinadas estaban reducidas significativamente por la recolección. Las abundancias de peces de acuario en sitios de recolección variaron de 38% menos (*Chaetodon multicinctus*) a 75% menos (*C. quadrimaculatus*) individuos que en los sitios control. En contraste, sólo dos de las especies no recolectadas para acuario mostraron un efecto significativo de recolección. No hubo diferencias significativas en el coral dañado entre los sitios control y de recolección que indiquen la presencia de prácticas pesqueras destructivas. Además, no hubo incrementos en la abundancia de microalgas donde la abundancia de herbívoros se redujo*

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por la recolección para acuarios. Aunque nuestros resultados sugieren que los colectores de acuarios tienen un efecto significativo sobre la abundancia de los peces de su interés, hace falta un mayor conocimiento de la intensidad y localización de las actividades de recolección para evaluar rigurosamente los efectos de la recolección sobre las poblaciones de peces costeros. Varias líneas de evidencia sugieren que el sistema actual de registros de captura subestima las remociones reales.

Introduction

Global trade in ornamental fishes is a major industry involving approximately 350 million fish annually with a value of $963 million (Young 1997). Although marine fishes account for only 10–20% of the total ornamental catch, rapid increases in the collection of marine species occurred in the 1980s (Andrews 1990). Moreover, whereas freshwater fishes are largely derived from cultivated stocks, <1% of marine fishes are cultivated, and the majority are taken from wild populations (Wood 2001). Almost all marine ornamental fish are of tropical origin, and many are removed from coral reefs. Because aquarium-fish collectors are highly selective and often capture large quantities of individuals of high value, the potential for overexploitation is high (Wood 1985, 2001).

Although numerous authors have discussed the potential effect of the aquarium trade on marine fishes in Australia (Whitehead et al. 1986), Djibouti (Barratt & Medley 1990), Hawaii (Taylor 1978; Walsh 1978; Randall 1987), Indonesia (Wood 1985), the Philippines (Albaladejo & Corpuz 1981), Puerto Rico (Sadovy 1992), and Sri Lanka (Edwards & Shepherd 1992), few studies have estimated the effects of collecting on natural populations. The most common approach has been to examine the rate of international trade (Lubbock & Polunin 1975; Wood 1985; Andrews 1990; Edwards & Shepherd 1992; Young 1997). Other approaches include qualitative or quantitative observations of fish densities in collected areas (Albaladejo & Corpuz 1981; Barratt & Medley 1990) or comparisons of collection rates to crude estimates of sustainable yield based on field estimates of density (Edwards & Shepherd 1992). Although Nolan (1978) concluded that aquarium collectors did not have a significant effect on natural populations in Hawaii, the results are suspect because of problems with suitable controls in the observational design. Thus, no study has conclusively documented the magnitude of aquarium collecting on natural populations, despite repeated calls for such studies to help develop sustainability in the aquarium trade (Walsh 1978; Wood 1985; Young 1997).

Many of the marine ornamentals originating from the United States are captured in Hawaii, which is known for its high-quality fishes and rare endemic species of high value (Wood 1985). Concern over the effects of aquarium collecting on reef fish populations arose in the early 1970s, principally for the Kona coast of the island of Hawaii (Taylor 1978; Walsh 1978). Controversy has centered on multiple-use conflict between aquarium-fish collectors and recreational dive-tour operators over apparent declines in nearshore reef fishes (Taylor 1978; Grigg 1997; Young 1997; Clark & Gulko 1999). These concerns prompted the Hawaii Division of Aquatic Resources (DAR) to instigate monthly collection reports from all permit holders in 1973 (Katekaru 1978), and these reports have been the primary basis for management of the aquarium industry in Hawaii (Miyasaka 1994, 1997).

Based on collection reports, about 90,000 fish, with a reported total value of $50,000, were harvested in 1973 under 75 commercial permits (Katekaru 1978). In 1995 the annual harvest had risen to 422,823 fish (total value of $844,843) under 160 commercial permits (Miyasaka 1997). Although aquarium collecting was primarily centered on the island of Oahu in the 1970s and 1980s, the Kona and Milolii areas of the island of Hawaii became the predominant collecting areas in the late 1980s and early 1990s. Between 1993 and 1995, the harvest from Kona increased 67% and accounted for 59% of the state harvest with 47 commercial permits (Miyasaka 1997).

Although 103 fish species were collected statewide in 1995, over 90% of the harvest was focused on 11 species: the Achilles tang (*Acanthurus achilles*), Potter's angelfish (*Centropyge potteri*), raccoon butterflyfish (*Chaetodon lunula*), multiband butterflyfish (*Chaetodon multicinctus*), ornate butterflyfish (*Chaetodon ornatissimus*), four-spot butterflyfish (*Chaetodon quadrimaculatus*), goldring surgeonfish (*Ctenochaetus strigosus*), longnose butterflyfish (*Forcipiger flavissimus*), clown tang (*Naso lituratus*), moorish idol (*Zanclus cornutus*), and yellow tang (*Zebrasoma flavescens*), with *Z. flavescens* accounting for 52% of the total collection (Miyasaka 1997; DAR, unpublished data). Thus, given the increasing rate of removal focused on a small number of species, the potential for overexploitation of these reef fishes is high.

In addition to the direct effects of collecting fish for the aquarium trade, there has been considerable concern about destructive practices associated with fish capture. These practices include the use of poisons and explosives to capture fish and damage to coral during collecting (Lubbock & Polunin 1975; Wood 1985, 2001; Randall 1987; Johannes & Riepen 1995; Young 1997). An additional concern is the effect on the coral reef community of large reductions in the number of herbivorous fishes, such as the yellow tang. Because herbivorous fishes may control the abundance of algae on coral reef ecosystems, their removal may cause shifts in community structure (reviewed by Hixon 1997).

Our goal was to obtain quantitative estimates of the effects of aquarium collectors on fishes on the Kona coast of Hawaii. Moreover, in response to reports of broken and bleached coral associated with destructive fishing practices, we also investigated changes in the associated coral reef habitat at each study site.

Methods

Observational Design

We used a paired control-impact design to estimate the effect of aquarium collectors on reef-fish abundance. The magnitude of the effect was estimated by comparing fish abundance at collection sites where aquarium-fish collecting was known to occur with geographically adjacent control sites where collecting was prohibited. Because the study was initiated after collection had begun, we assumed there were no differences between control and collection sites in the abundance of aquarium fishes prior to the onset of aquarium harvesting (i.e., their natural abundances were similar) (Osenberg & Schmitt 1996). We also assumed that all differences between the control and collection sites were due to aquarium-fish collecting and not other factors, such as fishing. As part of our study design, we gathered data to test these assumptions.

We established four study sites that served as two replicate control-collection pairs (Fig. 1). One pair of study sites was located at Honokohau (lat 19°40.26′N, long 156°01.82′W) and Papawai (lat 19°38.83′N, long 156°01.38′W). Papawai, a fishery management area (FMA) where collection of aquarium fishes has been prohibited since 1991 (Department of Land and Natural Resources 1996), served as our control site. Honokohau was frequented by aquarium collectors and served as a collection site. This pair of sites is hereafter referred to as the Honokohau study area. The second pair of sites was located at Red Hill North (lat 19°32.90′N, long 155°57.74′W) and Red Hill South (lat 19°30.32′N, long 155°57.17′W). Red Hill South is an FMA where the collection of aquarium fishes has been prohibited since 1991 (Department of Land and Natural Resources 1996), and it served as our control site. Red Hill North was frequented by aquarium collectors and served as a collection site. This pair of sites is hereafter referred to as the Red Hill study area.

At each study site, four permanent 50-m transect lines were established at 10- to 15-m depths by installing stainless steel eyebolts at the beginning and end points of each line. Transects served as reference lines for both the fish and coral surveys. We used a visual strip-transect search method to estimate fish abundances (Sale & Douglas 1981). A pair of divers swam side by side down either side of the transect line and counted all fishes seen within a corridor 3 m wide and extending to the surface.

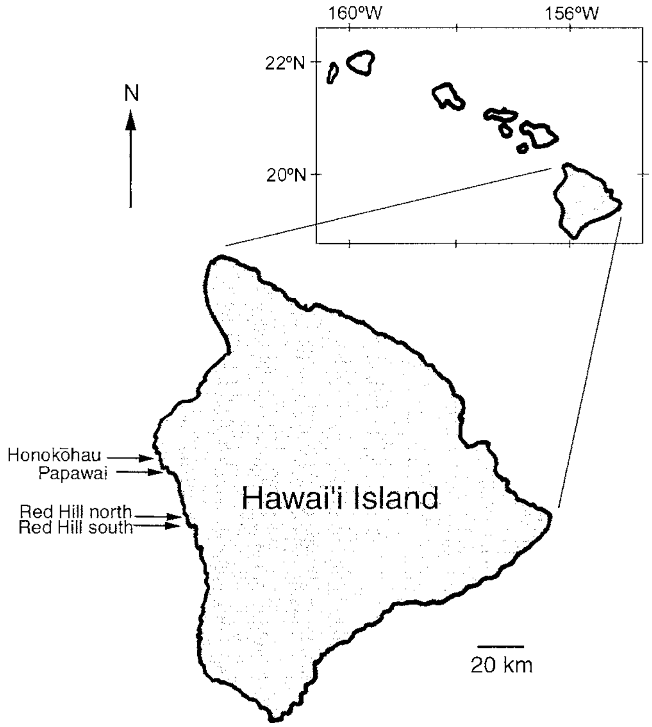

Figure 1. Map of study sites located off the island of Hawaii.

Surveys began at Honokohau in March 1997 and at Red Hill in September 1997 and ended at both areas in December 1998. All sites were sampled at 2- to 5-month intervals, for a total of eight surveys at Honokohau and five at Red Hill. During each survey we estimated the abundance of 21 fish species. These species included 11 aquarium fishes selected on the basis of high levels of capture, accounting for over 92% of the fish collected in Hawaii (DAR, unpublished data). Due to uncertainty in species identification, we pooled longnose butterflyfish as *Forcipiger* spp., which may include both *F. longirostris* and *F. flavissimus*, although most of the fish counted were probably the latter (personal observations). The remaining 10 fish species we surveyed were not targeted by aquarium collectors but were in guilds similar to those of collected species. These species were selected to provide tests of the assumptions of the observational design. Although the assumption of no difference between the control and collection sites prior to the study could not be tested directly, one prediction of this assumption was that uncollected species should not differ between control and collection sites. Accordingly, *Acanthurus nigrofuscus, A. nigroris, A. triostegus, Chaetodon lunulatus, C. unimaculatus, Paracirrhites arcatus, P. forsteri, Plectroglyphidodon johnstonianus, Stegastes fasciolatus*, and *Thalassoma duperrey* were also surveyed. The overall structure of the fish communities at control and collection sites should also be similar if the sites are ecologically similar. Thus, to test this prediction, during the next-to-last survey at each site all reef fishes seen were counted and identified to species.

Of the 21 species surveyed, 2 species (*C. lunula* and *C. unimaculatus*) were too rare for analysis, with one individual of each species observed during the entire study. These species were excluded from further analysis.

Divers were undergraduate students who had completed a rigorous coral reef monitoring course and were trained in species identification and standardized survey methodology (Hallacher & Tissot 1999). To minimize observer bias, the same diver pairs were used at each control-collection study site during each survey. Divers did, however, vary among surveys. To minimize temporal variation, all surveys were conducted during midday (generally from 0900 to 1500 hours), and both control and collection sites were surveyed either on the same day or on consecutive days.

To provide an additional test of similarities between control and collection sites and to test for destructive harvesting methods associated with aquarium collecting, we also conducted surveys on corals, macroalgae, and the general substratum of each transect. Divers took photographs of the substratum with a Nikonos V camera with a 15-mm lens attached to a PVC quadrat covering an area of approximately 0.50 m^2 (0.8×0.6 m). Along each 50-m transect line, 18 photographs were taken at randomly selected coordinates at all study sites at both the beginning and end of the study. Percent cover estimates were made of all living and nonliving substrata in each photograph by projecting the slide over a series of 50 random coordinates and recording the observed substratum under each point. In addition, the percent cover of bleached and broken coral was estimated for each slide. We identified broken coral as recently damaged coral fragments with no algal overgrowths. We identified bleached coral as unusually pale portions of the coral colony located at the tips or edges of coral colonies. To minimize observer bias, a single observer analyzed all the photographic data.

Data Analysis

We analyzed fish data with two-way repeated-measure analysis of variance (ANOVA). Fixed factors included control and collection study sites ("effect"), replicate study areas (Honokohau and Red Hill or "area"), and the interaction between effect and area. Although each survey provided an estimate of the level of collection through control-collection differences, because the same individual fish may have been counted between surveys, surveys were treated as a random, repeated measure in the analysis (Zar 1996). A significant "collection" effect indicates a similar difference between control and collection sites at both study areas. A significant "collection-area" effect indicates a difference between control and collection sites that varies between study areas. A significant "area" effect indicates spatial differences in abundance among study areas. Because our goal was to obtain estimates of the magnitude of collection effects, only factors associated with a significant collection effect were interpreted (e.g., only collection or collection-area interactions, not temporal variation).

We calculated the percent difference in abundance as the difference between control and collection sites using the formula

$$\text{percent difference} = \frac{D_{\text{collection}} - D_{\text{control}} \times 100}{D_{\text{control}}},$$

where D is density expressed as number of individuals per 100 m^2. Thus, a negative percent difference associated with a significant collection effect indicates the presence of significantly fewer fish at collection sites than at control sites, whereas a positive value indicates the opposite.

We analyzed coral cover, bleaching, and breakage data with a three-way ANOVA, with effect, area, and time (beginning of study vs. end of study) as fixed factors. Data from photoquadrats along transects were treated as a random nested factor.

Prior to all analyses, we examined data for homogeneity of sample variances. We used transformed data in cases where the original data demonstrated heteroscedasticity. We did not examine normality because samples were small ($n = 4$) and normality is not an important assumption for ANOVA (Box 1953). Following ANOVA, we used the procedure described by Underwood (1997) to pool nonsignificant factors.

We used species richness (S), evenness (J), and the Shannon-Wiener composite diversity index (H') to examine overall fish and coral-algal-substratum community structure. We compared community structures by using the percent similarity index (Krebs 1986). These indices tested the prediction that the overall structure of the fish and coral-algal-substratum communities at control and collection sites would be similar.

Results

There was a significant difference in the abundance of aquarium fishes between control and collection sites but no differences in the abundance of nonaquarium species between these sites (Table 1, Fig. 2). Seven of the 10 aquarium species displayed a significant collection effect in the two-way repeated-measure ANOVA. In contrast, only two of the nine nonaquarium species, *P. arcatus* and *S. fasciolatus,* displayed a significant collection effect (Table 1, Figs. 3 & 4).

Of the 10 aquarium species, three exhibited a significant collection-only effect (Fig. 3). All of these species

Table 1. Mean (SE) percent change in fish abundance between sites with aquarium-fish collection and without aquarium-fish collection for each study area.

		Percent change[a]								
		overall		*Honokohau*		*Red Hill*		p^b		
Species	*df*	*mean*	*SE*	*mean*	*SE*	*mean*	*SE*	*effect (E)*	*area (A)*	*E ∗ A*
Aquarium species										
Chaetodontidae										
Chaetodon multicinctus	1,88	−38.2	6.57	−42.0	9.05	−32.3	9.63	0.02	–	–
Chaetodon ornatissimus	1,88	−39.5	20.2	−37.0	25.8	−43.4	36.4	–	<0.01	–
Chaetodon quadrimaculatus	1,87	–	–	−94.4	4.81	21.8	94.7	0.01	<0.01	–
Forcipiger spp.	1,86	–	–	−60.9	6.20	−43.6	19.5	0.01	<0.01	0.01
Pomacanthidae										
Centropyge potteri	1,87	–	–	−29.2	15.8	−73.1	12.3	0.03	<0.01	–
Acanthuridae										
Acanthurus achilles	1,88	−57.1	10.2	−64.0	13.3	−46.0	16.3	<0.01	–	–
Ctenochaetus strigosus	1,88	−14.7	8.20	−33.6	4.96	15.4	9.65	–	–	–
Naso lituratus	1,88	31.2	34.2	66.5	50.8	−25.2	25.1	–	–	–
Zebrasoma flavescens	1,87	–	–	−49.8	6.89	−43.2	6.47	<0.01	<0.01	–
Zanclidae										
Zanclus cornutus	1,88	−46.5	11.9	−45.9	16.1	−47.5	19.2	<0.01	–	–
Nonaquarium species										
Cirrhitidae										
Paracirrhites arcatus	1,86	–	–	−12.1	14.1	−75.3	3.16	<0.01	<0.01	<0.01
Paracirrhites forsteri	1,88	58.4	59.3	168.3	85.7	−73.6	14.5	–	–	–
Chaetodontidae										
Chaetodon lunulatus	1,88	−70.0	10.4	−70.0	10.4	–	–	–	–	–
Pomacentridae										
Plectroglyphidodon johnstonianus	1,88	−31.3	12.6	−12.1	15.2	−61.9	14.2	–	–	–
Stegastes fasciolatus	1,87	–	–	488	281	50.0	22.4	0.04	<0.01	
Labridae										
Thallasoma duperrey	1,88	17.4	12.4	31.6	17.0	−5.3	13.2	–	–	–
Acanthuridae										
Acanthurus nigrofuscus	1,87	27.3	22.8	15.2	26.7	46.7	43.5	–	<0.01	–
Acanthurus nigroris	1,88	67.2	63.6	−18.0	36.7	186.5	140.0	–	–	–
Acanthurus triostegus	1,88	−4.26	20.8	−5.68	32.4	<0.10	<0.10	–	–	–

[a] *A negative mean percent change indicates fewer individuals at effect relative to control sites.*
[b] *The* p *values and degrees of freedom (df) are reported for a two-way repeated-measure ANOVA on density.*

displayed a similar significant difference between control and collection sites at both study areas in which individuals were significantly more abundant at the control sites. These species, and the magnitude of their overall percent difference at collection sites, were as follows: *A. achilles,* −57%; *C. multicinctus,* −38%; and *Z. cornutus,* −47% (Table 1). (The negative percent indicates fewer individuals at collection than at control sites.)

Four species exhibited a significant collection and area effect (Table 1; Fig. 4). These species displayed significant differences between control and collection sites, but their overall abundance varied between study areas. Both *C. potteri* and *S. fasciolatus* were more abundant at Honokohau than at Red Hill, whereas *C. quadrimaculatus* and *Z. flavescens* were more abundant at Red Hill than at Honokohau (Fig. 4). The magnitude of their overall percent difference (in parentheses) at collection sites were as follows: aquarium species: *C. potteri,* −56%; *C. quadrimaculatus,* −75%; *Z. flavescens,* −46%; nonaquarium species: *S. fasciolatus,* +64% (Table 1).

Two species exhibited a significant collection-area interaction effect, where differences between control and collection sites varied between study areas (Table 1; Fig. 4). In the aquarium species *Forcipiger* spp., percent difference was greater at Honokohau (−61%) than at Red Hill (−44%). In contrast, the nonaquarium species *P. arcatus* displayed a lower percent difference at Honokohau (−18%) than at Red Hill (−75%) (Table 1; Fig. 4).

The overall fish community structure of the paired control and collection sites was remarkably similar. The H' diversity index at control and collection sites, respectively, was 1.18 and 1.16 at Honokohau and 1.16 and 1.17 at Red Hill. Similarly, the evenness index at control and collection sites, respectively, was 0.72 and 0.69 at Honokohau and 0.69 and 0.69 at Red Hill. At Honokohau, 44 species were seen at the control site, whereas 48 species were seen at the collection site. Forty-nine species were observed at both control and collection sites at Red Hill. Overall fish densities were 27% higher at Red Hill (mean density = 146 fish/100 m^2) than at Honokohau

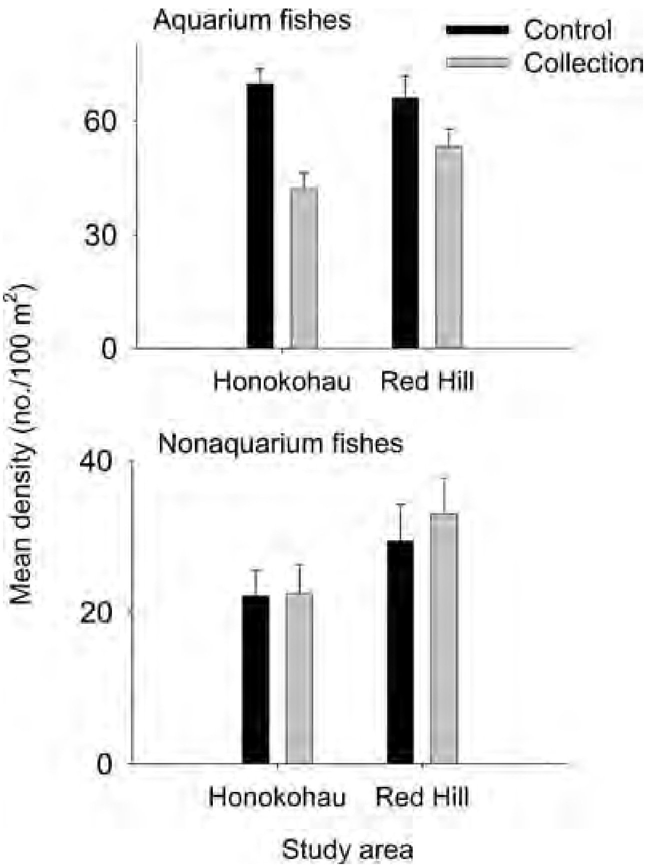

Figure 2. Mean fish density (±1 SE) for pooled aquarium and nonaquarium species at control and collection sites in both study areas.

(107 fish/100 m^2). Accordingly, control-collection pairs exhibited higher percent similarity (0.85–0.88) than that among study areas (0.75).

Live coral cover was significantly different between control and collection sites and between initial and final surveys, and there was a significant collection-survey interaction (all $p < 0.05$; df = 1,566; Fig. 5). Coral cover at all sites increased an average of 2.8% per year and was similar at both Honokohau sites but higher at the collection than at the control site at Red Hill. At Red Hill, coral cover increased 4.6% at the collection site and 2.3% at the control site (Fig. 5).

The amount of bleached coral was significantly different among areas ($p < 0.01$; df = 1,561): mean cover of bleached coral was 2.8% at Honokohau and 4.6% at Red Hill (Fig. 5). No other factors or interactions were significant. The percent cover of broken coral exhibited a significant difference among surveys ($p = 0.01$, df = 1,559): the mean cover of broken coral was 12% at the beginning of the study and 17% at the end (Fig. 5). No other factors or interactions were significant.

The abundance of macroalgae was low at all sites. No macroalgae was seen in the photoquadrats at Honokohau, and cover was <0.01% at the Red Hill sites. In contrast, coralline algae was fairly common at all sites.

The overall coral-substratum community structure of paired control and collection sites was similar. Species diversity, evenness, and richness were similar at all sites, and control-collection pairs exhibited higher percent similarity in community structure (79–82%) than that among study areas (63%).

Discussion

Seven of the 10 fishes targeted by the aquarium trade were significantly lower in abundance in areas subjected to collecting than in areas where collecting was prohibited. The magnitude of these differences ranged from −38% for *C. multicinctus* to −75% in *C. quadrimaculatus*. In contrast, only two of the nine nontarget species were significantly less abundant in collecting than in control areas, bolstering the conclusion that aquarium collectors have significant effects on the abundance of targeted fishes on the Kona coast of Hawaii.

Evaluation of Assumptions

The most critical assumption made when estimating the effects of differences between control and collection sites is that the parameter of interest is similar at both sites prior to the effect (Osenberg & Schmitt 1996). Otherwise, spatial variation in initial abundance can confound control-effect differences. For example, Nolan's (1978) study on aquarium collectors compared a collection site from the Kona area to a control, or "seldom-collected" site about 30 km away in north Kohala. His conclusion that collectors have no significant effect on abundance was based on finding a greater number of aquarium fishes at the collection site than at the control site. However, given the large distance between control and collection sites and the fact that aquarium collectors operated at both sites, this conclusion is unwarranted because of the high potential for confounding spatial variation with potential human effects.

Pairs of geographically adjacent sites minimize spatial variation, but this potential problem remains for all control-effect designs if there are no data prior to the onset of the effect (Osenberg & Schmitt 1996). Although the assumption of no prior differences cannot be tested explicitly, it can be inferred from several lines of evidence, including examination of spatial variation in fishes that are ecologically similar but not subjected to collecting and comparisons among the habitat of both sites. To evaluate this assumption, we used a combination of nontarget species that were ecologically similar to target species, species that were indicators of particular habitats, and examination of the coral habitat.

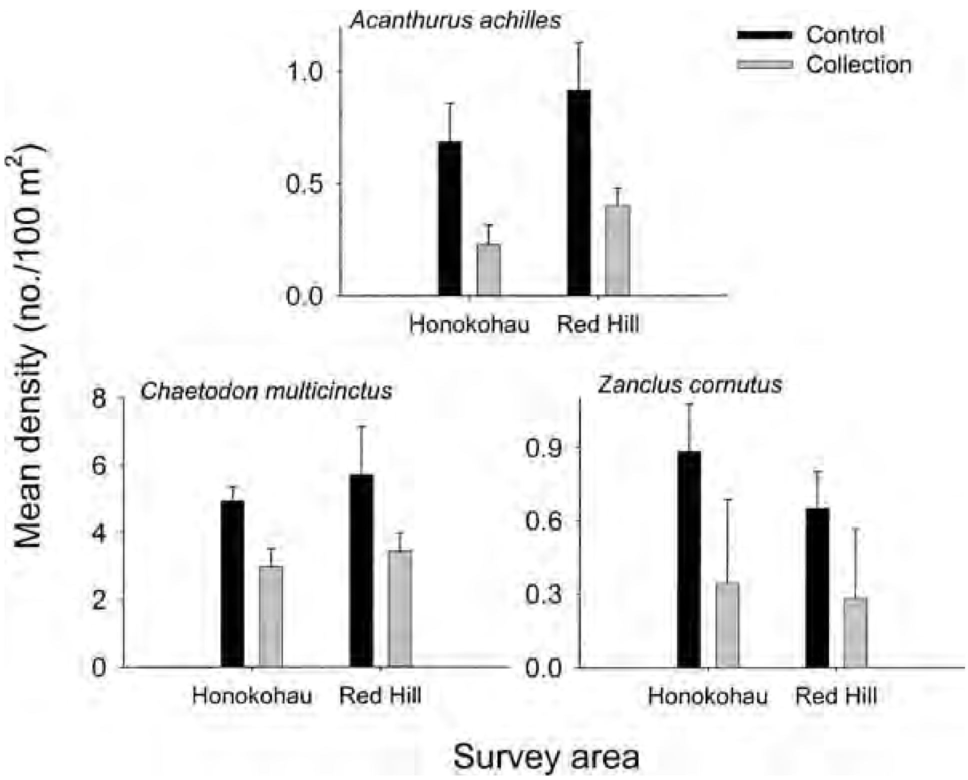

Figure 3. Mean fish density (±1 SE) for aquarium species that displayed significant collection-only effects. These three species are targeted by collectors of aquarium fish.

For example, the nontarget brown surgeonfish (*A. nigrofuscus*) and the targeted yellow tang (*Z. flavescens*) are both generalized herbivores that feed on filamentous algae, occupy the same depth ranges and habitats, and exhibit similar patterns of spawning and larval recruitment (Randall 1985; Walsh 1987; Lobel 1989). Yellow tangs were 47% less abundant at collection than at control sites, whereas brown surgeonfish did not differ significantly between the sites. Similarly, no differences were observed between control and effect sites among species that feed or live in close association with coral (*C. lunulatus, P. johnstonianus*), whereas their targeted counterparts (*C. multicinctus, C. ornatissimus, C. quadrimaculatus)* exhibited significantly lower abundances at effect sites. Moreover, nontarget species with generalized diets and distributions across the reef (*A. nigroris*, *A. triostegus*, *P. forsteri, S. fasciolatus, T. duperrey*) also did not vary, whereas ecologically similar aquarium species (*A. achilles*, *C. potteri*, *Z. cornutus*) were significantly different.

An additional line of evidence supporting the assumptions of our observational design is that the overall fish community structure of control and collection sites was remarkably similar in species diversity, richness, and evenness, with the percent similarity index ranging from 85% to 88%. At the habitat level, control and effect sites were also similar with respect to the diversity of coral, algae, and nonliving substratum composition, with percent similarity ranging from 79 to 82%. Thus, at several levels there was considerable support for the assumption that the reef communities were similar at both control and effect sites.

Another important assumption is that differences in abundance between control and effect sites were due to aquarium-fish collecting and not other processes that selectively affect these species, such as fishing. We addressed this assumption by selecting collection sites largely inaccessible from shore, thereby minimizing the effects of shore-based fishing. Moreover, both the aquarium fish *C. strigosis* and the nontarget species *A. triostegus* are commercially and recreationally fished in Hawaii. However, *A. triostegus* did not vary significantly between control and effect sites, indicating that fishing impacts were not significantly different in these areas.

Illegal collecting at control sites would also confound control-effect differences. Although some illegal collecting may be occurring in Kona, it is probably uncommon and unlikely to have a significant effect on fish abundances in existing protected areas (W. Walsh, personal communication). Thus, the only clear difference between the control and effect sites in this study was aquarium-fish collecting, as evidenced by the significantly lower abundance of aquarium species at the collection sites.

Indirect Effects of Aquarium Collecting

Destructive practices associated with the collection of fish are common and include breaking coral to capture

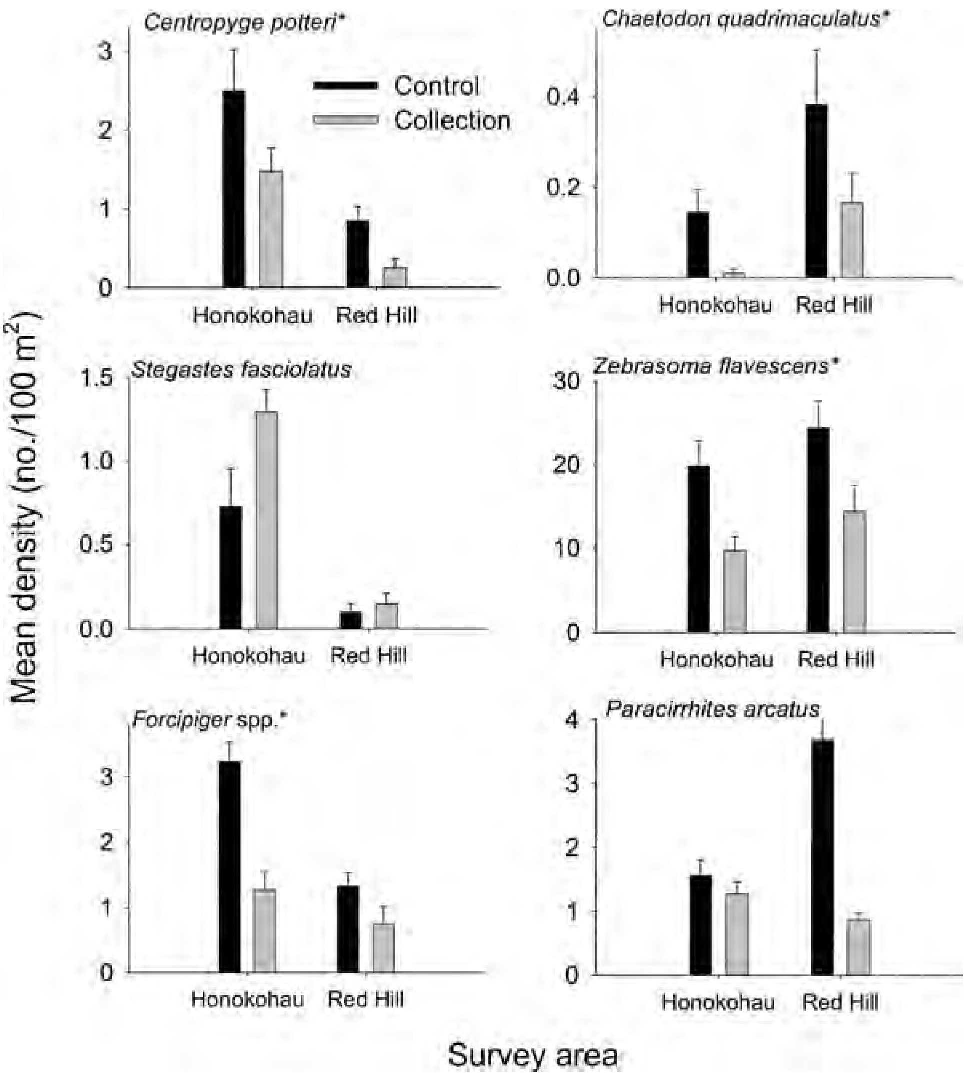

Figure 4. Mean fish density (±1 SE) for aquarium and nonaquarium species that displayed significant collection, area, or collection-area interaction effects. Species targeted by aquarium collectors are indicated with an asterisk (∗).

live animals, snagging nets on coral, and using bleach and cyanide to stun target species (Randall 1987; Johannes & Riepen 1995; Wood 2001). Both the breaking of coral and the use of bleach to collect aquarium fish have been observed in Hawaii, although they are prohibited by law (W. Walsh, personal communication). We examined differences in coral cover and the incidence of broken and bleached coral as indicators of these effects. Although some differences were noted in the extent of bleaching and coral cover among study areas, there were neither consistent nor significant differences between control and effect sites that would indicate the presence of destructive fishing practices.

An issue of more general interest is the extent to which large-scale removal of herbivorous fishes can alter reef community structure. Four of the aquarium fishes (*A. achilles, C. potteri, N. lituratus, Z. flavescens*) accounted for 61% of the herbivorous fishes at the Honokohau and Red Hill control sites. These species were reduced in overall mean abundance by 32% at the effect sites relative to the control sites. Given that herbivorous grazers control algal populations that can overgrow corals (review by Hixon 1997), it is of interest to examine the community structure in areas where herbivory is reduced. Macroalgae were rare at all study sites, suggesting that reductions in herbivory associated with aquarium-fish collecting did not have a significant effect on this group of algae. However, our study may not be a good test of this hypothesis for several reasons. First, based on the model of Littler and Littler (1984), algae may be limited more by nutrients than herbivores. Second, with the exception of *N. lituratus*, the herbivorous aquarium fishes fed primarily on filamentous algae, not macroalgae. Filamentous algae are not easily surveyed by our photographic methods, so we collected no data on their abundance. Lastly, other reef herbivores, such as sea urchins, may control macroalgal populations, so reductions due to aquarium collecting may not be functionally significant. Given the global scope of aquarium harvesting on coral reefs, this question warrants further investigation.

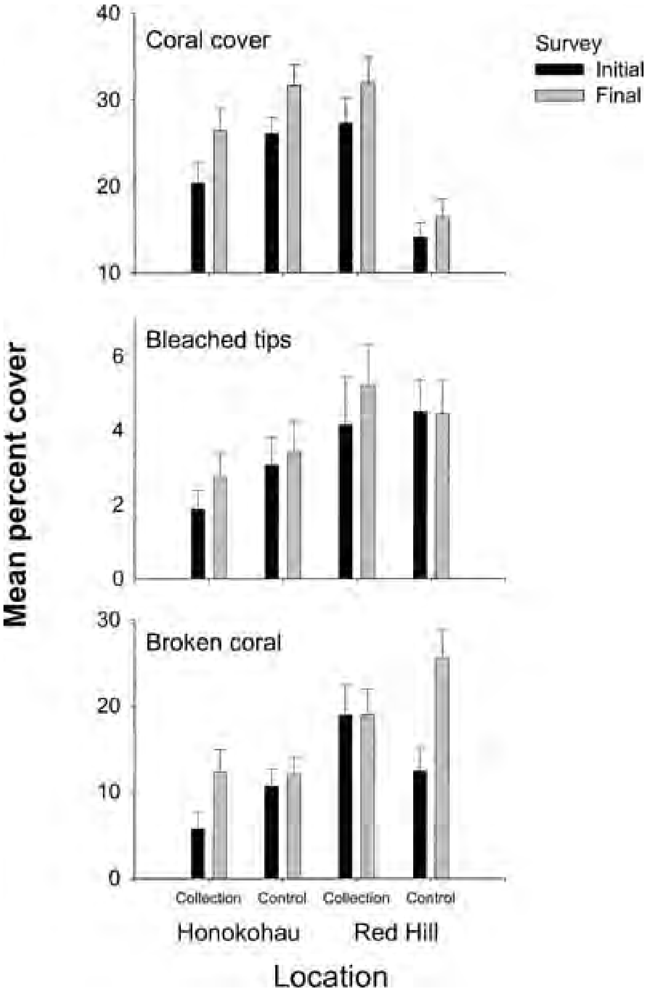

Figure 5. Changes in the mean percent (±1 SE) coral cover, bleached coral, and percent broken coral at control and collection sites in each study area at the beginning and end of the study.

Implications for Fishery Management

Aquarium collectors had significant effects on 7 of the 10 species of reef fish we examined. To determine whether these abundance patterns were clearly due to aquarium fish collecting will require better knowledge of the intensity and location of collecting activities. Although there are currently about 50 permits issued to collectors in western Hawaii, the number of active collectors is likely to be lower (W. Walsh, personal communication). The current system of catch reporting in Hawaii is limited to monthly collecting reports, with the 235-km coastline of western Hawaii divided into three large sections (Miyasaka 1997). Moreover, because these reports are not compared with actual catches, there is no assurance that the reports are accurate. Analysis of the current catch reports indicates that a significant portion of the monthly reports are not filed, although collectors are required to file a report even if no fish are collected (W. Walsh, personal communication). More specific information about location, catch, and effort are essential to support the results of this study. Moreover, random monitoring of collectors' catch reports would provide some level of quality assurance for these data.

We focused on major targeted species and did not collect data on rare species. Of the 103 species collected statewide, many are considered uncommon or rare and could also be threatened by overexploitation. For example, based on 1994–1995 collection reports, 204 Tinker's butterflyfish (*Chaetodon tinkeri*), a rare, deep-water species, were collected in western Hawaii and may possibly be overcollected. Other rare aquarium species, such as the Hawaiian turkeyfish (*Pterois sphex*) and the flame angelfish (*Centropyge loricula*), are also of concern and should be considered in future monitoring and management plans.

The magnitude and extent of the effects we documented and their relationship to the sustainability of aquarium collecting are problematic but warrant further investigation. In response to continued public outcry over the collection of aquarium fish, the Hawaii state legislature passed a bill in 1998 that focused on improving management of reef resources by establishing the West Hawaii Regional Fishery Management Area. A major component of the bill is to improve management of the aquarium industry by declaring a minimum of 30% of the western Hawaii coastline as fish replenishment areas (FRAs), protected areas where aquarium-fish collecting is prohibited. Based largely on input from the West Hawaii Fisheries Council, a community-based group of individuals, a network of nine FRAs was established in January 2000 as part of a plan to manage the aquarium industry. Current efforts are focused on monitoring these areas to evaluate the effectiveness of the reserve network as a fishery management tool.

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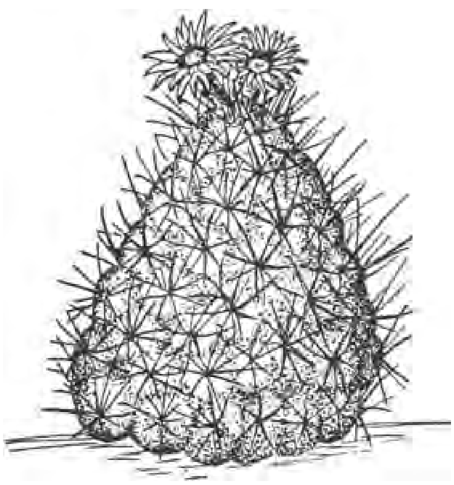

Evaluating Effectiveness of a Marine Protected Area Network in West Hawai'i to Increase Productivity of an Aquarium Fishery[1]

Brian N. Tissot,[2] William J. Walsh,[3] and Leon E. Hallacher[4]

Abstract: A network of nine Fish Replenishment Areas (FRAs) was established in West Hawai'i in 2000 in response to declines of reef fishes taken by aquarium collectors. In 1999, we established 23 study sites in FRAs, areas open to collectors, and reference areas (existing protected areas) to collect data both before and after the closure of the FRA network in 2000. To date we have conducted 23 bimonthly fish surveys as well as surveys of the benthic habitats of all sites. Baseline surveys, done before FRA closure, document significant effects of aquarium collector harvesting on selected fishes. On average, aquarium fishes were 26% less abundant in newly established FRAs (formerly open) than in adjacent reference areas. Analysis of postclosure surveys in 2000–2002 using a Before-After-Control-Impact procedure provided evidence of a significant increase in two of the 10 species examined, including the yellow tang (*Zebrasoma flavescens*), the most collected aquarium fish in Hawai'i. The recovery of yellow tangs to preexploitation levels in the FRAs was probably due to the high number of newly recruited fishes observed in 2001–2002. Large recruitment events are rare in West Hawai'i but are likely to be an important factor determining the effectiveness of Marine Protected Areas to help replenish depleted fish populations.

Coral reefs are diverse and productive biological communities that provide important natural resources in tropical areas. However, reefs in many parts of the world currently are being threatened with a wide variety of anthropogenic disturbances (Richmond 1993). On the island of Hawai'i, excessive harvesting by the aquarium trade is a major source of overfishing that warrants improved resource management (Grigg 1997, Clark and Gulko 1999, Tissot and Hallacher 2003). This project addresses the implementation and evaluation of a fishery management plan on the island of Hawai'i (Act 306 of 1998) focused on aquarium fish collecting using a network of Marine Protected Areas (MPAs).

MPAs are currently of wide national and international interest (Allison et al. 1998, Bohnsack 1998, Murray et al. 1999). However, very few studies of MPAs are replicated (e.g., have more than one protected area) or have statistically rigorous monitoring programs with data collected both before and after closure (Murray et al. 1999). This project represents a unique opportunity both to investigate the effectiveness of MPAs in fishery management and to provide an assessment of aquarium fish collecting effects on the island of Hawai'i that builds on earlier work (Tissot and Hallacher 2003).

The aquarium collecting industry in Hawai'i has had a long, contentious history. As early as 1973, public concern over collecting activities was first addressed by the Hawai'i Division of Aquatic Resources (DAR) by requiring monthly collection reports. However, the industry has been largely unregulated

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since then despite dramatic increases in the number of both issued collecting permits and collected fishes. Further, increases in fish collecting combined with growing public perception of dwindling fish stocks eventually developed into a severe multiple-use conflict between fish collectors and the dive tour industry.

In response to declines in reef fishes due to aquarium collectors, the Hawai'i State Legislature, through Act 306, created the West Hawai'i Regional Fishery Management Area in 1998 to improve management of fishery resources. One of the requirements of Act 306 mandates that DAR declare a minimum of 30% of the West Hawai'i coastline as Fish Replenishment Areas (FRAs), MPAs where aquarium fish collecting is prohibited. The Act also called for substantive involvement of the community in resource management decisions. In 1998, the West Hawai'i Fisheries Council, a community-based group of individuals, proposed nine FRAs along the West Hawai'i coastline that collectively prohibited aquarium fish collecting along 35% of the coast when combined with existing protected areas. The proposed management plan received 93% support at a public hearing, was subsequently approved by the Governor, and the FRAs were officially closed to aquarium collectors on 1 January 2000.

Our principal purpose in this paper is to provide a broad evaluation of the effectiveness of the nine FRAs to increase the productivity of aquarium fishery resources. Specifically, our goals in this paper are (1) to evaluate the general effectiveness of the MPA network by comparing fish abundances among reference, open, and FRA study sites before and after FRA closure; (2) to estimate the effects of aquarium fish collecting both in and outside of FRAs in West Hawai'i; and (3) to generate hypotheses on mechanisms that influence FRA effectiveness. A paper analyzing the effectiveness of individual FRAs will be published elsewhere.

MATERIALS AND METHODS

Our observational design compared FRA study sites before and after closure with sites that remained open to aquarium fish collecting (open sites) and those that were not subjected to aquarium fish collecting (reference sites). Reference sites included Marine Life Conservation Districts (MLCDs) and Fishery Management Areas (FMAs), both of which prohibit aquarium fish collecting, along with other activities. A total of 23 study sites was selected in early 1999. The sites were established in six existing reference areas, in eight open areas adjacent to FRAs, and in all nine of the FRAs (Figure 1, Table 1).

Study sites were selected within an area of suitable habitat and depth using a procedure that attempted to minimize among-site habitat variability yet selected unbiased locations within an area. A diver was towed behind a slow-moving vessel in the area of interest (open, FRA, or reference) to search for areas suitable as study sites. Criteria for acceptable sites included a substratum with abundant finger coral (*Porites compressa*) at 10- to 18-m depths. Finger coral is an important habitat for juvenile aquarium fishes, particularly the yellow tang, *Zebrasoma flavescens*, and typically dominates most areas of the West Hawai'i coast at 10- to 18-m depths except along exposed headlands and on recent lava flows (Grigg and Maragos 1974, Dollar 1982). Within an area of suitable habitat and depth a float with an attached weight was haphazardly thrown off a moving vessel and the ocean-side center transect pin was established at the coral colony nearest to the weight on the bottom. Using five additional stainless-steel bolts cemented into the bottom, we established four permanent 25-m transects in an H-shaped pattern at each of the study sites. During field surveys, study sites were located by differential global positioning system (GPS), and the transect lines were deployed between the eyebolts.

Survey Methods

We used a quantitative video sampling method to monitor benthic habitats at each study site (Aronson et al. 1994, Carleton and Done 1995). To ensure consistency with other coral reef survey methods used in the state of Hawai'i, we developed our design in

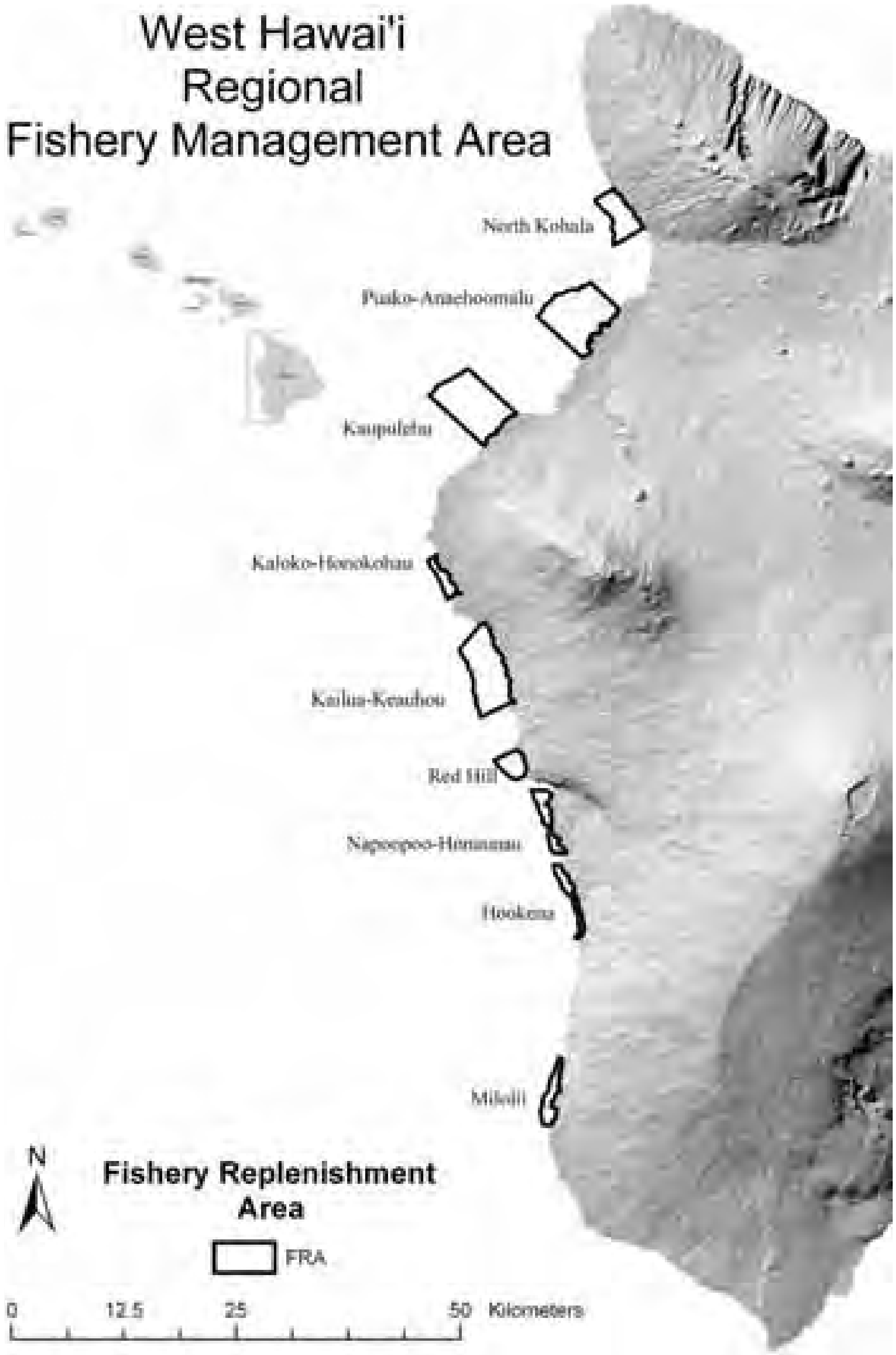

Figure 1. Locations of Fishery Replenishment Areas (FRAs) established in the West Hawai‘i Regional Fishery Management Area.

TABLE 1

Descriptions of Study Sites Established in the West Hawai‘i Regional Fishery Management Area in Relation to Observational Design Assignments

Site	Status[a]	Protected Activities at Site	Depth Range (m)
North Kohala			
1. Lapakahi	MLCD	No fishing, taking, or injuring of any type of marine life is permitted	10–15
2. Kamilo	Open	No restrictions	13–15
3. Waiaka‘īlio Bay	FRA	No taking of aquatic life for aquarium purposes or to engage in fish feeding	12–14
Puakō-‘Anaeho‘omalu			
4. Puakō	FMA	Prohibited to possess or use any type of net except throw net	9–10
5. ‘Anaeho‘omalu	FRA	No taking of aquatic life for aquarium purposes or to engage in fish feeding	10–11
6. Keawaiki	Open	No restrictions	11–15
Ka‘ūpūlehu			
7. Ka‘ūpūlehu	FRA	No taking of aquatic life for aquarium purposes or to engage in fish feeding	13
8. Makalawena	Open	No restrictions	10–11
Kaloko-Honokōhau			
9. Wāwāloli Beach	Open	No restrictions	10
10. Wāwāloli	FMA	No taking of aquatic life for aquarium purposes or to engage in fish feeding, except for ‘ōpelu fishing	12–15
11. Honokōhau	FRA	No taking of aquatic life for aquarium purposes or to engage in fish feeding	12–14
Kailua-Keauhou			
13. Papawai	FMA	No taking of aquatic life for aquarium purposes or to engage in fish feeding, except for ‘ōpelu fishing	9–13
14. S. Ōneo Bay	FRA	No taking of aquatic life for aquarium purposes or to engage in fish feeding	10–14
Red Hill			
15. N. Keauhou	FRA	No taking of aquatic life for aquarium purposes or to engage in fish feeding	9–12
16. Kualanui Point	Open	No restrictions	9–13
17. Red Hill	FMA	No taking of aquatic life for aquarium purposes or to engage in fish feeding except for ‘ōpelu fishing	12–15
Nāpō‘opo‘o-Hōnaunau			
18. Keōpuka	Open	No restrictions	9–14
19. Kealakekua Bay	MLCD	No fishing, taking or injuring of any type of marine life is permitted	6–11
20. Ke‘ei	FRA	No taking of aquatic life for aquarium purposes or to engage in fish feeding	9–15
Ho‘okena			
21. Ho‘okena (Kalāhiki)	FRA	No taking of aquatic life for aquarium purposes or to engage in fish feeding	9–12
22. Ho‘okena (‘Au‘au)	Open	No restrictions	11–15
Miloli‘i			
23. Miloli‘i (Omoka‘a)	FRA	No taking of aquatic life for aquarium purposes or to engage in fish feeding	10–15
24. Miloli‘i (Manukā)	Open	No restrictions	10–15

[a] Protection status: MLCD, Marine Life Conservation District; FMA, Fishery Management Area; FRA, Fishery Replenishment Area; Open, areas open to aquarium harvesting.

cooperation with the Hawai‘i Coral Reef Assessment and Monitoring Program (CRAMP) to estimate the abundance, diversity, and distribution of benthic habitats (see Brown et al. [2004], this volume).

The abundance of coral, nonliving substrates, and macroalgae was estimated at each site using a digital video camera (Sony DCR-TRV900) in an underwater housing (Amphibico). In the laboratory, individual contiguous still frames from each transect were extracted from each video and archived on CD-ROM. Percentage cover estimates of substrate types were then obtained using the program PointCount ’99 (P. Dustin, pers. comm.). PointCount projects a series of random dots on each image. An observer then identified the substratum type under each point. Abundance estimates of different substrate types were derived by examining the number of 50 points contacting each substrate within each video frame. Although as many as 40 frames were archived from some transects, we randomly selected 20 frames from each transect because this was a sufficient number of frames to detect a 10% change in mean coral cover between two surveys ($\alpha = \beta = 0.10$). For this paper, habitat data were analyzed to test the assumption of our observational design that habitat variation was similar among FRA, reference, and open areas.

Survey methods were developed specifically for the monitoring of fishes and benthic substrates in West Hawai‘i. Fishes were surveyed using visual strip transects, which have been shown to be highly repeatable and reasonably accurate (Brock 1954, Sale 1980). Because strip transect counts are known to be biased by different observers (e.g., McCormick and Choat 1987), we created a transect design that would allow us to survey a single reference, FRA, and open area on a single day with the same set of observers. Thus, our transect design was constrained around a maximum total daily bottom time of 2.5 hr, or about 50 min per site. Other considerations that influenced our design were the variability of abundance estimates, the number of species sampled, and the statistical power to detect meaningful changes in fish abundance (Mapstone 1996).

Pilot studies on the design of optimal transect length and number were conducted at Māhukona, Hawai‘i, during the final survey of the QUEST coral reef monitoring workshop in 1995, 1996, and 1997 (Hallacher and Tissot 1999). Each year, four 50-m transects were established at 7-m and 15-m depths and all fishes were counted at 10-m intervals along transects by a pair of divers. Sequential 10-m segments of each transect were then pooled to examine the effects of various transect lengths on abundance estimates.

Based on species accumulation curves the number of different fish species observed along transects increased with transect length and number (Figure 2*A*). The number of species seen increased dramatically from 10- to 20-m transects, with smaller increases among 20-, 30-, 40-, and 50-m transect lengths. Based on these results, longer transects are likely to sample more species, although there did not appear to be much difference between results from 40- and 50-m transect lengths. In contrast, mean estimates of a common (yellow tang) and uncommon (*Chaetodon quadrimaculatus*) aquarium fish did not vary strongly with transect length, nor was there marked variation in the standard error of the estimate (Figure 2*B*). Thus, accuracy and precision did not appear to vary with transect length. Based on these two results, and the previously mentioned time constraints, we used a design that maximized the number of transects we could reasonably sample with two pairs of divers at a single site in 50 min: four 25-m transects. Based on previous experience sampling coral reef fishes in Hawai‘i we selected a transect width of 2 m, which has been shown to produce reasonably precise estimates of fish abundance in other areas (Sale and Sharp 1983, Cheal and Thompson 1997).

Power analysis of preliminary fish transect data indicated that our observational design would detect 10–160% changes in the abundance of the principal targeted aquarium fishes in West Hawai‘i during the first year using reasonable error rates ($\alpha = \beta = 0.10$; see Mapstone 1996). Power analyses were based on the ability of a two-sample *t*-test to detect significant differences between two

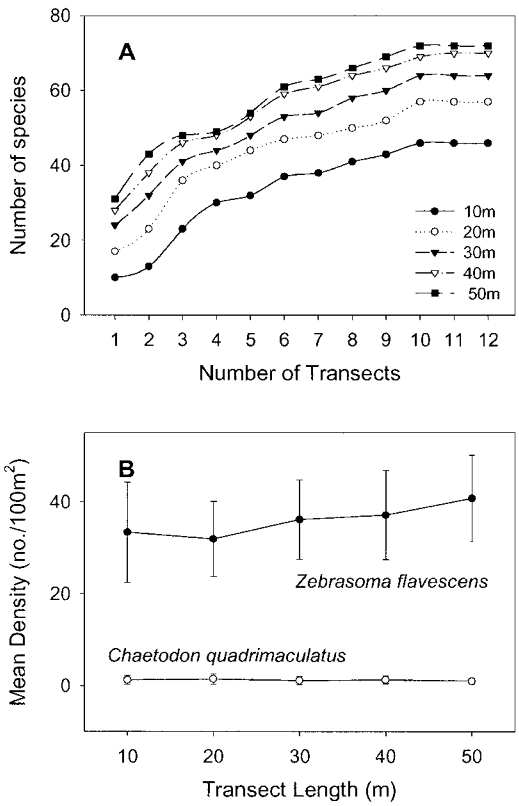

FIGURE 2. Results of pilot studies using visual strip transects that varied in transect length and number. *A*, Effects of various transect lengths and number on the total number of fish species observed. *B*, Effects of transect length on mean abundance and standard error of a common and an uncommon aquarium fish species.

samples. Our actual design is based on the BACI test (see under Data Analysis), which has even greater power to detect changes between surveys and locations (Underwood 1992).

Fish densities of all observed species were estimated by visual strip transect search along each permanent transect line. All divers either had extensive experience in conducting underwater fish surveys in Hawai'i or received training through QUEST before collecting any data. Two pairs of divers surveyed the lines, each pair searching two of the 25-m lines in a single dive. The search of each line consisted of two divers, swimming side by side on each side of the line, surveying a column 2 m wide. On the outward-bound leg, larger planktivores and wide-ranging fishes within 4 m of the bottom were recorded. On the return leg, fishes closely associated with the bottom, new recruits, and fishes hiding in cracks and crevices were recorded. All sites were surveyed bimonthly, weather permitting, for a total of six surveys per year (five in 2000). Due to problems with our research vessel, surveys were not conducted during the summer of 2002.

Data Analysis

All fishes observed were categorized as follows: (1) high rates of aquarium collecting (10 spp.), (2) any aquarium collecting (an additional 47 spp.), and (3) nonaquarium species (152 spp.). The presence and extent of collecting was based on reports in Miyasaka (1997).

We predicted that the density of protected fishes should increase in FRAs after closure, relative to reference areas, due to cessation of collecting. We tested the significance of our predictions using the Before-After-Control Impact (BACI) procedure (Osenberg and Schmitt 1996). This method tested for significant change in fish density by comparing mean FRA-reference differences before closure with mean FRA-reference differences after closure. The same comparison was also made for changes in open-reference differences to examine changes outside the FRAs.

We conducted the BACI procedure using a one-way, repeated-measure analysis of variance (ANOVA) with data from baseline surveys in 1999 (surveys 1–6) and the last six surveys in 2002 (surveys 18–23) to estimate the effectiveness of the FRAs after 3 yr of closure. Surveys were used as a random, repeated-measure factor. Data for the BACI analysis were limited to the five study areas that had reference, FRA, and open sites (Table 1). We evaluated effectiveness in two ways: (1) by calculating the percentage change in mean density from 1999 to 2002; and (2) by calculating the percentage change in the FRA-reference or open-reference difference from 1999 to 2002.

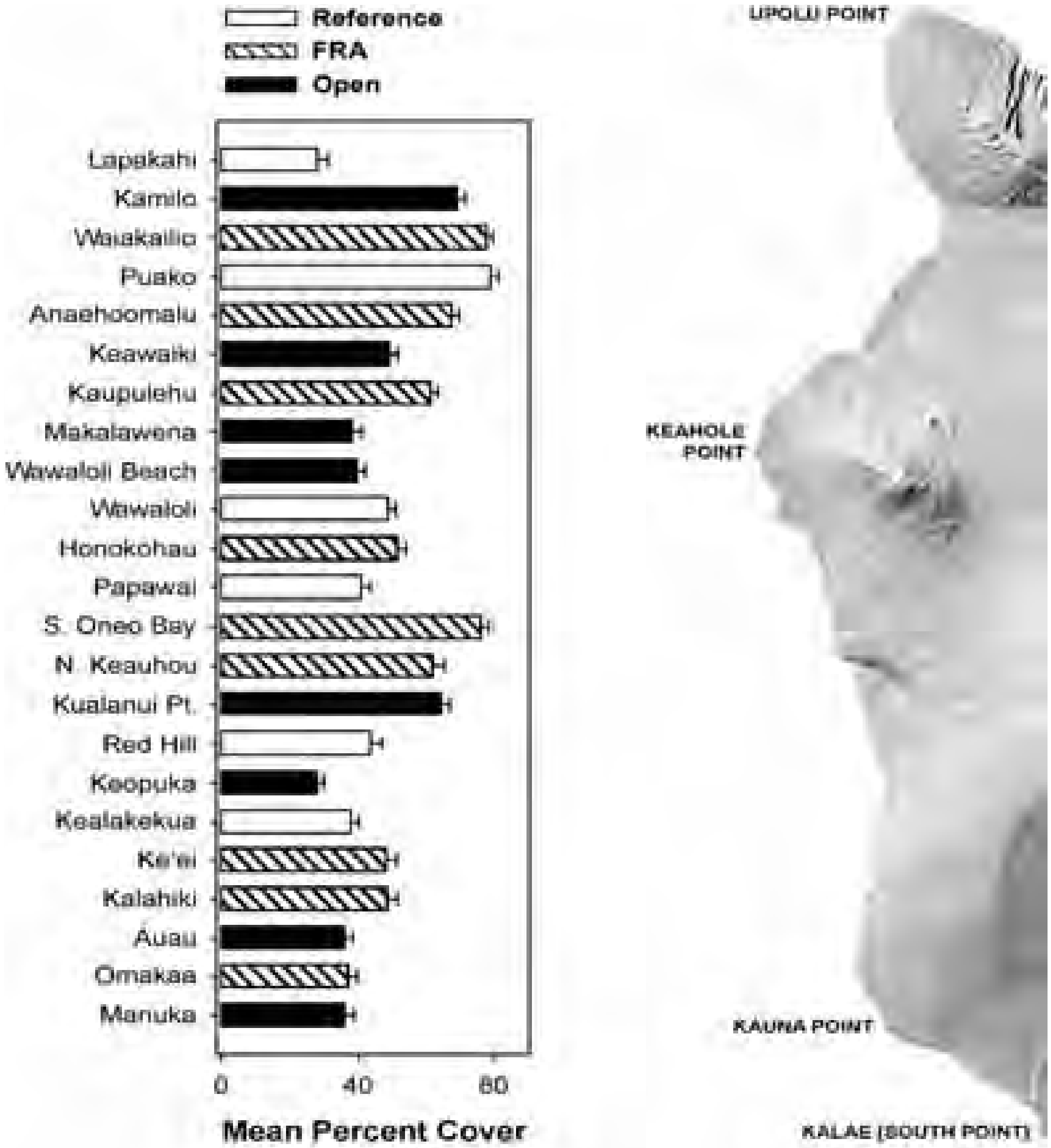

FIGURE 3. Mean percentage live coral cover at study sites in West Hawai'i (±1 SE). Site locations occur approximately opposite their geographic locations on the map (see Figure 1).

Estimates of the effects of aquarium collectors were made by comparing the mean density difference of target fishes in reference relative to FRA areas using the six baseline surveys from 1999 (see Tissot and Hallacher [2003] for a complete description of this method).

RESULTS

Benthic Habitat Analysis

Analysis of video transects revealed high variation in live coral cover in West Hawai'i (Figure 3). Overall, mean percentage coral cover ranged between 27% (Lapakahi) and

TABLE 2

Effects of Aquarium Collecting on Nine Species Estimated by Mean Percentage FRA-Reference Area Differences Using Data from Surveys before FRA Closure ($n = 6$ surveys)

Taxa	This Study	Tissot and Hallacher (2003)
Acanthurus achilles	−56*	−58*
Centropyge potteri	−42*	−46*
Chaetodon multicinctus	−4	−38*
Chaetodon ornatissimus	−7	−39*
Chaetodon quadrimaculatus	−97*	−42*
Ctenochaetus strigosus	−14*	−15
Forcipiger spp.	−55*	−54*
Zanclus cornutus	−49*	−46*
Zebrasoma flavescens	−43*	−47*
Overall	−26*	

Note: Statistical differences in density between reference and FRA sites were tested using a two-sample t-test (* = significant at $P < 0.05$). Mean estimates are compared with the study of Tissot and Hallacher (2003), which estimated the effects of aquarium collectors on these species in a previous study in West Hawai'i.

78% (Puakō). In general, coral cover was higher in sheltered areas (e.g., Puakō) and lower in areas located on more wave-exposed headlands (e.g., Keōpuka). One-way ANOVA among coral cover at reference, FRA, and open areas was not significant ($F = 2.18$; df = 2,22; $P = 0.14$).

Effects of Collectors

Overall, there were significantly less aquarium fishes in FRAs relative to reference areas in seven of the nine species analyzed during 1999 baseline surveys when collecting was still occurring (Table 2). Overall differences were significantly lower in *Acanthurus achilles* (−56%), *Centropyge potteri* (−42%), *Chaetodon quadrimaculatus* (−97%), *Ctenochaetus strigosus* (−14%), *Forcipiger* spp. (−55%), *Zanclus cornutus* (−49%), and *Zebrasoma flavescens* (−43%). There were no significant differences in *C. multicinctus* or *C. ornatissimus* (Table 2). Overall, aquarium fishes were 26% less abundant in FRAs relative to reference areas.

Effectiveness of FRAs

Overall there was a significant increase in the abundance of aquarium fishes in FRAs after 2 yr of FRA closure (Table 3A). The mean density of aquarium fishes increased 26%, and the mean density in FRAs relative to reference areas increased 50%, between pre- and postclosure surveys (Figure 4). Two of the 10 aquarium species examined had significant increases in FRAs relative to reference areas: the yellow tang, *Zebrasoma flavescens* (74%), and Potter's angelfish, *Centropyge potteri* (80%). In contrast, there were no significant changes in nonaquarium fishes in FRAs (Table 3A, Figure 4).

In areas open to collecting there were no significant overall changes among aquarium nor nonaquarium fishes before and after FRA closure (Table 3B). However, two of the 10 aquarium species had significant increases in abundance in open relative to reference areas: *Ctenochaetus strigosus* (51%) and *Forcipinger flavissimus* (61%) (Table 3B).

Recruitment

Although newly recruited individuals were present during the summers of all years, there were higher levels of recruitment of aquarium fishes after FRA closure during the summers of 2001 and 2002 relative to earlier years (Figure 5). In contrast, nonaquarium recruits were more common in 1999 before FRA closure, declining in 2000–2002. A two-way BACI ANOVA was not significant among aquarium and nonaquarium recruits, before and after closure, nor was there a significant interaction between these two factors (all $P > 0.05$).

DISCUSSION

Analysis of baseline surveys in 1999 supports earlier research documenting significant effects of aquarium collector harvesting on selected fishes in West Hawai'i. Preclosure surveys indicate that collectors continued to target seven of the nine aquarium species examined in the FRAs before closure on 1 January 2000. On average aquarium fishes were

TABLE 3

Two-way BACI Repeated-Measure ANOVA Testing for Significant Changes in before (1999) and after (2002) FRA Closure (BA)

Taxa	Mean Density (No./100 m^2) Before	After	% Change Density	% FRA-Reference Change	*P* (BA)
A. Reference-FRA differences					
Acanthurus achilles	0.22	0.28	+27	+13	0.76
Centropyge potteri	1.16	1.03	−17	+80	0.03*
Chaetodon multicinctus	4.88	3.92	−20	+76	0.26
Chaetodon ornatissimus	0.95	0.91	−4.2	−112	0.75
Chaetodon quadrimaculatus	0.01	0.02	+100	−61	0.08
Ctenochaetus strigosus	28.1	32.3	+15	+29	0.40
Forcipiger flavissimus	0.61	0.44	−28	+49	0.34
Forcipiger longirostris	0.27	0.45	+67	−47	0.32
Zanclus cornutus	0.27	0.13	−52	+27	0.57
Zebrasoma flavescens	14.2	24.6	+73	+74	<0.01*
All aquarium fishes	50.6	64.0	+26	+50	0.01*
All nonaquarium fishes	42.1	47.2	+12	−27	0.12
B. Reference-open differences					
Acanthurus achilles	0.53	0.46	−13	+131	0.15
Centropyge potteri	1.62	1.43	−12	+161	0.06
Chaetodon multicinctus	4.70	4.22	−11	−44	0.86
Chaetodon ornatissimus	0.72	0.67	−6.9	−37	0.60
Chaetodon quadrimaculatus	0.53	0.51	−3.8	−127	0.23
Ctenochaetus strigosus	22.4	30.5	+36	+51	<0.01*
Forcipiger flavissimus	0.46	0.45	−2.2	+61	0.01*
Forcipiger longirostris	0.36	0.49	+36	−72	0.32
Zanclus cornutus	0.35	0.44	+26	+167	0.06
Zebrasoma flavescens	13.7	13.8	+0.7	−21	0.16
All aquarium fishes	45.0	52.8	+17	+14	0.11
All nonaquarium fishes	60.8	74.8	+23	+0.7	0.94

Note: *P* values are reported for the most commonly targeted aquarium fishes, all aquarium species pooled ($n = 57$ species), and nonaquarium species (* = significant at $P < 0.05$).

14–97% less abundant, and overall 26% less abundant in FRAs than in adjacent reference areas. With the exception of *C. multicinctus* and *C. ornatissimus*, these estimates are remarkably similar to those reported previously by Tissot and Hallacher (2003), whose study was conducted in 1997–1998 at two of the nine areas surveyed in this study.

Three years after closure of FRAs there were significant increases in the overall abundance of fishes targeted by collectors. It is interesting that the estimated increase in abundance (26%) is the same amount as the estimated reduction due to collectors before FRA closure, suggesting that as a group these fishes may have increased to their preexploitation levels. However, only two species, the yellow tang and Potter's angelfish, showed significant (74–80%) increases in FRAs relative to previously protected reference areas. Moreover, several others species, notably *C. multicinctus* and *F. flavissimus*, showed high (>40%) but nonsignificant increases in FRAs relative to reference area (Table 3), and several other species (*C. ornatissimus*, *C. quadrimaculatus*, and *F. longirostris*) showed high but nonsignificant *decreases* in FRAs relative to reference areas. Thus, because Potter's angelfish is not abundant, it seems likely that the significant increase in aquarium fishes was largely driven by the dramatic increase in yellow tangs to preexploitation (or reference)

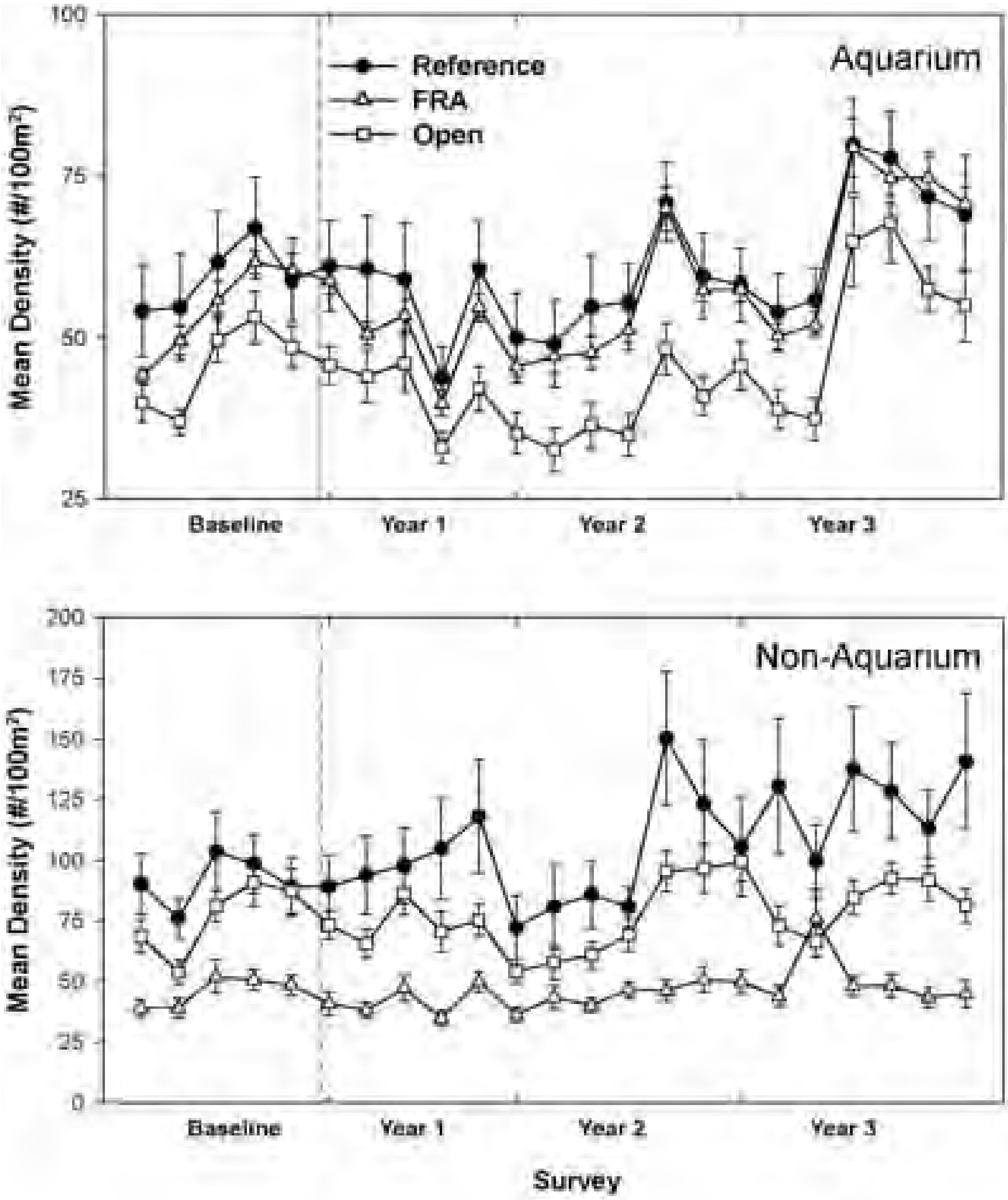

FIGURE 4. Changes in mean density of fishes in reference, open, and FRA areas pooled across all surveys before and after FRA closure (±1 SE). *Top:* aquarium fishes; *bottom:* nonaquarium fishes.

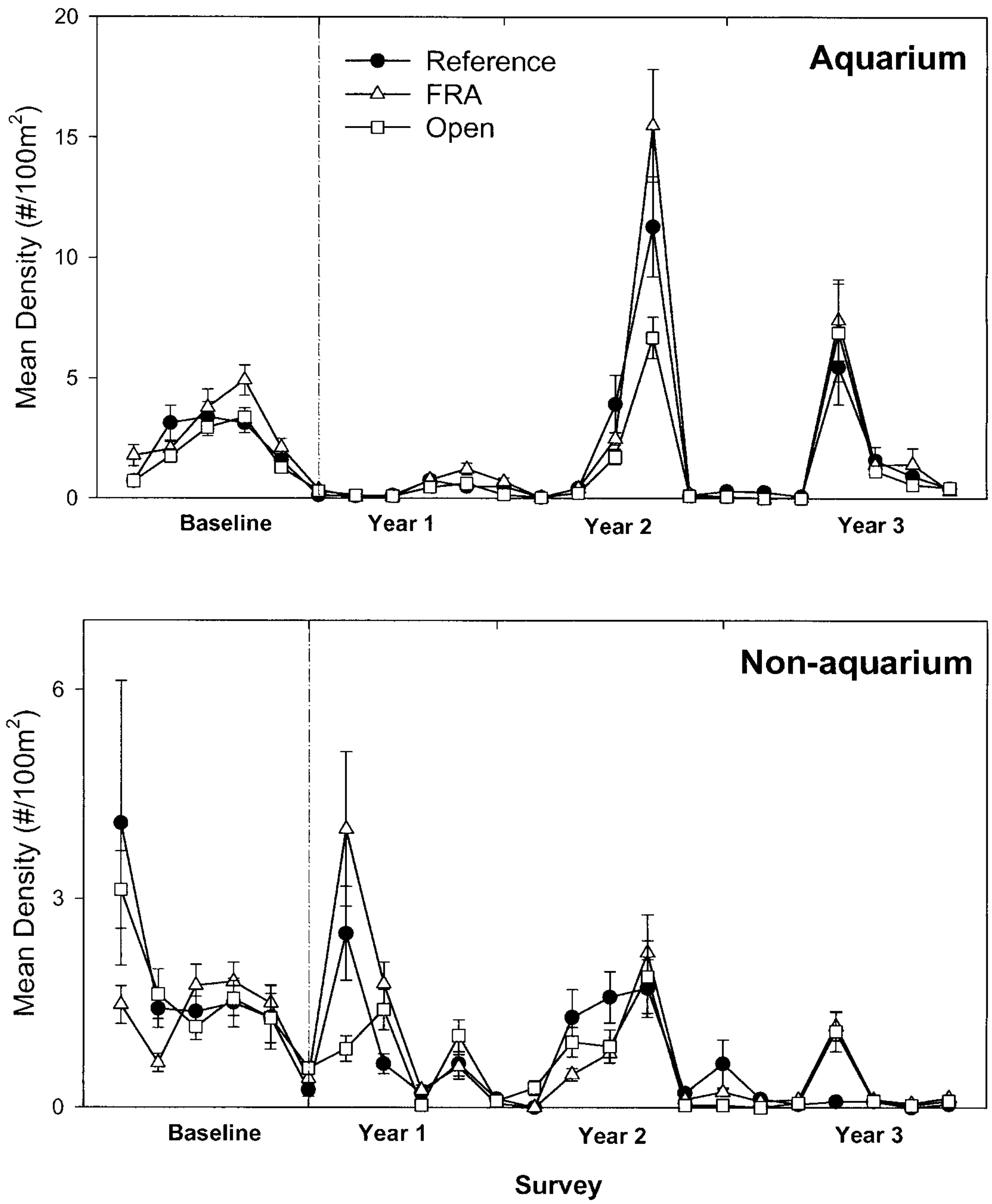

FIGURE 5. Changes in mean density of newly recruited fishes in reference, open, and FRA areas pooled across all surveys before and after FRA closure (±1 SE). *Top:* aquarium fishes; *bottom:* nonaquarium fishes.

levels. This observation is supported by the fact that the yellow tang composes about 82% of the total aquarium catch in West Hawai'i (Miyasaka 1997).

In contrast, there were no significant changes among noncollected species within FRAs or in aquarium and nonaquarium species in areas outside FRAs. Furthermore, no aquarium fishes declined in abundance in open areas as might be expected if the intensity of harvest increased outside the FRAs. In fact, two species displayed significant increases in abundance. Thus, overall the results of this study indicate that FRAs can help aquarium fish recover abundance, at least for the yellow tang and Potter's angelfish, without associated decreases in abundance outside FRAs, a common criticism of MPAs (e.g., Chapman and Kramer 1999).

There was strong interannual variation in the abundance of newly recruiting fishes in West Hawai'i. In general nonaquarium species had higher rates of recruitment before FRAs were closed in 1999, whereas aquarium species had higher recruitment in 2001 and 2002, after closure. It should be noted that the 2002 recruitment event of aquarium fishes was much larger than in 2001; the low number in the data is due to the fact that no surveys were conducted during the main summer months of 2002, only in September. Thus, it is tempting to associate the recovery of aquarium fishes in FRAs with high rates of recruitment, suggesting that the FRAs are enhancing recruitment. However, there was no significant variation between newly recruiting aquarium and nonaquarium fishes before or after FRA closure, and similar high temporal variation in reef fish recruitment in West Hawai'i was observed by Walsh (1987) over a 5-yr period. Thus, significant recovery in FRAs in some species during high levels of recruitment in 2001–2002 indicates that the frequency of recruitment is likely to be an important mechanism replenishing depleted stocks within MPAs in Hawai'i.

The results of this study demonstrate that the MPAs can effectively promote recovery of fish stocks depleted by fishing pressures in Hawai'i, at least in heavily exploited species, without significant declines outside MPAs. Within 3 yr two species, the yellow tang and Potter's angelfish, both reduced by over 40% before protection, displayed significant increases inside FRAs relative to reference areas. Yellow tangs increased in density 73% between 1999 and 2002, or about 10.4 fish per 100 m^2.

Based on these results it would be prudent to establish additional MPAs throughout Hawai'i as a precautionary measure against overfishing of marine resources. Currently, less than 1% of the main Hawaiian Islands is protected by MPAs (Clark and Gulko 1999). Furthermore, because recruitment appears to be an important mechanism influencing the replenishment of nearshore populations, we also advocate for increased monitoring of recruitment and nearshore oceanography to help better understand the dynamics of recruitment processes.

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The Commercial Marine Aquarium Fishery in Hawai‘i 1976-2003

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Abstract

The commercial aquarium fishery in Hawai‘i has developed over the last 50 years into one of the state’s major inshore fisheries, with landings of over 708,000 specimens with a reported value of $1.06 million. The true economic value of this fishery is substantially underestimated. The catch is diverse, with a total of over 200 different fish and invertebrates collected. The top 10 species constitute 73% of the entire catch. In the early days of the fishery, most collecting activity was centered on the island of O‘ahu. This fishery has declined over the years due to hurricane impacts and localized overfishing. Low-value invertebrates are increasingly replacing previously caught fishes. In contrast to O‘ahu, the aquarium fishery on the island of Hawai‘i is expanding and now accounts for 55% of the catch and 68% of the total state value. Recent research shows that collecting activities can significantly affect targeted species. A network of Fish Replenishment Areas (FRAs) has been established on the island of Hawai‘i to ensure sustainability of the aquarium fishery and to reduce user conflicts. Three years after implementation of the FRAs there are significant increases in several targeted species, and the overall value of the fishery is at an all-time high. Catch report compliance is low on this island and likely elsewhere within the state. Actual aquarium catch is underreported. Specific management actions increase reporting compliance by collectors.

Introduction

The marine aquarium fish trade has expanded into a multi-million dollar industry in fisheries throughout the tropical world. Total annual catch may exceed 30 million fish (Wood, 2001). Many of the marine ornamentals originating from the U.S. are caught in Hawai‘i, which is known for its high-quality fishes and rare endemics of high value. Here fish are collected without the use of chemicals or explosives; instead small-mesh fence and hand nets are used, resulting in a high survival rate of collected animals.

Background

Commercial aquarium collectors have been working Hawaiian waters for at least 50 years. The early collectors operated almost exclusively in the nearshore waters along the leeward coast of the island of O‘ahu. These collectors were usually experienced watermen skilled at spearing fish for food, and many of the same skills proved useful in collecting aquarium animals. Their equipment was rudimentary and included primitive goggles (bone and glass), pole spears, and cotton or linen nets. To collect specimens they practiced breath-hold diving. (DAR, undated a).

SCUBA gradually became more commonplace among collectors in the years following World War II. Synthetic nets were also introduced, which greatly increased the efficiency of collecting. In 1953 the territorial government of Hawaiʻi enacted Act 154, which authorized the Board of Agriculture and Forestry to establish a permit system for the use of fine-mesh nets and traps for the taking of aquarium fish. The law permitted the use of such otherwise-prohibited gear to take small fish that were not considered to be of food value. In creating the permit system, the legislature apparently anticipated that the aquarium fishery would grow over time and ultimately prove to be a substantial source of employment and export revenue (DAR, undated b).

The early growth of the aquarium fishery was constrained by the lack of airline connections and slow overseas flight times. With the arrival of commercial jet service to Hawaiʻi in 1959, exporters could now ship expeditiously to the U.S. mainland. Beginning in 1969 there was a rapid increase in the number of aquarium permittees, especially non-commercial ones collecting for their own aquaria. The number of commercial collectors began to increase substantially after 1971. (Table 1).

Table 1. Number of aquarium permits issued statewide for Fiscal Years 1969-1975.

Fiscal Year	Non-Commercial	Commercial
1975	218	78
1974	230	82
1973	360	36
1972	238	28
1971	144	6
1970	42	7
1969	55	4

Commercial aquarium collecting was well established on Oʻahu by 1973, when public concern about the fishery prompted the Division of Fish and Game (precursor to DAR) to place a moratorium on aquarium collecting and to suspend the issuance of aquarium fishing permits. This moratorium was to commence July 1, 1973, the start of the fiscal year, but was rescinded two days prior to its start. After the suspension was lifted, the ten-member State Animal Species Advisory Commission recommended restricting the issuance of aquarium fishing permits pending “full and extensive study.” At a September, 1973, meeting called by Fish and Game, a number of university marine scientists recommended the establishment of sanctuary areas and the prohibition of collecting within their confines (Walsh 1999).

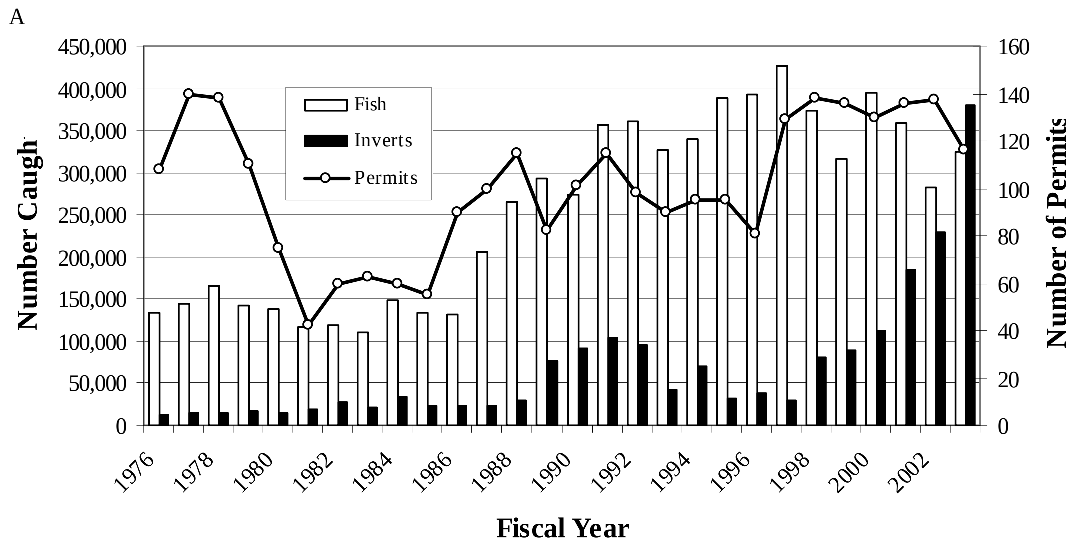
Prior to 1973, commercial aquarium collectors reported their catches on the same forms (C-3) as those used by all other commercial fishermen. These forms proved unsuitable for the multi-species aquarium catch, and the resulting data is considered unreliable. As part of the lifting of the 1973 moratorium, collectors were now required to report their monthly catch on a separate, more detailed aquarium fish catch report (C-6). The penalty for failing to submit timely catch reports is revocation of the aquarium permit and prosecution of an enforcement action.

Much of the data provided in this report are from monthly catch reports. In 1989 the aquarium permit statue (HRS §188-31) was amended to require a report to the Board of Land and Natural Resources (BLNR) of the monthly catch of each species of aquarium fish. Annual summaries were reported by DAR until 1994. The last catch report was a five-year summary for FY 1995-1999 (Miyasaka 2000).

As has been noted, the reliability of this data is dependent upon the sincerity (and integrity) of the permittees (Katekaru, 1978). At present there is no provision for verification of submitted reports. Given that there are indications of underreporting (see Kona section), catch numbers and dollar amounts should be regarded as minimum and not absolute values. Data from FY 74 and FY75 are not included in this analysis due to problems with early C-6 versions, which produced data not comparable with that of subsequent years. Only commercial data are presented, as non-commercial permit holders are not required to submit monthly catch reports. Non-commercial permit holders are also limited to a total take of five fish or aquatic specimens per person per day, so their overall potential catch is considerably less than that of commercial collectors. In FY 2003, 108 non-commercial permits were issued in comparison to 116 commercial ones.

Statewide Perspective

The Hawai‘i aquarium fishery developed at an extraordinary rate in the early 1970s. During FY 1973, 36 commercial permit holders reported a catch of 35,556 animals, which sold for a value of $74,100 (Ego, 1973). Five years later in 1978 the catch had increased 500% (179,900 specimens) and the value of the fishery had increased 400% to $296,850 ($812,900 adjusted value) (Figure 1). There were now 138 commercial collectors. This period of expansion ended at the end of the decade as a recession took hold in Hawai‘i and the United States. The recession was closely tied to a substantial cutback in production by oil-producing nations, resulting in worldwide oil and fuel shortages. Inflation during 1978 to 1981 averaged over 10%, further eroding the real value of the catch. The number of commercial collectors fell to 42, the lowest number recorded since reporting began.



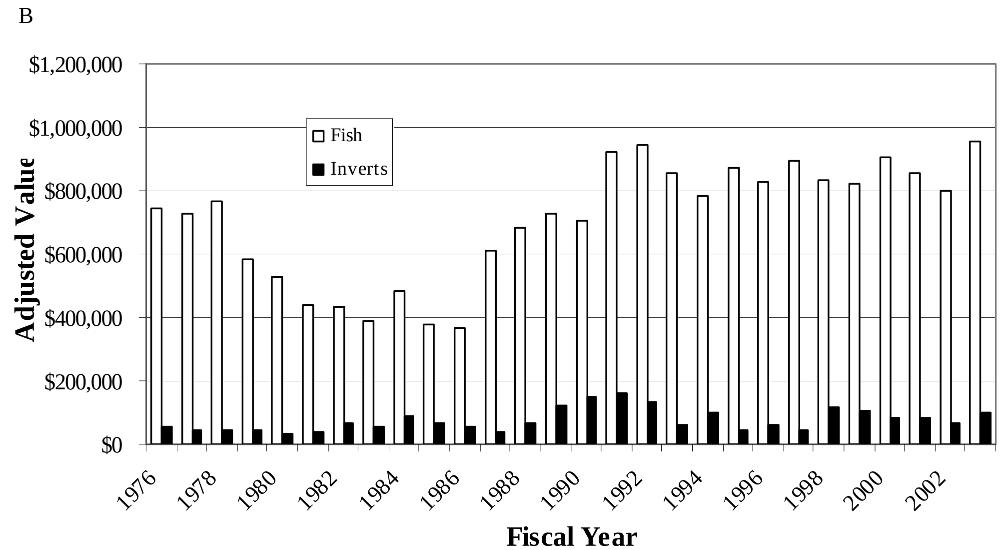


Figure 1. A. Number of commercial aquarium permits issued statewide and the numbers of fish and invertebrates reported caught. B. Dollar value of commercially caught fish and invertebrate aquarium specimens. Value is adjusted for inflation by means of Honolulu Consumer Price Index (Dept. of Labor and Industrial Relations, State of Hawai‘i).

The overall aquarium catch has been diverse, comprised of a total of 235 taxa of fish and 37 of invertebrates (Appendix A). A relatively small number of species dominates the catch; the top 10 species constitutes 73.3% of the total historical catch (Table 2). Surgeonfishes, Butterflyfishes, and wrasses are the most commonly caught fish species, while feather duster worms, hermit crabs, and shrimp predominate among the invertebrates. Particularly noteworthy is the substantial increase in invertebrate catch over the last several years (see Island section).

Table 2. Top ten taxa of collected animals over the period FY 1976-2003.

Taxa	Common Name	Total Caught	% of Total
Zebrasoma flavescens	Yellow Tang	3,386,860	37.2
Sabellastarte sanctijosephi	Feather Duster Worm	741,949	8.1
Hermit Crabs	Hermit Crabs	707,654	7.8
Ctenochaetus strigosus	Goldring Surgeonfish	346,944	3.8
Acanthurus achilles	Achilles Tang	337,781	3.7
Naso lituratus	Orangespine Unicornfish	298,884	3.3
Centropyge potteri	Potter's Angelfish	287,668	3.2
Forcipiger flavissimus	Forcepsfish	251,523	2.8
Zanclus cornutus	Moorish Idol	187,662	2.1
Halichoeres ornatissimus	Ornate Wrasse	121,766	1.3

Based upon catch report data (DAR 2001), the value of the aquarium fishery is among the highest of all inshore fisheries in Hawai‘i, exceeded only by the akule (bigeye scad - *Selar crumenopthalmus*) hook and line/net fishery (Figure 2).

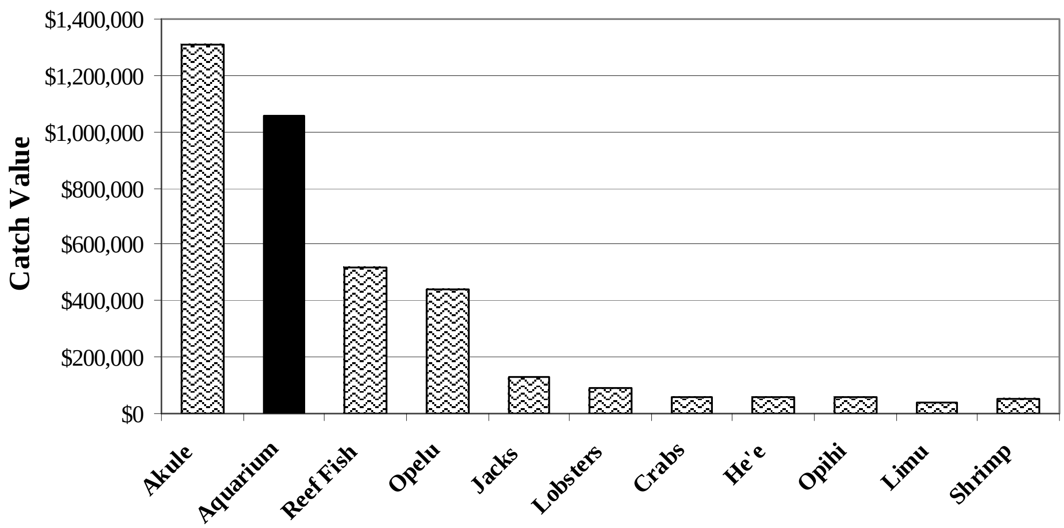


Figure 2. Value of Hawai‘i commercial marine landings for FY 2001.

Due to the fact that the aquarium industry is composed of both independent contractors (collectors) and wholesalers, who may or may not be collectors themselves, the overall economic value of the aquarium fishery is estimated to be substantially higher than shown in Figure 2. Cesar et al. (2002) estimated industry gross sales at $3.2 million and industry profits at $1.2 million. A 1993 analysis based on export figures by an aquarium trade group (Hawai‘i Tropical Fish Association 1993) pegged total sales of Hawaiian fish (inclusive of freight and packing) at $4,909,654. DAR reported total average value for FY 1993 /FY 1994 as only $819,957 (Miyasaka 1994a, 1994b).

It is difficult to precisely compare the scale of the Hawai‘i aquarium fishery with those of other countries around the world. The international distribution network for marine ornamentals is often complex, involving a number of intermediaries, and record keeping has not been standardized or centralized. Although it is clear that aquarium collecting is one of the most important inshore fisheries in Hawai‘i, total catch is substantially less than that of the major exporting countries such as the Philippines and Indonesia. The Philippines exports 6 million aquarium fish a year (Wood, 2001). Aquarium fishery data from Indonesia is scarce, but its 40 exporters of marine ornamentals (NAFED 2002) and a 1999 export value of US$11.4 million (Suara Pembaruan 1998) attest to its international prominence. Hawai‘i nonetheless is one of the major exporters among the second-tier countries (Figure 3).

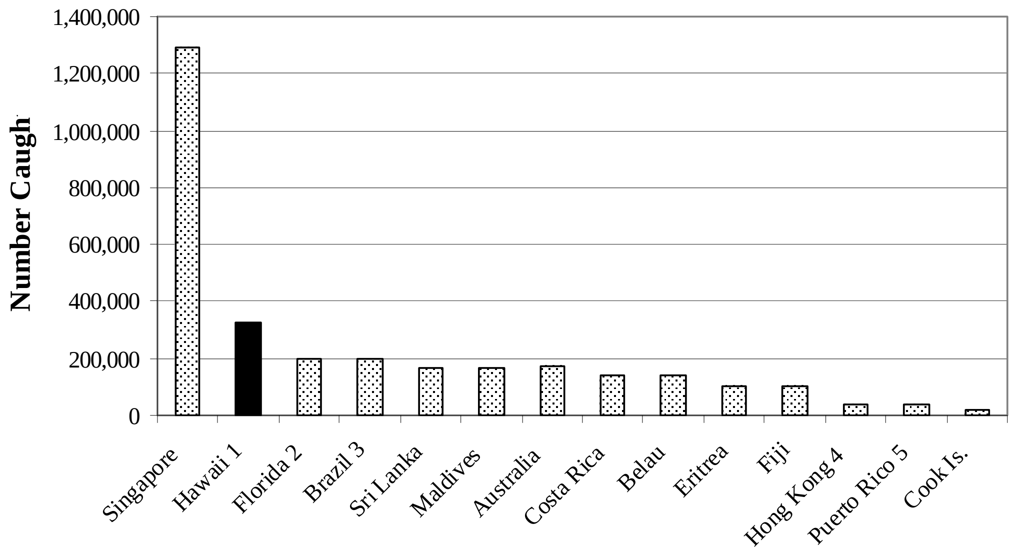


Figure 3. Number of marine aquarium fish caught or exported in recent years. All data from Wood 2001 except for 1-This study; 2- Adams et al. 2001; 3-Cassiano et al. 2003; 4- Chan and Sadovy 1998; 5-Mote 2002.

Island Comparison

Subsequent to the overall contraction of the aquarium fishery in the late 1970s and early 1980s, there has been a trend for an increasing number of commercial permits on all islands (Figure 4). The largest growth has occurred on the island of Hawai`i, which has experienced a 645% increase over the last two decades. The expansion on Hawai‘i was due to both an influx of new collectors and the relocation of collectors from O‘ahu.

In the early years of the aquarium fishery, O‘ahu was the most productive area, accounting for between 64% (1976) and 84% (1981) of the fish catch (Figure 5). The southern and leeward reefs of the island were prime collecting areas. While there is

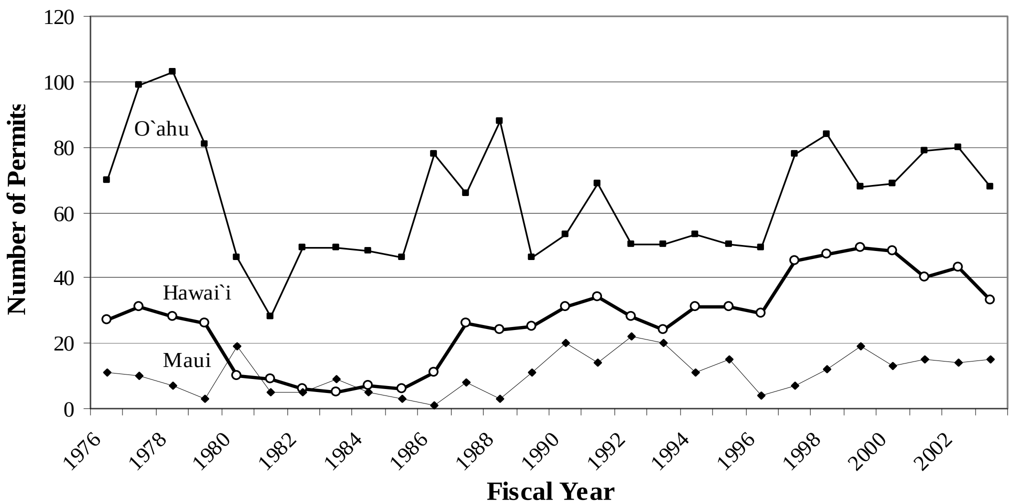


Figure 4. Number of commercial aquarium permits issued on each island per fiscal year. Maui refers to Maui county and includes the islands of Maui, Moloka`i and Lana`i. Kaua‘i is not shown due to the low number of permits (mostly 0 and 2, 1 and 3 in the last three fiscal years).

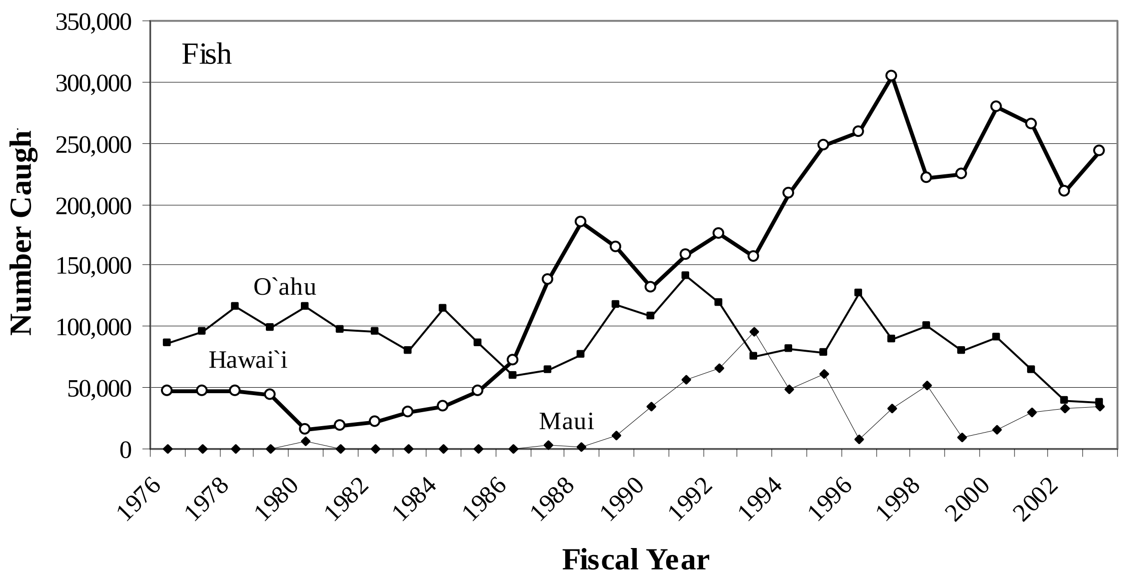


Figure 5. Number of aquarium fish caught on each island per fiscal year. Kaua‘i's catch has been omitted due to low numbers.

considerable between-year variability in the O‘ahu catch, there has been an overall decline in catch over time. This decline is in marked contrast to the catch of the island of Hawai‘i, which has increased dramatically since the 1980s.

At the present time, the O‘ahu catch represents only 12% of total aquarium fish catch in contrast to Hawai‘i's 75%. The sharp decline in catch on Maui in FY 1996 may have been due to the temporary close of business by the primary exporter on the island (Miyasaka 2000).

While the overall economic value of the aquarium fishery in the state has been relatively stable over the last decade (Figure 2), as with total catch, there have also been substantial changes in value on each of the islands (Figure 6). The value (adjusted for inflation) of the O‘ahu aquarium fish catch in FY 2003 has declined by 76% while that of Hawai‘i island has increased 282%.

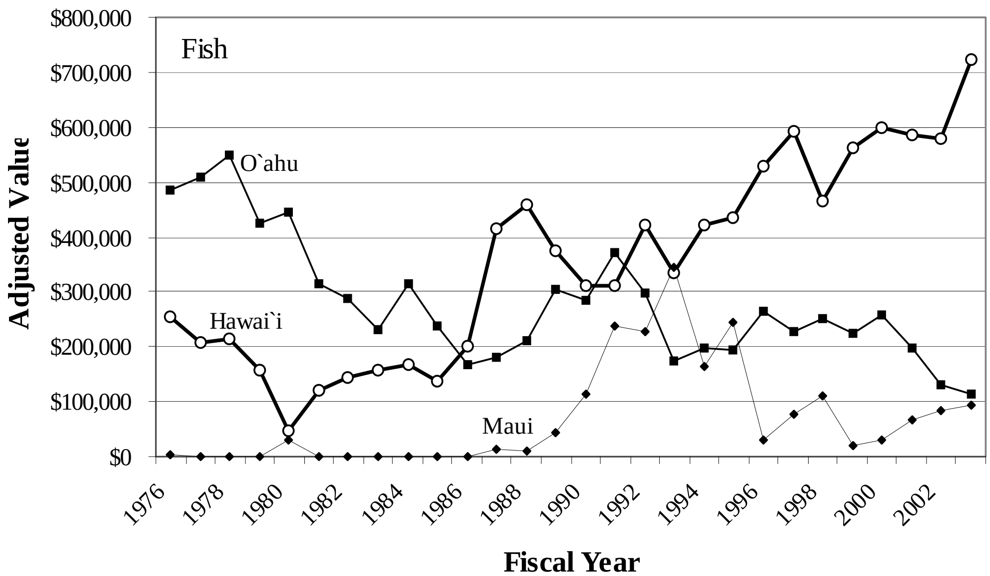


Figure 6. Dollar value (adjusted for inflation) of aquarium fish catch on each island per fiscal year. Kaua‘i omitted.

The catch of invertebrates is largely confined to O‘ahu. As the number of fish caught has dropped, the number of invertebrates has increased (Figure 7). Over the last 10 years 99% of all such animals were caught on O‘ahu. In 1997 and 1998, 5000-6000 invertebrates of 22 species were caught on Hawai‘i island but numbers dropped rapidly to just dozens in recent years. The majority of these animals were shrimps, especially the red striped shrimp *Saron marmoratus* (45% of catch). Similarly Maui had short-lived peaks of invertebrate catches around 1993, primarily echinoderms, hermit crabs, and pencil urchins, and then again in 2003 (hermit crabs collected on Moloka‘i).

The O‘ahu invertebrate catch has been dominated in recent years by a relatively few species. Over the past 10 years the top 10 species have accounted for 95% of the catch. Two groups in particular are the main target of collectors: feather duster worms (*Sabellastarte sanctijosephi*) and hermit crabs (species not specified) (Figure 8). The collection of hermit crabs has increased dramatically on O‘ahu and to a lesser extent on Maui. On O‘ahu alone over 291,000 hermits were caught last year. The unit value per crab over the last five years has been $.11 while feather dusters bring in $1.15. Feather dusters appear to be collected mostly from in and around Kāne`ohe Bay. It is unclear where on O‘ahu hermits are being collected because catch reports do not specify localities, but there is some indication that the Kāne`ohe Bay region is key.

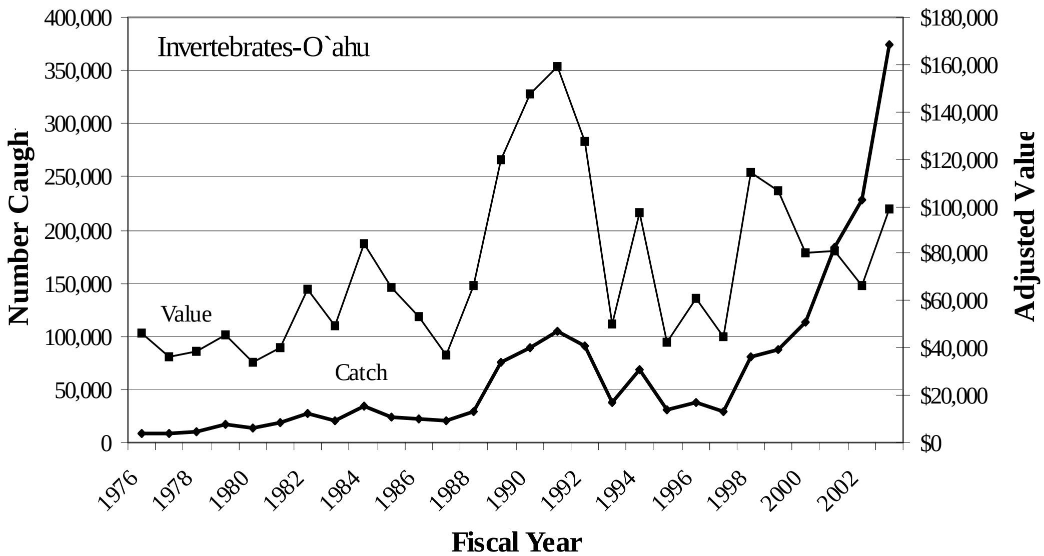


Figure 7. Number of invertebrates caught on O‘ahu per fiscal year and dollar value (adjusted for inflation).

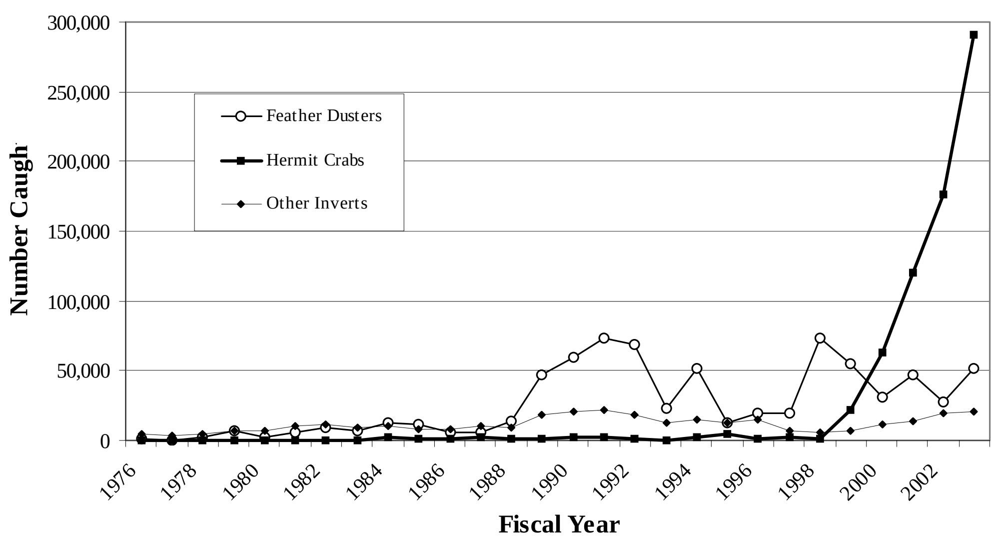


Figure 8. Number of invertebrates caught on O‘ahu per fiscal year. “Other Inverts” refers to 3-10th most abundant species caught.

Hurricane Effects

Three major storms struck the Hawaiian Islands during the past twenty-five years. The earliest one was a large three-day "Kona" storm, which occurred during January, 1980. This storm was one of the most severe of its type in at least 20 years (Hawai‘i County Civil Defense). The effects of this storm on the coral reefs of Hawai‘i island were substantial (Dollar 1982, Dollar and Tribble 1993) but patchy. Effects on the fish community were ameliorated by the presence of deeper-water refuges and remaining undamaged areas (Walsh 1983). The effect of this storm on other islands remains unclear, although at least one area of leeward O‘ahu (Kahe Pt.) suffered extensive coral damage. Thirty of 32 coral-monitoring stations at Kahe showed reductions in coral coverage up to 100% at some stations (Mean = 52±6.4% SE) (Coles and Brown, in prep.).

Subsequent to this storm, two major hurricanes struck the islands with substantial impacts on O‘ahu and Kaua‘i. On November 23, 1982 Hurricane ‘Iwa passed to the southwest of O‘ahu, striking Kaua‘i. The hurricane generated maximum waves of 9-14.8m (Dengler et al. 1984, Coles and Brown in prep). On September 11, 1992, Hurricane ‘Iniki passed to the west of O‘ahu, again striking Kaua‘i. ‘Iniki was the most powerful hurricane to strike the Hawaiian Islands in recent history. The areas most affected on O‘ahu were the leeward coast, with lesser damage along the south shore (Rosendale web site).

Coral and habitat damage as a result of ‘Iwa were substantial on Kaua‘i and parts of O‘ahu (W. Aila, pers. comm.). According to an undated, anonymous DAR report, ‘Iwa damaged "extensive inshore reef areas, especially the prime aquarium fishing grounds along O‘ahu's western coast." Pfeffer and Tribble (1985) similarly noted that ‘Iwa resulted in extensive subtidal damage along the west and south shores of O‘ahu. The majority of coral 30' to 150' deep were severely damaged and most small coral patch reefs were destroyed. ‘Iniki also impacted coral reef communities on O‘ahu (Brock 1996, Coles and Brown, in prep.) but limited evidence suggests the effects may have been less than with ‘Iwa (Miyasaka 1994).

With one notable exception, the overall effects of either of these two hurricanes on the O‘ahu aquarium fishery have not been well documented. The exception is the study done by two collectors (Pfeffer and Tribble 1985) on the effects of ‘Iwa on their collection efforts. The data in the study was based upon billing invoices compiled from collecting trips over several years before and after the hurricane. The area collected on the south shore of O‘ahu (‘Ewa) is termed Zone 401 on the monthly catch report forms.

Pfeffer and Tribble reported that their catch (and gross earnings) declined markedly after the storm. This was most apparent for yellow tangs (*Zebrasoma flavescens*), which was one of their primary targets. In the weeks following the storm, numerous dead and injured fish were observed and many appeared stunned and disoriented. Shortly after the storm, some fish could even be caught by just allowing them to swim into an open collection container. Observations also revealed that many fish had migrated to areas that escaped major damage. Catches at some of these sites increased and remained high after the hurricane. Subsequently, however, catches declined. The authors attribute this decline to increased fishing pressure in these areas. With the loss of collecting habitat, collectors concentrated their efforts in those sites still economically utilizable. In some cases the numbers of collectors working a particular area also increased. The net result was that storm effects combined with overfishing resulted in the collapse of the aquarium fishery along this portion of the O‘ahu coastline.

Catch report data was used to examine possible hurricane effects on the O‘ahu aquarium fishery. The first approach specifically examined those areas deemed to be most impacted by the storms (Figure 9). For presentation purposes, the west coast zones were combined into two sections.

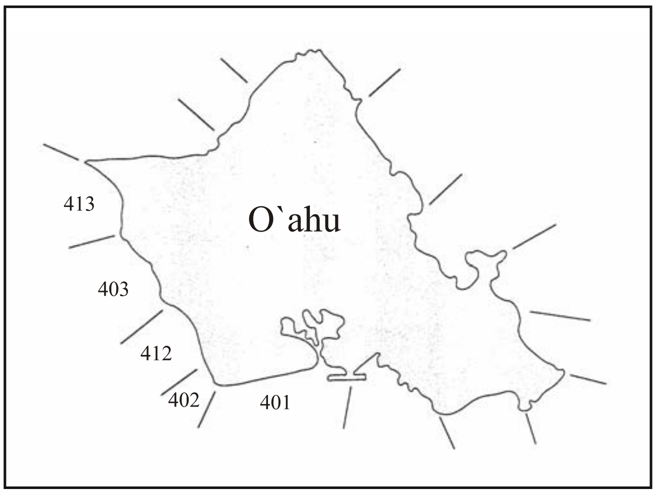


Figure 9. C-6 Aquarium Fish Catch Report zones for southwest O‘ahu.

The number of commercial permittees reporting catch in these areas is shown in Figure 10. These zones constituted the heart of the early O‘ahu fishery and to a large part determined the overall statewide patterns (e.g. Figure 1). It is clear that the number of collectors working all these areas had declined substantially prior to ‘Iwa. As noted before, this contraction may have been due to an economic recession. Subsequent to this period, the number of collectors working these areas was relatively stable. This is not to say that the same individual collectors were present during this time, however. Apparently, subsequent to ‘Iwa, several O‘ahu collectors relocated to Maui or Hawai‘i.

The number of fish caught in these zones varied widely over this time period (Figure 11). Zone 401, the area reported on by Pfeffer and Tribble, showed an overall increase in the year following the storm and then a pattern of valleys and peaks afterwards. Average fish catch in the years after ‘Iwa was quite comparable to the years prior to the storm. The maintenance of catch numbers may have been due to a compensatory shift of target species (e.g., Thalassoma *duperrey, Ctenochaetus strigosus*) after more desirable ones

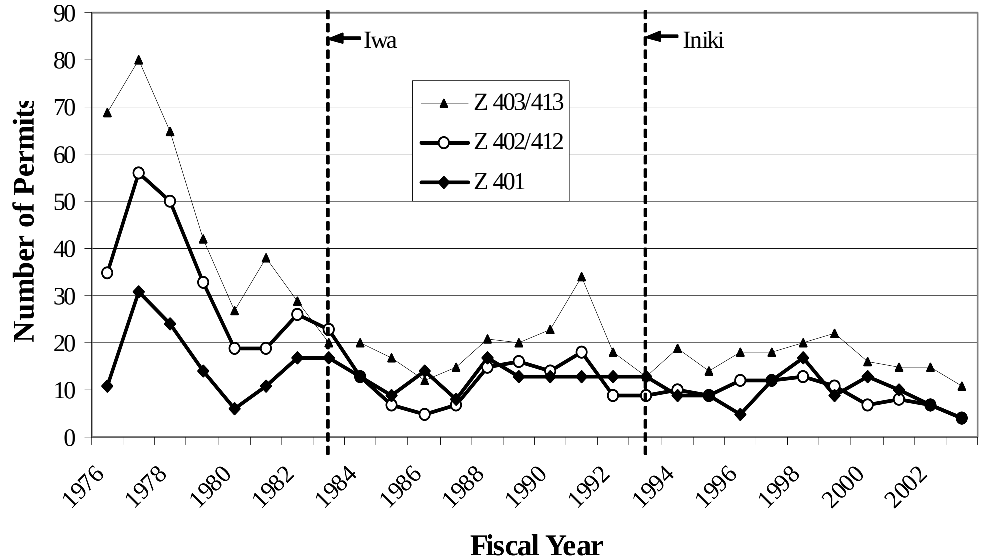


Figure 10. Number of aquarium permittees reporting catch from southwest O‘ahu reporting zones.

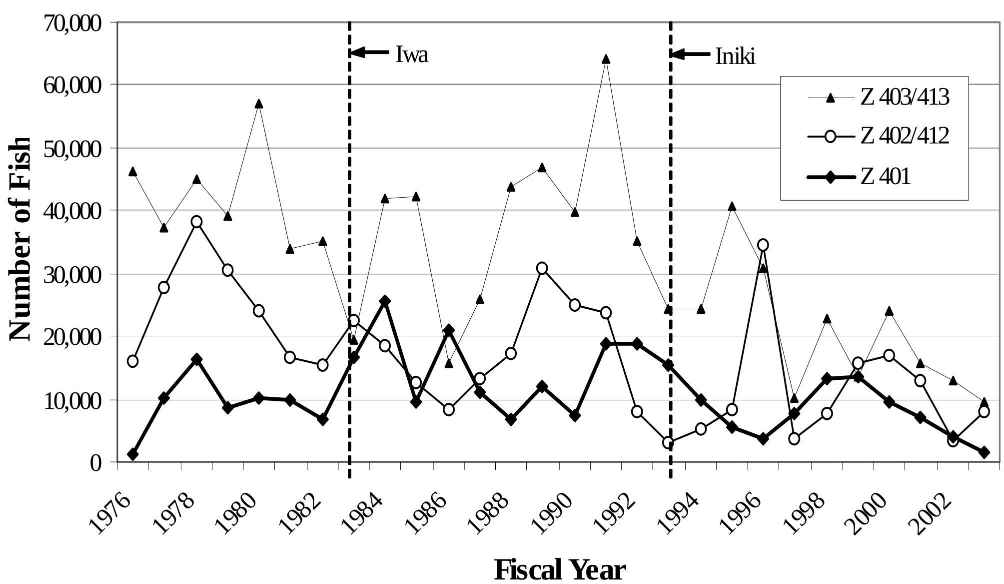


Figure 11. Number of fish caught of all species in southwest O‘ahu reporting zones.

such as yellow tangs became less abundant (Figure 12). A declining trend was apparent after ‘Iniki and again in recent years. Invertebrates now make up the majority of collected animals in this zone.

No consistent storm-related decreases are apparent in the other two zones. Both areas had markedly declining catches *prior* to the hurricanes and, in three out of the four cases, catch increased over the subsequent year or two. As with zone 401, recent fish catch in these areas is on a decidedly downward trend, and in zone 403/413 (Wai`anae), invertebrates now make up the majority of collected animals.

The temporal pattern of the yellow tang catch in the pre-‘Iwa period (Figure 12) closely tracks that of the total catch, highlighting the importance of this species in the fishery at that time. The highly variable but general decline in catch from the late 1970s and early 1980s may be due to the reduction in the number of commercial collectors. Although Pfeffer and Tribble reported that their catch of yellow tangs decreased markedly after ‘Iwa, in fact, the overall catch in the area increased both during the year of the storm (FY 1983) and the year after. This apparent contradiction may be due to an increase in the number of collectors working the zone in response to loss of their collecting areas elsewhere. This increase was relatively short-lived, however, as the number of collected tangs subsequently plummeted with only a single exception, FY 1992, the year before ‘Iniki.

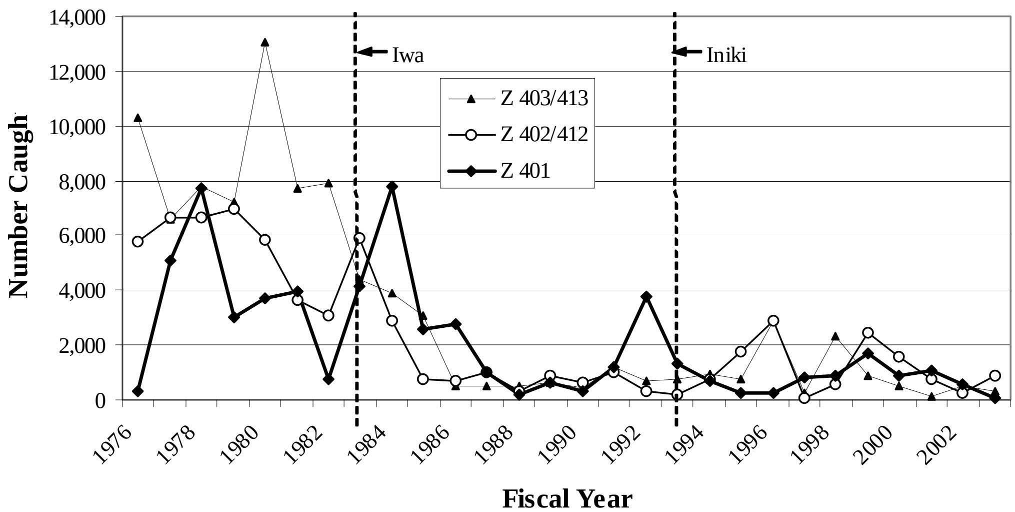


Figure 12. Number of yellow tangs caught in southwest O‘ahu reporting zones.

The two other areas along the west coast of the island also showed clear and persistent declines in yellow tang catch after ‘Iwa. Given the desirability of the species within the aquarium trade, these declines undoubtedly reflect low numbers of yellow tangs on the reefs, at least a decline in the number of small individuals. The aquarium fishery primarily targets young of the year and small, sexually-immature individuals. These size classes are strongly associated with a finger coral (*Porites compressa)* habitat (Walsh 1984) and may recruit preferentially to this habitat. This habitat is very vulnerable to destruction by unusually large storms such as ‘Iwa and ‘Iniki. It is not unreasonable that substantial reduction of suitable finger coral habitat will result in reduced recruitment and/or increased recruit mortality. Given that even very small (5 cm.) recently-recruited yellow tangs are marketable (D. Dart, pers. comm.), it is likely that the overall poor catch in recent years is due to low recruitment levels. The small peaks in the years after ‘Iwa likely reflect recruitment pulses of yellow tangs. It is interesting to note the yearly asynchrony of some of the peaks in these three geographically proximate locales.

Examination of changes in the effort involved in catching aquarium specimens over time would seem to be an appropriate method to assess the impacts of these hurricanes. Unfortunately Catch per Unit Effort (CPUE) data derived from the aquarium catch reports is fraught with uncertainties. Collectors use varying techniques, they often work in teams which change over time, and some target primarily invertebrates while others target fish and some target both. Varying interpretations of what constitutes actual (i.e., reported) collecting time further confounds the situation. Nevertheless, an attempt was made to pull together CPUE information for the three areas under consideration. In an effort to increase the reliability of the data, two separate CPUEs were calculated, one for fish and one for invertebrates. Only permittees reporting just fish or just invertebrates were included in the CPUE calculations. As the invertebrate fishery is largely a recent development, only fish CPUE data are presented.

Even with these adjustments, CPUE values often vary wildly from one year to the next (Figure 13), and clear and consistent hurricane effects are difficult to discern. In zone 401 and to a lesser extent in zone 403/413, an increase in CPUE the year of ‘Iwa then subsequently decreased. The CPUE was of a similar magnitude, however, as that which had occurred several years earlier in FY 1980, the year of the previously-mentioned “Kona” storm. It is possible that both these increases were directly related to storm effects on species catchability. In contrast to these two areas,403/414 showed a slight decrease in CPUE the year of ‘Iwa and then an increase afterwards.

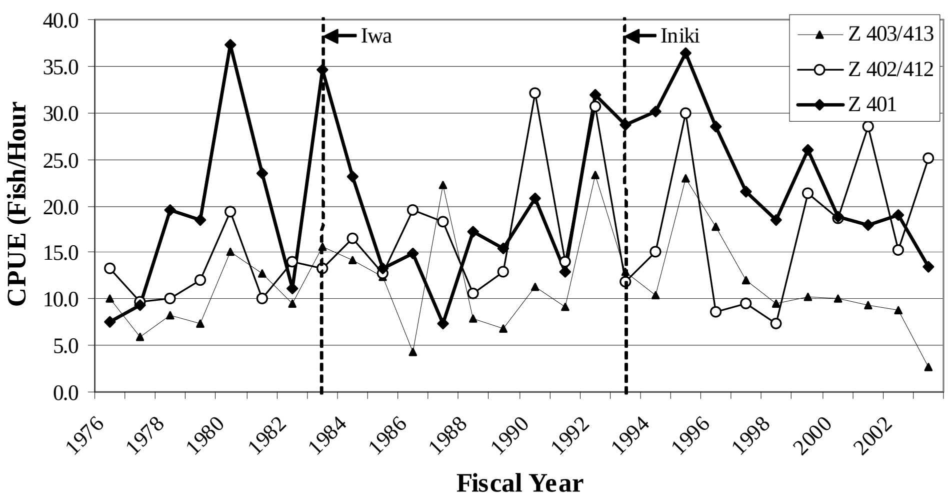


Figure 13. Catch per Unit Effort (CPUE) data for fish in southwest O‘ahu reporting zones. CPUE was calculated per permit per area per month, and fiscal year CPUE is the average of all these values.

The pattern during ‘Iniki is in marked contrast to the pattern during ‘Iwa in that all areas had a decline in CPUE followed by a peak two years later (FY 1995). Dramatic declines subsequently followed, and in two of the areas have continued to the present time. This pattern suggests that in recent years it is getting increasingly more difficult to collect aquarium fishes in these areas.

Although caution is called for in interpreting the CPUE findings, these, along with other indications, seem to clearly indicate the southwest O‘ahu aquarium fishery is not what it once was. Indeed the O‘ahu fishery as a whole is not static, but rather is a dynamic entity which has changed in response to physical, fishery, market, and economic factors. On a geographic basis there has been a major shift in the fishery from the west side to the east over the past 27 years (Figure 14). The proportion of fish and invertebrates caught along the west coast is significantly less in the present period (1994-2003) than it was in the years 1976-1982 (1 way ANOVA with Tukey’s test P<0.001, P<0.012). Conversely, the east side has significantly increased its proportion of both fish and invertebrate catch during these periods (P=0.004, P<0.001). The north shore has also become a more important collection area for fish (P<0.001). The south shore has not changed significantly.

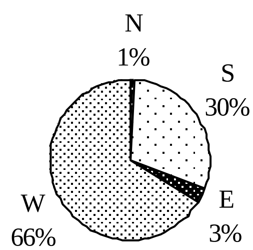
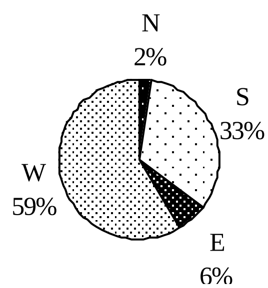
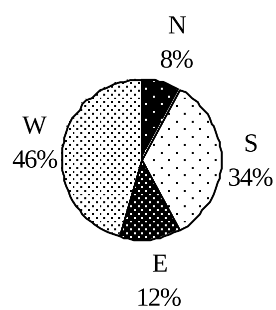
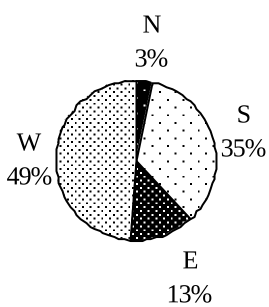
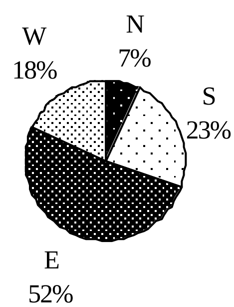
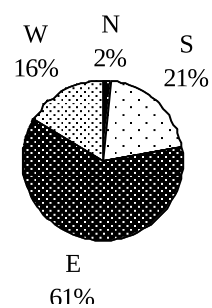
	Pre ‘Iwa	**Post ‘Iwa**	**Post ‘Iniki**
	1976 - 1982	**1984 - 1992**	**1994 - 2003**
Fish			
Invertebrates			

Figure 14. Average proportion of fish and invertebrate catch from four geographic sectors of O‘ahu over three hurricane-related time periods. Data from the fiscal years of hurricane ‘Iwa and ‘Iniki are omitted.

The West Hawai‘i Fishery

In contrast to O‘ahu, the aquarium fishery in West Hawai‘i has undergone dramatic expansion over the past twenty years (Table 3, Figs. 5 and 6). The majority of animals caught in the state and their resulting value now come from the Big Island, and almost all of that (98.6%) from West Hawai‘i. Invertebrates constitute a minor component of the West Hawai‘i catch (.02% of catch and value).

Table 3. Changes in West Hawai‘i aquarium fishery over last twenty years. Dollar Value is adjusted for inflation.

	FY 1983	**FY 2003**	Δ
No. Permits	5	33	660% ↑
Total Catch	30,000	243,908	813% ↑
Total Value	$159,756	$722,255	452% ↑
% of State Fish Catch	27%	75%	47%↑
% of State Total Catch	23%	55%	32% ↑
% of State Value	36%	68%	32% ↑

This growth has not come without controversy and conflict, however (Walsh 1978; Randall 1978; Taylor 1978; Walsh 1999). In response to growing public concern over the impacts of collecting on nearshore coral reef communities, a number of initiatives were developed to address the issue. An informal ‘Gentlepersons’ Agreement” was worked out among user groups in 1987 whereby collectors would refrain from collecting in certain areas. In 1991 these areas were incorporated into four no-collecting zones (Kona Coast Fishery Management Area) totaling approximately 4 miles of coastline. The next year, a Marine Life Conservation District (MLCD) of 1.3 mi. was established at the Old Kona Airport, where collecting was also precluded.

Public concern continued to escalate as the aquarium fishery further expanded. Despite widespread anecdotal reports of impacts, clear scientific evidence of overfishing was lacking. An early 1974 attempt to investigate the impact of aquarium collecting (Nolan 1978) reported that collecting had no significant effects. This study was fraught with methodological problems and the results are suspect (Tissot and Hallacher, in press). It was also conducted during a period of substantially less collection. (Figure 5). In the mid-1990s, DAR contracted with the University of Hawai‘i Hilo to conduct research to assess impacts of aquarium collecting along the Kona Coast of Hawai‘i. This paired control-impact study (Tissot and Hallacher 1999, in press) found that the numbers of 7 of 10 aquarium species surveyed were significantly reduced by collecting. The magnitude of the percent reduction in abundance at collection sites ranged from 38% (*Chaetodon multicinctus*) to 75% (*Chaetodon quadrimaculatus*). In contrast, only two non-aquarium species (*Stegastes fasciolatus* and *Paracirrhites arcatus*) exhibited a significant difference in numbers.

In response to a perceived lack of success in adequately dealing with aquarium collecting, a grassroots organization of citizens successfully lobbied for legislation to control collecting. In 1998, the state legislature passed Act 306, which established a West Hawai‘i Regional Fisheries Management Area to provide for effective management of marine resources. Among a number of provisions was the requirement to establish Fish Replenishment Areas (FRAs) where aquarium collecting would be banned. The West Hawai‘i Fisheries Council, composed of stakeholders and government representatives, developed a network of nine FRAs encompassing 35.2% (including existing protected areas) of the coastline (Walsh 1999; Capitini, in prep.).

Research is presently underway (WHAP-West Hawai‘i Aquarium Project) to evaluate the effectiveness of these reserves and to better understand the ecological dynamics of the nearshore reef environment. Preliminary analysis (Tissot et al., in press) indicates that three years after closure of the FRAs there have been significant increases in the overall abundance of fishes targeted by collectors. Two species, the yellow tang and Potter's angelfish (*Centropyge potteri*), showed significant (74-80%) increases in FRAs relative to previously protected reference areas. Furthermore, no aquarium fishes declined in abundance in open areas as might be expected if the intensity of harvesting increased outside of the FRAs. In fact, two species displayed significant increases in abundance in the open areas. Thus early results of this study demonstrate that MPAs can be a highly effective strategy for managing these resources (Friedlander, 2001).

After two years of declining yellow tang catch subsequent to the implementation of the FRAs, the numbers caught have increased in FY 2003 (Figure 15). This is due primarily to successful recruitment of this as well as several other species in the summer of 2002. Good recruitment was also apparent this past summer (2003). Of special note is the fact that the dollar value of each yellow tang has increased in the past two years. Indeed, the overall value of the West Hawai‘i aquarium fishery in FY 2003 is the highest it has ever been (Figure 6).

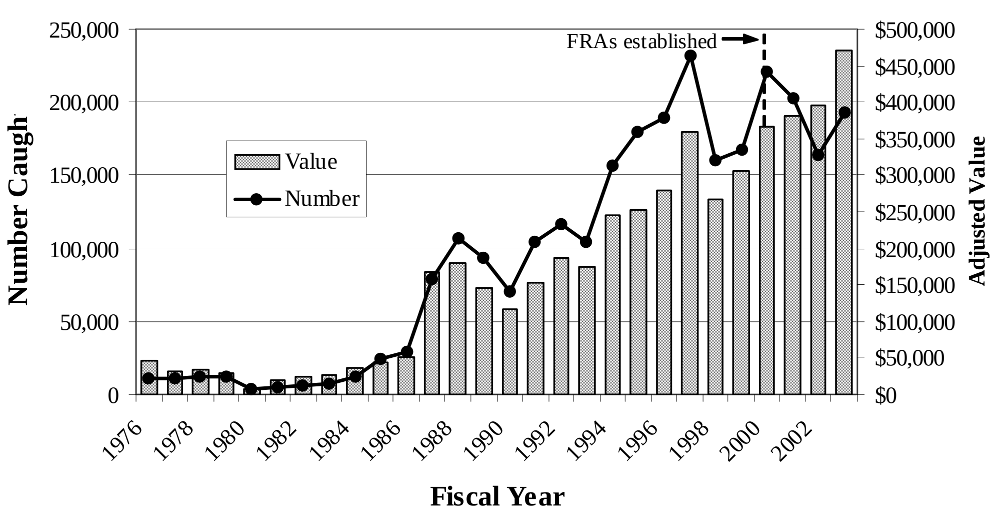


Figure 15. Number and value (adjusted for inflation) of yellow tangs caught in West Hawai‘i per fiscal year.

The trends for the four next most heavily collected species are shown below (Figure 16). Kole (*Ctenochaetus strigosus*) catch has been consistently increasing since the late 1980s and now ranks second in collected fishes both in West Hawaiʻi and statewide. Catch in FY 2003 is the highest it has even been. In contrast, catch of the clown tang (*Acanthurus achilles*) has been in decline since FY 1990.

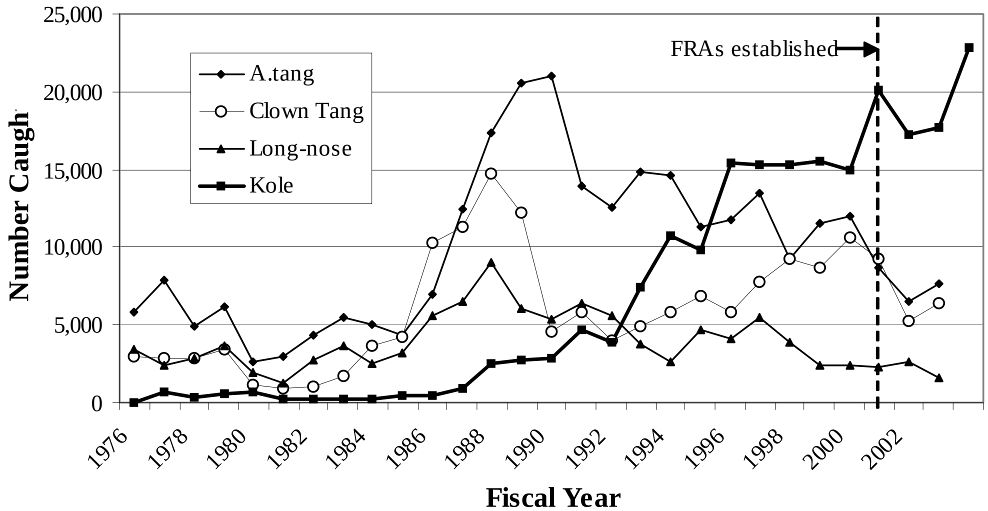


Figure 16. Number caught of top 2nd-5th West Hawaiʻi species per fiscal year.

CPUE has historically been the highest in West Hawaiʻi (Figure 17) due in large part to the abundance of and relative collecting ease of commonly targeted surgeonfishes. There appears to be a substantial decrease in CPUE in West Hawaiʻi coincident with FRA establishment. This could possibly reflect an increase in travel and dive time as collectors work unfamiliar areas distant from their previous ones. The average CPUE for West Hawaiʻi over the last ten years (37.7 ±16.8 SD fish/hour) is considerably higher than that reported for other areas such as Australia (20-45 fish/day), Cook Islands (24-36 fish/day), and Sri Lanka (30-50 fish/day) (Wood, 2001). As noted previously CPUE data is by far the weakest part of the aquarium catch report data, and these findings must be viewed cautiously.

One of the caveats implicit with catch report analyses is that catch report data accurately reflect what is being caught. At present there is no provision or means to verify this information. DAR is working to change this. In an effort to gain insight into the limitations of the catch report data, an analysis was done on the West Hawaiʻi reports. For each month over two time periods, the required catch report was sorted as to whether it indicated catch, no catch, or had not been filed (i.e., no report) (Figure 18). The two time periods were demarcated by the date of a letter sent to all West Hawaiʻi collectors from DAR reminding them of the requirement to file monthly catch reports. It is clear that a substantial number of collectors are not complying with the reporting requirement. Many of these delinquencies were from short-term and/or part-time collectors, but several of the more active collectors were delinquent as well. Of all 97 collectors who were active over these two periods, only 14% filed every required monthly catch report. It is likely that report compliance is as poor or worse on the other islands, where less attention is paid to the fishery. The mailing to the collectors did have a positive effect and significantly improved reporting compliance (X^2=30.18, P<0.001). With additional effort and appropriate enforcement this situation will improve.

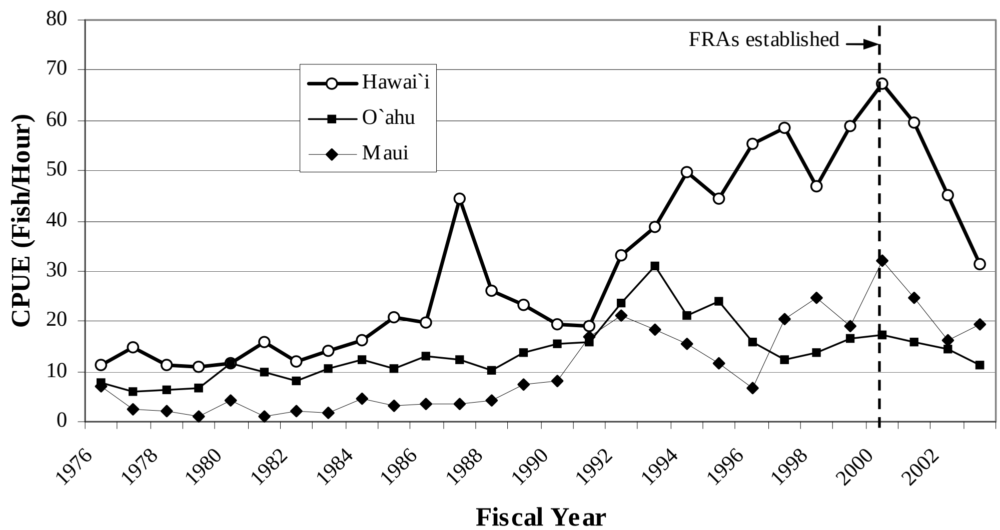


Figure 17. Catch per unit effort for Hawai'i collecting areas. Maui includes the islands of Maui, Moloka`i and Lana`i.

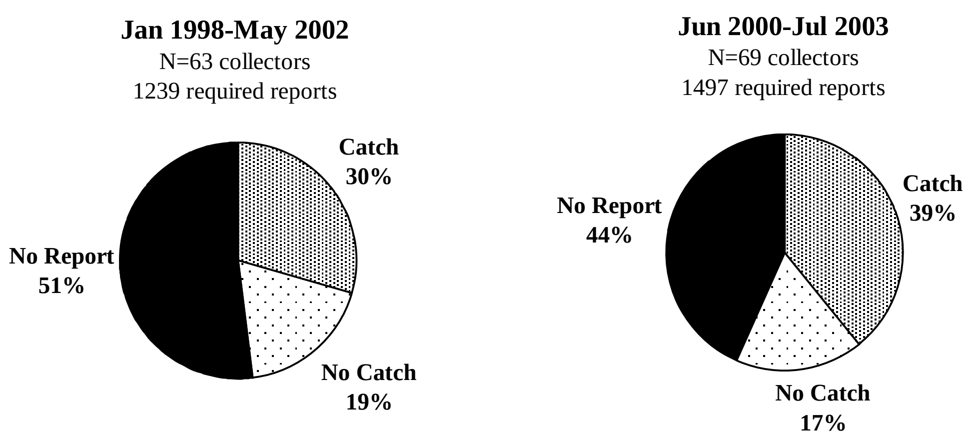


Figure 18. Aquarium catch report compliance for West Hawai'i collectors over two time periods.

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Appendix A. List of all taxa collected statewide for period FY 1967-2003 ranked by number caught. Total value is not adjusted for inflation.

Taxa	Common Name	Type	# Caught	Total Value
Zebrasoma flavescens	Yellow Tang	Fish	3,386,860	$ 5,567,252.60
Sabellastarte sanctijosephi	Feather Duster Worm	Invert	741,949	$ 860,362.09
Hermits Miscellaneous	Hermits Miscellaneous	Invert	707,654	$ 95,341.03
Ctenochaetus strigosus	Goldring Surgeonfish	Fish	346,944	$ 519,922.12
Acanthurus achilles	Achilles Tang	Fish	337,781	$ 1,197,423.19
Naso lituratus	Orangespine Unicornfish	Fish	298,884	$ 888,861.14
Centropyge potteri	Potter's Angelfish	Fish	287,668	$ 845,679.09
Forcipiger flavissimus	Forcepsfish	Fish	251,523	$ 537,155.00
Zanclus cornutus	Moorish idol	Fish	187,662	$ 445,958.61
Halichoeres ornatissimus	Ornate Wrasse	Fish	121,766	$ 190,280.77
Chaetodon multicinctus	Multiband Butterflyfish	Fish	111,454	$ 115,515.53
Chaetodon quadrimaculatus	Fourspot Butterflyfish	Fish	109,021	$ 226,275.92
Chaetodon miliaris	Milletseed Butterflyfish	Fish	105,411	$ 104,052.83
Lysmata amboinensis	Cleaner Shrimp	Invert	86,862	$ 178,283.07
Canthigaster jactator	HawaiianWhitespotted Toby	Fish	69,869	$ 66,760.97
Chaetodon unimaculatus	Teardrop Butterflyfish	Fish	69,033	$ 142,611.23
Ostracion meleagris	Spotted Boxfish	Fish	63,482	$ 149,856.61
Anampses chrysocephalus	Psychedelic Wrasse	Fish	62,481	$ 179,068.71
Thalassoma duperrey	Saddle Wrasse	Fish	53,220	$ 61,164.90
Labroides phthirophagus	Hawaiian Cleaner Wrasse	Fish	51,650	$ 158,839.06
Coris gaimard	Yellowtail Coris	Fish	51,052	$ 153,698.17
Chaetodon fremblii	Bluestripe Butterflyfish	Fish	50,280	$ 87,290.92
Dascyllus albisella	Hawaiian Dascyllus	Fish	49,930	$ 47,928.05
Crabs Miscellaneous	Crabs Miscellaneous	Invert	49,338	$ 53,798.20
Chaetodon kleinii	Blacklip Butterflyfish	Fish	47,397	$ 45,890.15
Stenopus hispidus	Coral-banded Shrimp	Invert	41,460	$ 45,529.24
Heniochus diphreutes	Pennantfish	Fish	41,320	$ 79,796.57
Forcipiger longirostris	Longnose Butterflyfish	Fish	40,630	$ 82,474.29
Anemones	Anemones	Invert	37,978	$ 57,830.55
Chaetodon lunula	Raccoon Butterflyfish	Fish	37,470	$ 104,793.79
Hippolytidae	Green Shrimp	Invert	34,740	$ 31,708.58
Cirrhitops fasciatus	Redbar Hawkfish	Fish	33,449	$ 47,173.50
Macropharyngodon geoffroy	Shortnose Wrasse	Fish	33,172	$ 44,841.15
Pseudocheilinus octotaenia	Eightline Wrasse	Fish	32,169	$ 56,630.63
Saron marmoratus	Marbled Shrimp	Invert	30,759	$ 37,481.20
Canthigaster coronata	Crown Toby	Fish	30,146	$ 33,046.50
Sea-Stars Miscellaneous	Sea-Stars Miscellaneous	Invert	29,020	$ 29,493.37
Sargocentron xantherythrum	Hawaiian squirrelfish	Fish	27,917	$ 25,988.55
Centropyge fisheri	Fisher's angel	Fish	26,947	$ 72,694.03
Chaetodon auriga	Threadfin Butterflyfish	Fish	25,640	$ 64,284.09
Sea Cucumbers	Sea Cucumbers	Invert	25,030	$ 21,673.05
Pervagor spilosoma	Fantail Filefish	Fish	25,007	$ 27,279.53
Gomphosus varius	Bird Wrasse	Fish	24,799	$ 86,095.56
Ctenochaetus Hawai'i ensis	Black Surgeonfish	Fish	24,600	$ 265,244.60
Acanthurus olivaceus	Orangeband Surgeonfish	Fish	22,107	$ 40,349.63
Shrimp Miscellaneous	Shrimp Miscellaneous	Invert	20,585	$ 27,297.45
Echinoderms	Echinoderms	Invert	18,845	$ 17,659.35
Pseudojuloides cerasinus	Smalltail Wrasse	Fish	18,807	$ 28,300.50

Taxa	**Common Name**	**Type**	**# Caught**	**Total Value**
Chaetodon ornatissimus	Ornate Butterflyfish	Fish	17,554	$ 31,931.97
Paracirrhites arcatus	Arc-eye Hawkfish	Fish	17,300	$ 21,502.04
Naso unicornis	Bluespine Unicornfish	Fish	17,193	$ 32,968.05
Pseudanthias bicolor	Bicolor Anthias	Fish	16,957	$ 49,190.25
Desmoholacanthus arcuatus	Bandit Angelfish	Fish	16,828	$ 171,041.24
Pseudanthias thompsoni	Thompson’s Anthias	Fish	16,716	$ 46,005.55
Holocentridae	Squirrelfish/Soldierfish	Fish	16,109	$ 18,685.90
Taenianotus triacanthus	Leaf Scorpionfish	Fish	15,216	$ 31,089.84
Xanthichthys mento	Crosshatch triggerfish	Fish	15,193	$ 59,861.35
Cirrhilabrus jordani	Flame Wrasse	Fish	13,919	$ 133,166.40
Limu	Limu	Algae	13,483	$ 10,477.50
Heterocentrotus mammillatus	Red Pencil Urchin	Invert	13,310	$ 19,754.03
Labridae sp.	Wrasse	Fish	13,306	$ 22,144.00
Sufflamen bursa	Lei Triggerfish	Fish	12,920	$ 19,620.67
Bodianus bilunulatus	Hawaiian Hogfish	Fish	12,917	$ 22,659.00
Dardanus gemmatus	Jeweled Anemone Crab	Invert	12,878	$ 16,008.10
Hemitaurichthys polylepis	Pyramid Butterflyfish	Fish	11,685	$ 35,316.98
Priacanthus sp.	Bigeye	Fish	11,597	$ 15,829.25
Rhinecanthus rectangulus	Reef Triggerfish	Fish	11,369	$ 32,059.01
Acanthurus triostegus	Convict Tang	Fish	11,294	$ 11,255.65
Stethojulis balteata	Belted Wrasse	Fish	11,290	$ 20,316.37
Aulostomus chinensis	Trumpetfish	Fish	10,827	$ 22,032.55
Urchins Miscellaneous	Urchins Miscellaneous	Invert	10,631	$ 10,017.22
Cantherhines dumerilii	Barred Filefish	Fish	10,452	$ 9,705.10
Acanthurus nigricans	Goldrim Surgeonfish	Fish	9,747	$ 40,236.85
Melichthys niger	Black Durgon	Fish	9,605	$ 25,174.84
Cowries Misc.	Cowries Misc.	Invert	9,198	$ 6,874.40
Pseudocheilinus tetrataenia	Fourline Wrasse	Fish	8,978	$ 35,330.75
Naso sp.	Unicorn sp.	Fish	8,845	$ 31,386.70
Worm	Worm	Invert	8,710	$ 6,754.50
Acanthurus thompsoni	Thompson's Surgeonfish	Fish	8,642	$ 19,236.10
Nudibranchs Miscellaneous	Nudibranchs Miscellaneous	Invert	8,244	$ 8,713.00
Pseudocheilinus evanidus	Disappearing Wrasse	Fish	8,159	$ 10,784.15
Gymnothorax eurostus	Stout Moray	Fish	8,098	$ 23,630.05
Zebrasoma veliferum	Sailfin tang	Fish	7,863	$ 31,468.35
Novaculichthys taeniourus	Rockmover Wrasse	Fish	7,799	$ 27,968.10
Balistidae	Triggerfish Misc.	Fish	7,532	$ 17,089.30
Anampses cuvier	Pearl Wrasse	Fish	7,049	$ 20,579.55
Thalassoma trilobatum	Christmas Wrasse	Fish	6,716	$ 14,921.65
Melichthys vidua	Pinktail Durgon	Fish	6,635	$ 21,074.99
Worms Miscellaneous	Worms Miscellaneous	Invert	6,483	$ 4,654.40
Chromis ovalis	Oval Damselfish	Fish	6,385	$ 4,791.50
Gymnomuraena zebra	Zebra Moray	Fish	6,320	$ 35,248.65
Acanthurus nigrofuscus	Brown Surgeonfish	Fish	6,269	$ 10,468.22
Chaetodon tinkeri	Tinker’s Butterflyfish	Fish	6,186	$ 353,240.45
Lactoria fornasini	Thornback Cowfish	Fish	6,165	$ 9,455.05
Molluscs Miscellaneous	Molluscs Miscellaneous	Invert	5,917	$ 1,802.55
Enoplometopus occidentalis	Red Reef Lobster	Invert	5,878	$ 21,028.95
Lutjanus kasmira	Bluestripe Snapper	Fish	5,615	$ 6,967.05
Exallias brevis	Shortbodied Blenny	Fish	5,090	$ 15,472.15
Paracirrhites forsteri	Blackside Hawkfish	Fish	4,999	$ 10,639.10
Acanthurus dussumieri	Eye-stripe Surgeonfish	Fish	4,981	$ 9,597.75
Hymenocera picta	Harlequin Shrimp	Invert	4,731	$ 31,350.80
Centropyge loricula	Flame angelfish	Fish	4,707	$ 44,968.70

Taxa	Common Name	Type	# Caught	Total Value
Dendrochirus barberi	Hawaiian Lionfish	Fish	4,643	$ 9,511.20
Sargocentron diadema	Crown Squirrelfish	Fish	4,624	$ 5,201.25
Hemitaurichthys thompsoni	Thompson's Butterfly	Fish	4,511	$ 7,237.25
Blenniidae	Blenny	Fish	4,107	$ 7,604.70
Coris venusta	Elegant Coris	Fish	4,009	$ 8,743.65
Echidna nebulosa	Snowflake Moray	Fish	3,982	$ 22,246.50
Coris ballieui	Lined Coris	Fish	3,919	$ 7,916.10
Arothron meleagris	Spotted Pufferfish	Fish	3,813	$ 8,069.70
Pterois sphex	Hawaiian Turkeyfish	Fish	3,680	$ 13,459.45
Medusa worms	Medusa Worms	Invert	3,586	$ 5,006.75
Panulirus marginatus	Spiny Lobster	Invert	3,484	$ 9,377.30
Parapercis schauinslandi	Sand Perch	Fish	3,416	$ 5,522.45
Coris flavovittata	Yellowstripe Coris	Fish	3,337	$ 8,529.20
Diodon holocanthus	Spiny Pufferfish	Fish	3,331	$ 9,868.25
Canthigaster amboinensis	Ambon Toby	Fish	3,271	$ 3,339.65
Cirrhitidae	Hawkfish	Fish	3,151	$ 5,134.50
Sea-Slugs Miscellaneous	Sea-Slugs Miscellaneous	Invert	3,094	$ 4,298.50
Damselfish	Damselfish	Fish	3,093	$ 2,523.20
Arothron hispidus	Stripebelly Pufferfish	Fish	3,048	$ 5,686.20
Antennarius sp.	Frogfish	Fish	3,043	$ 26,567.50
Pleuronectidae	Right-eye Flounders	Fish	2,878	$ 4,118.70
Acanthuridae sp.	Surgeonfish	Fish	2,710	$ 5,078.63
Myripristis berndti	Bigscale Soldierfish	Fish	2,485	$ 5,750.83
Bothus sp.	Lefteye Flounder	Fish	2,457	$ 3,737.30
Chromis vanderbilti	Blackfin Chromis	Fish	2,450	$ 1,828.00
Myripristis amaena	Brick Soldierfish	Fish	2,432	$ 2,842.25
Ostracion whitleyi	Whitley's Boxfish	Fish	2,408	$ 10,329.40
Cirrhitus pinnulatus	Stocky Hawkfish	Fish	2,358	$ 3,814.53
Aniculus maximus	Hairy Yellow Hermit Crab	Invert	2,273	$ 5,015.50
Mulloidichthys vanicolensis	Yellowfin Goatfish	Fish	2,236	$ 2,547.75
Parupeneus multifasciatus	Manybar Goatfish	Fish	2,204	$ 2,760.31
Chaetodon trifasciatus	Oval Butterflyfish	Fish	2,202	$ 4,425.30
Rhinecanthus aculeatus	Lagoon Triggerfish	Fish	2,190	$ 5,845.10
Chaetodontidae	Butterflyfish	Fish	2,149	$ 3,701.59
Diodon hystrix	Porcupinefish	Fish	2,050	$ 5,794.00
Canthigasteridae	Sharpnose Puffer	Fish	2,039	$ 2,537.00
Gymnothorax sp.	Moray eel	Fish	1,915	$ 8,742.75
Poecilidae	Mollies/Guppies	Fish	1,908	$ -
Thalassoma ballieui	Blacktail Wrasse	Fish	1,889	$ 3,097.85
Echidna polyzona	Barred Moray	Fish	1,864	$ 6,476.75
Scarus sp.	Parrotfish	Fish	1,747	$ 10,262.55
Chromis verater	Threespot Chromis	Fish	1,703	$ 1,529.87
Mullidae	Goatfishes	Fish	1,656	$ 2,136.30
Enchelycore pardalis	Dragon Moray	Fish	1,644	$ 73,544.00
Gymnothorax meleagris	Whitemouth Moray	Fish	1,636	$ 7,039.35
Abudefduf abdominalis	Sergeant Major	Fish	1,588	$ 1,420.25
Chaetodon reticulatus	Reticulated Butterflyfish	Fish	1,530	$ 3,945.72
Soft Coral Miscellaneous	Soft Coral Miscellaneous	Invert	1,500	$ -
Cones Misc.	Cones Misc.	Invert	1,492	$ 987.50
Hexabranchus sanguineus	Spanish Dancer	Invert	1,393	$ 3,005.50
Iniistius pavo	Peacock Razorfish	Fish	1,317	$ 3,743.10
Lactoria diaphana	Spiny Cowfish	Fish	1,257	$ 2,457.50
Oxycirrhites typus	Longnose Hawkfish	Fish	1,241	$ 13,515.00
Parupeneus porphyreus	Whitesaddle Goatfish	Fish	1,164	$ 2,070.75

Taxa	Common Name	Type	# Caught	Total Value
Canthigaster epilampra	Lantern Toby	Fish	1,142	$ 2,860.50
Canthigaster rivulata	Maze Toby	Fish	1,109	$ 1,196.95
Scorpaenopsis sp./ *Scorpaena* sp.	Scorpionfish	Fish	1,107	$ 1,608.26
Pseudanthias Hawai'i ensis	Hawaiian Longfin Anthias	Fish	1,080	$ 11,979.50
Snappers	Snappers	Fish	1,057	$ 2,136.25
Cheilio inermis	Cigar Wrasse	Fish	1,021	$ 1,693.50
Gymnothorax flavimarginatus	Yellowmargin Moray	Fish	991	$ 3,566.50
Uropterygius macrocephalus	Largehead Snake Moray	Fish	968	$ 3,885.40
Microcanthus strigatus	Stripey	Fish	930	$ 1,245.25
Scorpaenopsis diabolus	Devil Scorpionfish	Fish	928	$ 1,302.30
Xanthichthys auromarginatus	Gilded Triggerfish	Fish	902	$ 20,604.00
Kuhlia sandvicensis	Hawaiian Flagtail	Fish	876	$ 159.50
Cirripectes vanderbilti	Scarface Blenny	Fish	852	$ 2,379.25
Aluterus scriptus	Scrawled Filefish	Fish	832	$ 1,383.05
Chaetodon ephippium	Saddleback Butterflyfish	Fish	810	$ 2,919.65
Thalassoma lunare	Lyretail Wrasse	Fish	806	$ 1,188.85
Oxycheilinus bimaculatus	Twospot Wrasse	Fish	755	$ 989.20
Dactyloptena orientalis	Helmet Gurnard	Fish	752	$ 2,446.50
Acanthaster planci	Crown-of-thorns Seastar	Invert	746	$ 1,507.55
Scyllarides sp.	Slipper Lobster	Invert	734	$ 1,782.25
Sponges Miscellaneous	Sponges Miscellaneous	Invert	730	$ 1,920.90
Cephalopholis argus	Peacock Grouper	Fish	675	$ 3,874.50
Chaetodon lineolatus	Lined Butterflyfish	Fish	652	$ 3,590.75
Acanthurus blochii	Ringtail Surgeonfish	Fish	632	$ 2,012.55
Plectroglyphidodon imparipennis	Brighteye Damselfish	Fish	617	$ 560.50
Entomacrodus marmoratus	Marbled Blenny	Fish	611	$ 1,037.00
Istiblennius zebra	Zebra Blenny	Fish	607	$ 818.25
Cirripectes obscurus	Gargantuan Blenny	Fish	600	$ 1,392.05
Amblycirrhitus bimacula	Twospot Hawkfish	Fish	599	$ 962.00
Iniistius umbrilatus	Blackside Razorfish	Fish	526	$ 1,932.15
Cantherhines sandwichiensis	Squaretail Filefish	Fish	517	$ 569.75
Cosmocampus balli	Pipefish	Fish	494	$ 2,327.00
Chaetodon citrinellus	Speckled Butterflyfish	Fish	474	$ 693.25
Fistularia commersonii	Cornetfish	Fish	469	$ 61.41
Pervagor aspricaudus	Yellowtail Filefish	Fish	466	$ 882.25
Gymnothorax undulatus	Undulated Moray	Fish	449	$ 1,796.75
Parupeneus pleurostigma	Sidespot Goatfish	Fish	448	$ 537.70
Synodus sp.	Lizardfish	Fish	442	$ 544.00
Carangidae	Jack	Fish	430	$ 1,880.20
Myripristis kuntee	Epaulette Soldierfish	Fish	401	$ 711.50
Scutaria tigrinus	Tiger Moray	Fish	397	$ 1,804.75
Sebastapistes coniorta	Speckled Scorpionfish	Fish	394	$ 581.75
Stenopus pyrsonotus	Flameback Coral Shrimp	Invert	386	$ 1,584.50
Gobiidae sp.	Goby	Fish	382	$ 814.75
Chaetodon trifascialis	Chevron Butterfly	Fish	374	$ 1,054.40
Foa brachygramma	Bay Cardinalfish	Fish	370	$ 486.75
Abudefduf sordidus	Blackspot Sergeant	Fish	355	$ 101.50
Acanthurus thompsoni	Thompson's Surgeonfish	Fish	354	$ 367.50
Crayfish	Crayfish	Invert	346	$ 0.01
Plectroglyphidodon johnstonianus	Blue-eye Damselfish	Fish	335	$ 327.25
Cheilodactylus vittatus	Hawaiian Morwong	Fish	329	$ 605.55
Apogon sp.	Cardinal fishes	Fish	293	$ 281.25
Jellyfish	Jellyfish	Invert	283	$ 273.25
Bubble Shells	Bubble Shells	Invert	240	$ 259.25

Taxa	Common Name	Type	# Caught	Total Value
Myrichthys magnificus	Magnificent Snake Eel	Fish	223	$ 848.25
Conger cinereus	Mustache Conger	Fish	222	$ 711.50
Naso hexacanthus	Sleek Unicornfish	Fish	202	$ 311.50
Grammistidae	Soapfish	Fish	195	$ 473.00
Octopus cyanea	Day Octopus	Invert	187	$ 1,150.00
Thalassoma purpureum	Surge Wrasse	Fish	186	$ 540.00
Naso brevirostris	Paletail Unicornfish	Fish	173	$ 331.00
Chanos chanos	Milkfish	Fish	169	$ 1,171.00
Syngnathidae	Pipefish	Fish	167	$ 147.50
Malacanthus brevirostris	Flagtail Tilefish	Fish	160	$ 636.60
Sebastapistes coniorta	Speckled Scorpion	Fish	156	$ 236.15
Chromis leucura	Whitetail Chromis	Fish	151	$ 144.95
Plagiotremus ewaensis	Ewa Fangblenny	Fish	141	$ 261.00
Gymnothorax steindachneri	Steindachner's Moray	Fish	124	$ 372.50
Gymnothorax rueppelliae	Banded Moray	Fish	123	$ 400.00
Monotaxis grandoculis	Bigeye Emperor	Fish	123	$ 330.25
Acanthurus leucopareius	Whitebar Surgeonfish	Fish	118	$ 172.90
Thalassoma lutescens	Sunset Wrasse	Fish	117	$ 344.95
Chromis hanui	Chocolate-Dip Chromis	Fish	109	$ 85.00
Stegastes fasciolatus	Pacific Gregory	Fish	100	$ 57.50
Ophichthidae	Snake Eel	Fish	97	$ 417.50
Iniistius sp.	Razor fish	Fish	97	$ 268.05
Acanthurus nigroris	Bluelined Surgeonfish	Fish	94	$ 392.00
Gymnothorax melatremus	Dwarf moray	Fish	93	$ 3,229.50
Brotulidae	Salt-water Cat	Fish	92	$ 197.25
Acanthurus xanthopterus	Yellowfin Surgeonfish	Fish	89	$ 200.00
Mulloidichthys flavolineatus	Yellowstripe Goatfish	Fish	86	$ 135.00
Blenniella gibbifrons	Bullethead Rockskipper	Fish	86	$ 114.50
Caracanthus typicus	HawaiianOrbicular Velvetfish	Fish	80	$ 95.75
Plagiotremus goslinei	Gosline's Fangblenny	Fish	75	$ 149.50
Cymolutes lecluse	Hawaiian Knifefish	Fish	70	$ 211.50
Upeneus arge	Bandtail Goatfish	Fish	65	$ 86.20
Apogon kallopterus	Iridescent Cardinalfish	Fish	63	$ 42.50
Doryrhamphus excisus	Blue-stripe Pipefish	Fish	61	$ 129.25
Apogon maculiferus	Spotted Cardinalfish	Fish	61	$ 23.50
Acanthurus guttatus	Whitespotted Surgeonfish	Fish	60	$ 829.50
Parupeneus cyclostomus	Blue Goatfish	Fish	49	$ 74.25
Uropterygius sp.	Snake Moray	Fish	47	$ 195.00
Istiblennius sp.	Blenny	Fish	44	$ 65.50
Spratelloides delicatulus	Delicate Roundherring	Fish	41	$ 109.00
Genicanthus personatus	Masked Angelfish	Fish	39	$ 2,829.50
Elagatis bipinnulata	Rainbow Runner	Fish	31	$ 26.00
Sargocentron punctatissimum	Peppered Squirrelfish	Fish	27	$ 15.25
Oxycheilinus unifasciatus	Ringtail Wrasse	Fish	26	$ 43.50
Apogon erythrinus	Hawaiian Ruby Cardinalfish	Fish	26	$ 32.50
Apogon menesemus	Bandfin Cardinalfish	Fish	26	$ 4.00
Cantherhines verecundus	Shy Filefish	Fish	25	$ 53.75
Epinephelus quernus	Hawaiian Grouper	Fish	16	$49.00
Kyphosus sp.	Sea Chub	Fish	12	$ 36.00
Parupeneus bifasciatus	Doublebar Goatfish	Fish	12	$ 16.00
Decapterus macarellus	Mackerel Scad	Fish	12	$ 12.00
Scarus rubroviolaceus	Redlip Parrotfish	Fish	10	$ 51.00
Neomyxus leuciscus	Sharpnose Mullet	Fish	5	$ -
Mugil cephalus	Striped Mullet	Fish	4	$ 4.50

Taxa	Common Name	Type	# Caught	Total Value
Hemiramphus sp.	Halfbeaks	Fish	2	$ 80.00
Lutjanus fulvus	Golden Perch	Fish	2	$ -
Plectroglyphidodon sindonis	Rock damselfish	Fish	2	$ -
Polydactylus sexfilis	Six-fingered Threadfin	Fish	2	$ -
Tetraodontidae	Pufferfish	Fish	1	$ 8.95
Elops hawaiensis	Hawaiian Tenpounder	Fish	1	$ 2.00
Pseudocaranx dentex	Thicklipped Jack	Fish	1	$ 2.00
Ranina ranina	Kona Crab	Invert	1	$ 2.00
Baitfish	Baitfish	Fish	1	$ -
Unknown Fish spp.	Unknown Fish spp.	Fish	7,655	$ 17,557.30
Unknown spp.	Unknown spp.	???	5,318	$ 5,739.65
Unknown Invert spp.	Unknown Invert spp.	Invert	876	$ 953.00

From: pfouce@aol.com
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda item F.1
Date: Wednesday, October 6, 2021 3:43:59 AM

Aloha Board Members,

I oppose the EIS as invalid, illegitimate, in disregard of HEPA and the Hawaiian culture and in disregard as well to the environmental impact requiring assessment, as ruled by the Supreme Court of the State of Hawaii.

Chair Case, this trade is against the will of the people of Hawaii, the aquarium trade should stop in Hawaii.

The powers that be have been using the claim of “sustainability” for too long, at the expense of Hawaii public trust, for the benefit of commercial interests, in this case outside the State of Hawaii.

The aquarium trade only takes from Hawaii and leaves nothing. People around the world have Hawaii in their hearts and come here to leave a billion dollars annually on reef activities that take nothing away from Nature, and cause no harm to the environment, ocean, reef and wildlife species.

Thank you,
Paula Fouce

From: Dragonoire
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Re: Stop the outrageous stripping of Hawaii"s national resources!
Date: Sunday, October 3, 2021 5:57:22 PM

Stop the pilfering of Hawaii's marine life and decimation of natural resources. Every time another species of fish is eradicated another

death knell for our environment is struck.

Shame for allowing and encouraging these immoral and criminal practices by the aquarium trade for instant gratification with no regard

for our environment. In the sake of common decency, stop it now!

Sincerely,

Dayle Friedman

From: Spectrum
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Oahu’s FEIS
Date: Monday, October 4, 2021 5:24:04 AM

Aloha Board Members,
My name is Glenn Fukuda and in support of this EIS. I’ve been a fisherman most of my 70 year life and my interest is in attaining the highest sustainability for aquarium fish, which is probably the reason for my longevity. It barely provides a normal livelihood for my wife and 99 year old mother but the physical and adventurous unknowns keep my interests high. Of course, I see no end in fish supplies through my years of fishing so puzzled why we are guilty of it and the urgency to punish these fishermen with no income especially when this pandemic usher financial aid to everyone else. Where is the evidence for these actions, but excuses to condemn our industry while all other fishing and permitted ocean activities are not required to go through this process and stipulations we are required to obey. Oahu fishers are a model fishery who care to keep our industry sustainable by keeping ocean and harbor use to a minimum. Please approve this EIS to restore our livelihood which was savagely taken away. I would like to present an oral testimony at the land board discussion of Oahu’s FEIS on October 8th. Thank you
Glenn t Fukuda #01738
gfukuda@twc.com

Sent from my iPad

From: Shawna Gaskins
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Testimony on behalf of Oahu FEIS
Date: Tuesday, October 5, 2021 2:05:33 AM

Aloha,

We want to encourage our BLNR committee to approve the impact statement and cease the tropical fish ban here in Hawaii IAW Hawaii Administrative Rules Title 13, Department of Land and Natural Resources, Subtitle 4, Fisheries, Part IV, Fisheries Resource Management, Chapter 77, Oahu Aquarium Life Management.

My testimony is on behalf of my Uncle Dave Ramos who has been fishing in our Hawaiian waters for 35 years and counting. His expertise and intricate process he uses to gather tropical fishes for aquariums are handled with care and his methods are of the utmost importance to support the aquatic ecosystem with thriving fishes in Hawaii.

I would like to recommend that experts in the field of aquatic aquarium fishing in the waters of Hawaii be permitted to provide their expertise in helping the BLNR provide a fair assessment and decision on this matter.

We want to ensure that unnecessary restrictions are not inadvertently discriminatory towards our aquarium fisherman from other licensed fisherman's like freshwater or marine life fisherman.

We are asking for a fair assessment of the impact assessment to be approved for our Aquarium fisherman to continue to provide tropical fish to our children and people of Hawaii who may have a love for the ocean and life within it. Our people and children may have a desire to have aquarium fishes to cultivate future fisherman, scientist, EPA activist, conservationist, zoo's, educational purposes, or occupations as saltwater or marine life fisherman's… etc.

We hope the limitations of aquarium fishing does not affect these organizations or educational environment with a lack of resources.

These are just a few examples we hope your committee can incorporate into your decision-making on whether or not BLNR will be in favor for my uncle Dave's plea as a veteran fisherman.

I appreciate this opportunity to support this cause and wish you and your committee the best of luck on your decision.

Mahalo,
Shawna Gaskins

Sent from my iPhone

From: Michael Gast
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] In opposition to EIS
Date: Monday, October 4, 2021 7:24:24 PM

To whom it may concern.
I am a Hawaii resident and an ardently opposed to the EIS prepared by the aquarium industry.
- Michael Gast

Sent from my iPhone

From:	Laura Gerwitz
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Please don"t allow aquarium collecting
Date:	Saturday, October 2, 2021 2:42:51 PM

Aloha,

I am a Honolulu resident of 30+ years. I went snorkeling on my first visit to Hawaii in 1986 and was entranced by the beautiful fish I saw. Now that I live here, I snorkel twice a week and love seeing the marine life - fish, eels, turtles, rays. Please do not allow aquarium collecting. It is not a sustainable pursuit and moreover, endangers and hurts the fish.

Sincerely,
Laura Gerwitz
Honolulu, HI

From:	michael gilbert
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Fish Collecting
Date:	Saturday, October 2, 2021 6:56:10 AM

Aloha I'm a Hawaii resident and my family all live here.
The fish collection is terrible reject this as it strips our reefs
I have watched them personally do this at Makena landing in Maui over the years and first hand saw the result.
Stop Stop Stop
Reject restarting this so short sighted rape of our reefs which are already in decline
Michael Gilbert MA.CR
981 Kupulau Dr

Sent from my iPad

From:	karen spachner
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F1 Testimony
Date:	Sunday, October 3, 2021 12:34:28 PM

Dear People Concerned in This Vote,

Please reject the EIS. As a tax paying citizen for 30 years I am concerned about our marine systems. I have noticed a considerable reduction of precious reef fish over the years. Generations to come will hold us responsible for this tragedy. The very survival of our systems is at stake.

Yours truly in Aloha, Karen and Craig Goard

From:	Melanie Goetz
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Save the reefs
Date:	Wednesday, October 6, 2021 5:31:16 AM

Hello,

We spent over 60% of our awake hours this last week snorkeling in Maui and while it was truly amazing seeing 3 white spotted eels, 1 moray eel, 40+ sea turtles, an octopus, a sea snake, and so many tropical fish, the color of the coral wasn't much of a contrast to the sand. I remember vibrancy in the coral growing up. I'm one of the many San Dieagans that grew up with Hawaii being our go to summer vacations. This time, if the color wasn't similar to the sand, it was lighter. I was so glad to see so many signs about what to avoid in sunscreens. And to see only reef friendly sunscreens sold in Maui. However, travelers still packed unfriendly sunscreens into check-in luggage and sprayed it on right before going in. Others treat the reefs as places to stand to catch their breath. It would truly be awesome to have a 5 minute educational video of getting into the water and staying horizontal above reefs, of swimming away to a sandy area if you need to go vertical for a breath or readjust gear. Something that teaches distance from turtles and reef to continue protecting the reef and all its' inhabitants.

Thank you for what you have already done, are doing, and can continue to do to help the reefs!

Peace be with you,
Melanie Goetz

From: Z. Gonsalves
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] In favor and support tropical fisherman!
Date: Monday, October 4, 2021 4:02:05 PM

Aloha,

My name is Lucas, born and raised in Oahu, Hawaii! I am in favor for the Aquarium Tropical fisherman EIS as I have dived many Hawaiian islands waters and have seen many tropical fish. I feel that what these fisherman/ fisherwoman are doing is "Pono" is the greatest possible solution for them to keep there livelihood!

Mahalo

From: James Grainger
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda item F.1
Date: Tuesday, October 5, 2021 9:18:57 PM

Dear Hawai'i BLNR:
Re: Agenda item F.1

I oppose the Environmental Impact Statement as invalid, and illegitimate, and in disregard of the Hawai'ian culture as ruled by the Supreme Court of the State of Hawai'i. The Pet Industry Joint Advisory Council prepared the document seeking permits on behalf of 10 individuals. The Board of Land and Natural Resources has the discretion and authority to prevent the issuing of aquarium permits" through the Hawai'i Constitution.

The claim of "sustainability" has been used for too long, at the expense of Hawai'i public trust, for the benefit of commercial interests. The aquarium trade only takes reef wildlife from Hawai'i and leaves nothing. People around the world have Hawai'i in their hearts and spend a billion dollars annually on reef activities that take nothing from the reef. Hawai'ian reef wildlife should remain in the waters of Hawai'i, not in glass tanks globally.

Sincerely,
James Grainger
Reef Wildlife Lover

From: Angela Grater
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] EIS Testimony
Date: Tuesday, October 5, 2021 6:24:13 AM

Hello,

My Sister is a resident of Hawaii as well as many friends we both have. We are all in opposition of the current EIS in place for Hawaii.

Kind regards,
Angela M Grater
--
Angela Grater
(717) 916-1745
graterangela@gmail.com

From: Kelly Greene
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Hawaii reef species need protection
Date: Tuesday, October 5, 2021 5:44:01 AM

I oppose the EIS that was recently done in Kona. This is not in the best interest of the reef species that are suffering from aquarium extraction- to include the Hawaiian dascyllus, which deserves our protection. This is simply not sustainable. Aquarium extraction kills reefs- this is a proven scientific fact. Please do the right thing on behalf of our beautiful Hawaiian reef habitat.

From: Daniel Greenwald
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1
Date: Tuesday, October 5, 2021 11:12:28 AM

To whom it may concern,

I oppose the aquarium extraction. I believe that it would have deleterious effects on the reefs and on vulnerable species of fish. In the interest of preserving the habitat, please vote against the extraction.

Thank you,
Daniel Greenwald

From: Michael Greenwald, Ph.D.
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Environmental impact statement and reef extraction
Date: Tuesday, October 5, 2021 4:47:23 AM

I am a property owner in Hawaii and a regular visitor. I strongly oppose the environmental impact statement and the aquarium extraction plan. Please protect the Hawaii reefs and fish life and do not permit the aquarium extraction. Thank you very much.

Regards,

Michael Greenwald

From: Gregg G
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] I Strongly Oppose Aquarium Fish Collection on Oahu
Date: Tuesday, October 5, 2021 5:04:56 PM

Obviously, Board members have not been snorkeling Oahu and Hawaii Island since the 80s like myself.

If you had, you would easily see the vast reduction in fish populations.

This practice IS NOT sustainable!

I urge you to vote NO this Friday!

Mahalo-Gregg Gruwell, Hawaii resident

From: Briana Hanashiro
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] EIS
Date: Monday, October 4, 2021 8:23:29 PM

To Whom It May Concern,

I, Briana Hanashiro, support the Oahu Tropical Fish EIS.

Sincerely,
Briana Hanashiro

Sent from my iPhone

From:	Jenna Hancock
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1 Testimony
Date:	Tuesday, October 5, 2021 12:54:39 PM

Aloha,

My name is Jenna Hancock and am a marine scientist and resident of the Big Island Hawaii and I am writing to ask BLNR to **REJECT the EIS!**

I am concerned that allowing the aquarium trade to open back up again it will completely crash the already fragile ecosystems that we have here in Hawaii. Already on the reefs, the fish populations are so small that you can count the individual fish. This is not how the reef populations should be. One big concern I have is for the Pyramid Butterflyfish at Robs reef. I fear someone has already come out and collected a big number of them in the past year. This past February we saw very large schools of them on our weekly snorkeling trips of the Hula Kai vessel out of Keauhou Bay. In the past weeks, we are seeing numbers of approximately less than 50 individual fish. I fear humans do not know when to stop taking from the ocean as we all are already seeing the impacts of the mistakes we've made before. If aquarium collectors want more tropical fish they need to put the time and money into learning how to reer them themselves. Here on the Big Island, we have the prime location to do those things in the Hawaii Ocean Science Park / NELHA area. **The aquarium industry needs to look outside of the ocean for their resources and follow the path that Biota Aquariums is paving**. They take nothing from the ocean but actually give back to it through their aquaculture practices. Taking the fish out of the ocean in no way shape or form benefits those who live on our islands and actually negatively impacts the tourism industry that we do have. The fish need to stay in the ocean and we need to learn how to grow them ourselves and get the natural populations back where they historically were.

Best Fishes,
Jenna Hancock

From: michael hazard
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1
Date: Tuesday, October 5, 2021 11:58:49 AM

To Whom It May Concern,

As a resident of Hawaii, and a professional in the dive tourism and education industry, I hope you will REJECT the EIS. The aquarium trade is an inhumane industry that exploits Hawaii's natural resources with no real benefit to its people or economy, no connection to traditional Hawaiian harvest and resource management practices, and significant detriment to its environment. A fish is worth so much more on the reef! Please don't let this wasteful, cruel, and exploitative practice continue. We must strive to be good stewards of the land (and sea).

Mahalo for your attention to this matter.

Sincerely,

Michael S. Hazard

808-430-4119
mongodiver@gmail.com

October 6, 2021

Testimony in opposition to the acceptance of EIS for Aquarium Trade on O`ahu

Aloha Chair Case and members of the BLNR,

I urge you to reject the EIS for the aquarium trade on O`ahu because it is legally flawed as it relies on insufficient, faulty, inadequate, and improper data and assumptions.

Poor Data and Improper Analyses:

1) The EIS fails to disclose the high degree of scientific uncertainty in the estimated fish populations used in the analyses. This is a critical issue that was highlighted by the NOAA team that provided the data for the EIS, and which described the quality of data as ranging from “marginal” to “terrible” for a majority of fishes on the proposed new White List.
2) The EIS repeatedly refers to fish populations as “possibly being underestimated”, never disclosing that according to the NOAA team, fish populations are just as likely to be overestimated. The EIS uses take as a % of island-wide fish populations to assess impacts and ignores the fact that collectors often heavily target a few areas—potentially wiping out entire species in just one area. This would create impacts that are far worse than the hypothetical “island-wide” collection that is proposed.
3) The EIS fails to accurately analyze the environmental consequences of their plan, claiming that less than 4.5% of the island-wide populations of 31 fish species would be taken, when in reality, far more would be taken from specific areas.
4) The EIS proposes zero analyses for 3 fish species on the White List, and for all 4 invertebrates because there are no population estimates for them. Still, it proposes annual take of nearly 5,000 individuals of those fish species, two of which are endemic, and rare, due to the trade, and proposes annual take of 200,595 hermit crabs, cleaner shrimps, and feather duster worms -- all important cleaners of our coral reef ecosystem.

Excessive Take Limits:

The EIS proposes levels of take that far exceed historical reported take: the highest annual reported take since 2000 was 53,920 fish -- by 42 collectors in 2015. The EIS proposes annual take that is nearly double that historical high: 92,238 fish -- by 15 collectors.

Cultural Impact Assessment (CIA):

1. The CIA stated substantial prohibited areas yet NO prohibited areas proposed in the EIS.
2. The CIA was based on an alternative that was never proposed in the EIS where collection would be prohibited in four zones (representing 21% of windward O‘ahu’s coastline). Therefore, consultation was requested with those having knowledge or those involved in cultural practices occurring anywhere EXCEPT those excluded areas.

Additional Issues:

1) The EIS fails to accurately analyze the cultural and socioeconomic consequences of aquarium collection on Oʻahu and ignores the research showing that Hawaiʻi residents receive ZERO benefits from the trade, but suffer ALL the costs
2) The EIS fails to propose any mitigation or meaningful alternatives that would reduce the impacts
3) The EIS fails to adequately incorporate input of Native Hawaiian cultural practitioners, experts, community members, and consulted parties
4) The EIS proposes no enforcement or compliance measures, even though DLNR requested that, and that numerous collectors have been charged with poaching.

Thank you for your time and consideration,

Kawika Winter, PhD
Reserve Manager, He`eia National Estuarine Research reserve

From: Grant Heidrich
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1 Testimony
Date: Saturday, October 2, 2021 5:51:58 AM

I am a substantial landowner in Hawaii and I am writing you to ask the BLNR to REJECT the EIS!

I am a lifetime lover of the ocean and all things in it, and I have profound respect for the natural resources in our great state. The ongoing extraction of ornamental fish from our reefs is not only an environmental disaster, but is in conflict with our native Hawaiian practices- this extraction ignores our kuleana, and must be stopped.

For the sake of our community today, and the prosperity of our people and resources in the future, reject this EIS- it is poorly done, and has flawed documentation.

Thank you for your consideration,

Grant Heidrich

From: JEANNETTE HEIDRICH
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1 Testimony
Date: Tuesday, October 5, 2021 3:21:28 AM

I am a resident of Hawaii. I urge you to reject the EIS! Our oceans are depleted of the beautiful fish targeted for collections for aquariums. Please let the oceans rest and restore themselves and bring the fish back
thank you
Jeannette Heidrich

From:	Jeanne Herbert
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F1 testimony
Date:	Wednesday, October 6, 2021 2:20:14 PM

Aloha,
I am a resident of Oahu, Hawaii and I would like to go on record as being 100% against aquarium collecting in Hawaii. As Hawaii becomes ever more aware of the importance of sustainability on our ‘aina and our oceans, aquarium collecting is against everything our community is working towards. Just look at the “try wait” program on the Kohala coast and the positive impact that program has had on our reef fishes. It doesn’t make sense to continue to allow our marine life to be decimated by aquarium collectors. There is no good reason to allow these negative impacts on the health of our reefs and fishes.

Please decide against reopening Hawaii’s aquarium fish collecting!

Mahalo,
Jeanne Herbert

From: Nataliaemi Hirai
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Re: Agenda item F.1
Date: Tuesday, October 5, 2021 4:38:45 PM

Dear Hawai'i BLNR:

I oppose the Environmental Impact Statement as invalid, and illegitimate, and in disregard of the Hawai'ian culture as ruled by the Supreme Court of the State of Hawai'i. The Pet Industry Joint Advisory Council prepared the document seeking permits on behalf of 10 individuals. The Board of Land and Natural Resources has the discretion and authority to prevent the issuing of aquarium permits" through the Hawai‘i Constitution.

The claim of "sustainability" has been used for too long, at the expense of Hawai'i public trust, for the benefit of commercial interests. The aquarium trade only takes reef wildlife from Hawai'i and leaves nothing. People around the world have Hawai'i in their hearts and spend a billion dollars annually on reef activities that take nothing from the reef. Hawai'ian reef wildlife should remain in the waters of Hawai'i, not in glass tanks globally.

Sincerely,

Natalia Emi Hirai

From:	Haley Hitchcock
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Eis Testimony
Date:	Wednesday, October 6, 2021 9:02:14 PM

Aloha my name is Haley Hitchcock and I support this eis! I believe it is the right for people in Hawaii to live off the land and the sea along as it's done in a sustainable manor and managed by the Dlnr.

Mahalo!

From:	Cheryl Hopkins
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1
Date:	Thursday, October 7, 2021 2:44:06 AM

Please reject the plan to remove fishes from the wild and sell them to aquariums!
It is distressing to have yet another exploitative event happen to remove fishes from their natural habitat and by purposely invading Nature's natural ecosystem, UPSET the natural balance in the Ocean! This goes against trying to save the environment and instead is another step toward harming the ecosystem whereas Hawaiin's don't even benefit from this scheme!

I will NEVER visit Hawaii again and support tourism that your state depends on!
This is revolting!

Please, use positive creativity and take action that benefits the Ocean and it's precious inhabitants instead of forcing destruction upon it, all for "humans" greed and ignorance!

Please stop this!

cheryl hopkins
tweeter617@gmail.com

From:	Bill Horton
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Oahu Final Environmental Impact Study(FEIS): Testimony in support of Oahu"s acceptance of the EIS recommendations: Friday, October 8, 2021
Date:	Sunday, October 3, 2021 11:49:40 AM

Dear Members of the Hawaiian Board of Land and Natural Resources (BLNR):

As an environmental advocate and supporter of sustainable fisheries, I urge your approval and acceptance of the Oahu Final Environmental Impact Study to be presented to the BLNR on Friday, October 8, 2021.

There are many factors that support acceptance of the FEIS; the most significant of these include:

- In concert with the Division of Aquatic Resources (DAR), the allowed catchable species has been substantially lowered – with the 'white list' of collectable species reduced from 504 to only 34 fish and 4 invertebrates. The significance of the white list reduction is further reflected by the reduction in the requested number of aquarium permits (15) as compared to the commercial permits issued by the DAR in 2020 (491).
- Other mitigation strategies, such as professional practice standards for net setting that avoid coral damage, as well as coral density and anchoring guidelines, will prevent any negative impact to these sensitive resources.
- As important as the environmental considerations are, acceptance of the EIS will also have a major economic impact. For example, aquarium fisheries fully support the development and growth the local aquaculture industry – without the fisheries there is insufficient brood stock required to sustain operations.

Also, aquarium fishing is performed sustainably with 100% of outside money sources remaining in the local community in support of working families and local businesses. With the fishery closed, fisherman have had to find supplemental work/income sources. In concert with the limitations created by the pandemic, it has been a difficult time for many. Acceptance will allow these families and businesses to remain self-supportive.

In summary, your support and acceptance of the Oahu FEIS is needed. Over 20 eminent scientists have already provided their support and championed for its acceptance. This fishery can be a worldwide example for its sustainable practices, and serve an ambassadorial role in encouraging future Hawaiian visitors to see the beauty the islands offer.

Thank you in advance for your support.

Bill Horton
Principal, Eastward Point Consulting
Bill.horton811@gmail.com
4201 48th Ave South
St Petersburg, Fl. 33711

Sent from Mail for Windows

From: Heather Huitt
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Reject the EIS!
Date: Tuesday, October 5, 2021 3:29:16 AM

Dear Board,

As a former collector of saltwater fish from the age of 9 onward for over 30 years, I feel I have the experience to give a knowledgeable testimony. I can tell you that even with the best of conditions; clean water, proper temperature (chiller required to do this as room temp in Hawaii on average is too warm); proper filtration, large enough tank (minimum 75 gallons); the list goes on; most aquarium fish from Hawaiian waters do NOT survive long term. Many collectors do not have the resources to maintain the fish properly as all the required mentioned items are quite costly.

The diets of these fish are often extremely specialized and impossible to duplicate; even the hardiest of species may only survive a few years. It is a travesty to keep these often spectacular and unique ocean creatures of the wild in captivity.

This entire business needs to go away! I stopped keeping fish after realizing it was really cruel to do so; nothing more. Please do Not continue to sustain this industry! It must be shut down!

One last note; I live on Kaneohe Bay and watched the additional decimation of the feather duster population. I won't name the store but they were collecting them from in front of my house and selling them. I haven't seen one for years.

Mahalo for your time and I hope you make the right decision for the environment, not profit.

Aloha, Heather Huitt
Sent from my iPhone

Sent from my iPhone

Aloha,

My name is Adrienne Isham. I am the wife of an aquarium fisher, resident of O'ahu and a native Hawaiian. Our lives have been disrupted having to defend our way of living and defend the right to gather resources from the island with our time and money. The negative impact on my household income reached a breaking point after the January 2021 ruling that the Commercial Marine License was invalid. My husband's sole source of income in his business was suddenly illegal, and he subsequently filed bankruptcy.

I support this FEIS and am asking for the reissue of Commercial Aquarium Fishing permits and Commercial Marine Licenses.

In the FEIS 4.4.8 (pg 83) it states, **no species** collected by aquarium fishers occur on the state or federal list of threatened and endangered species. DATA SHOWS THAT NONE OF THE FISH SPECIES THAT THE CML HOLDERS CATCH ARE THREATENED.

In the FEIS 4.4.4 - 4.4.4.7.5, each of the species detailed in these sections were identified as not having threatened populations. DATA SHOWS THAT NONE OF THE 33 SPECIES OF FISH AND ADDITIONAL SELECTED MARINE LIFE (EG INVERTEBRAE) STUDIED ARE THREATENED.

The data in the FEIS show minimal impact. It is not reasonable to dismantle an entire industry that has minimal negative impact, and promises even less impact when the terms of the FEIS are implemented. Less than 1% take on majority of the white list with a few exceptions is a more than reasonable and sustainable proposal. The aquarium fishers have always spoke of the data from their experience, and now there is the **science** to back it up. Please allow them to resume lawful, responsible and sustainable commercial fish collection.

From a **cultural** perspective, I'd like to point out:

1) The right to gather resources (in this case, aquarium fish) is constitutionally protected as it is "exercised for sustenance" (our income, purchase of shelter and food) pursuant to HRS 1-1 and 7-1, and article 12-7 of the Constitution of the State of Hawaii.
2) This right is being exercised on undeveloped or less than fully developed area (ocean, shoreline)
3) This right is exercised consistent with traditional values, as in **Native Hawaiian Conservation values**. This is demonstrated during common fishing practices and as aquatic licensees comply with DLNR regulations
    a. MANA'O'I'O (faith, respect for nature): This is a must if you want the ocean to keep providing for you year after year. We are a vulnerable outsider asking for a share. Data from fishers catch reports to DLNR show consistent populations, small and temporary

fluctuations, not declines which reflect the institution of this value. Without this value, the resource would perish.

b. KAPU: AFR's already in place
c. NOA (that which is not kapu but considered sacred): There is general knowledge among fishers which areas are off limits or to be avoided (in addition to AFRs). This includes areas recently fished to allow area to replenish, and sanctuary areas designated by "gentlemen's agreement."
d. 'IKE (knowledge): filing reports for data collection provides 'ike. The FEIS supported by the fishers provides 'ike. Fishers provide 'ike through communication, meetings, discussing trends, sharing information, supporting each other and helping each other be PONO in the collection of fish and care of the ocean.
e. 'AINA (that which feeds and provides sustenance, which refers to all Earth, including her Ocean): to comply with and support DLNR is to quite literally practice the conservation value of 'aina.
f. LOKAHI (unity, harmony, balance): DLNR is obviously a department that exists to assist in the balance and harmony between population and 'aina. The aquarium fisherman have hui'd together to work towards lokahi in their goals for management and sustainability in the industry by developing their own white list and catch limits.
g. MALAMA: Common core values of malama the ocean among fishers are: No one owns the ocean, no one owns a dive spot; It is shared, and the bounty is also shared. To care for it is to not over-exploit it.

Please pass this FEIS.

Mahalo,

Adrienne Isham

Aloha,

My name is Jerry Isham, and I fully support this EIS.

I am a proud Fisherman for the past 30 years since I was a teenager. I have done over 25,000 dives in my life and know what the entire coastline looks like from Hawaii kai all the way around the west side up to Mokuleia from 10ft out to 120ft.

I feel this industry is the most Pono, eco and animal friendly wildlife fishery in the state and is an example to similar fisheries around the world. We rotate our fishing grounds and take only what we need with no bycatch or waste. Our fish need to be in 100% pristine condition to sell and our fish being sold alive allows, others around the globe to enjoy them as well letting the fish live out the rest of its life in an aquarium while still feeding my family, this in my book is a (Win Win) and to me the definition of Pono.

Oahu does not have user conflicts with the tourism industry due to the large reefs that extend as far out as 2 miles from shore. Aquarium fisherman on Oahu normally stay as much as a mile away from all tourist dive areas to stay away from user conflicts as well as staying away from those areas that are mostly inhabited by larger marine fish due to tourist feeding.

As an Example, if you were to open aquarium collecting in Hanauma bay I wouldn't even waste my time because mostly big fish live there. In fact, most divers have great relations with some of the dive shops. I can't tell you how many times I've personally took a tourist to shore or back to the harbor due to motion sickness or even something as little as taking a person's lunch out to them that they have forgotten. Or asking the dive charter loan me a mask or weight belt that I have left at home by mistake.

People always talk about the negative impact's fisherman have on the environment; well, I'd like to share some of the positive impacts we do for the environment. Personally, I've been on 2 Ghost net clean ups on the west coast and at least 2 dozen Beach clean ups over the years with my friends and family during church activities. I've saved probably almost a dozen turtles tangled in cargo netting or fishing line in my life time and can't even express the amount of trash and cargo nets my crew and I have pulled out of the ocean. My Dad always taught my family it's our responsibility, we use the ocean and we need to take care of it. I'm a firm believer in no house! no fish! So, Coral damage is ever accepted.

I come from a family fisherman and one of the 1st things my dad taught me is how to rotate my fishing grounds allowing the reef to rest. He said we are really like underwater farmers and we would start at certain areas and not go back till the next season allowing it to replenish. If we even saw a diver in the area previously, we would avoid that area for a while. As aquarium fisherman we have a preorder list that the customers are looking for and roughly 15-40 min depending on dept we are diving per Tank to collect as much healthy fish our orders are asking for. So, because of this we target the easier fish to get in the lower coral density areas, High coral density areas make it extremely difficult to catch if your able to catch them at all so we fish away from those areas.

All the money I make is spent here on the Island and goes right back into the economy. As you all know we are going through some of the most economic challenges of our life time with Covid and the cost of living in the Islands going up every year forcing most of my Kapuna and family to move off Island and into the mainland. Without the $ I make from this industry since January I've been forced to file for Bankruptcy and the Job, that I currently have is just not enough to provide a living for my family.

I have donated fish personally to the Waikiki aquarium as well as food fish and tako to friends that are houseless at Waianae harbor never taking a Dime! This is my way of giving back to the community.
The opposition is not looking for a sustainable fishery, their goal is to create a total world reserve so no EIS, no matter the amount of Data will ever be accepted by them!

In closing I'd like to remind the land board that if anyone has any doubts or dislikes about the suggested takes or species on the EIS that it can be removed or adjusted in Permitting.

I totally support the Governors 30/30 plan and look forward to helping the DLNR create more FRA's on Oahu like the fishery on the Big Island and create an even more sustainable fishery for our Keiki.

Please pass this EIS!

Mahalo!
Jerry Isham

Aloha,

My name is Kelly Isham from Waianae and I am a 2nd generation fisherman and I fully support this EIS.

I am a Local husband and father who due to no fault of my own lost my entire way of providing a decent living for my family. Since losing my license I have been working 2 jobs and now having barely any family time and still falling short on generating enough income for my family. Since our industry/state has been ordered by the state to conduct an EIS, we the fisherman have done everything we can and spent what little savings we have on this EIS.

As people of Hawaii we have the right to live off the land and the oceans as long as it is well managed and which this EIS plan has. Everyone always blames the fisherman for a lack of fish at areas when actually its us fisherman who care the most about our fishing grounds because we have the most to lose

We do not only have negative effects on the environment Its us fisherman who are removing the most trash and invasive species like Taape and Roy that is harming our reefs, not the tourism industry or any of the animal rights activist here today. During the covid 19 shutdown there was a study at Hanauma Bay that hit the news and they found that since tourism was shut down fish populations went up and since reopening fish populations have now gone back down.

There is very good reason for this these spots unlike fisherman who rotate fishing grounds these areas are hit with human traffic on a daily basis and although some fish don't mind (usually because they are being fed), most fish leave the area for safety.

We do not even fish in tourist spots!

Now I want to be clear, I am not against the tourism industry in any way and know it is important to our Islands survival but like everything else it just needs to be properly managed. But as long as the focus of issues is just blaming fisherman the problem will persist.

Fishing is fishing it doesn't matter if your taking a fish for food or sell it to buy food!

I'd like to point out that from what I read about the court case the judge sided with the activist because there were no real limits. This EIS goes above and beyond to address not only limits but also creates a new white list to better manage our fishery.

Every aquarium fisherman I know on this EIS is willing to work with DLNR to help create the most sustainable fishery in the world.

Please pass this EIS

Mahalo!

From:	Maika Isham
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL]
Date:	Tuesday, October 5, 2021 11:23:59 AM

Aloha,

My name is Maika isham, and I support this EIS. To not support it would be to ignore all factual studies made by real scientists (not activists).

Mahalo.

Sent from my iPhone

From: Saidee Isham
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] I support this Eis
Date: Tuesday, October 5, 2021 9:11:33 PM

My name is Saidee Isham & I support this EIS.
I believe as long as the environment has been proven to be sustainable they should be allowed continue to do what they have been doing

To: Board of Land and Natural Resources
A Testimony is support for the Oahu FEIS

Date: October 5th 2021

My name is **Kevin Izumi**, I am the founder and President of **Reef and Ray Marine Inc.**

I support the passage of the Oahu FEIS

Reef and Ray Marine Inc. have been consultants to living exhibits to Public Aquariums for 25 years, where we provided live acquisition services for conservation education exhibits and scientific research facilities. We were active as Commercial fishers who fished Hawaii waters in our 25 years in operation. I ask that you approve the FEIS which you are reviewing on October 8th 2021. As you review the FEIS, I ask that you consider only the scientific data collected by the DLNR biologists and disregard the generalizations and misinformation claimed by the opposition to the fishery.

Powerful Animal Rights organizations combined with the Ocean-Use special interest groups supporting the Charter diving industry, have succeeded in pressuring Hawaii's policy makers in in temporarily shutting down the fishery. This abrupt move has negatively impacted numerous individuals and businesses, in the worst of times, those who are affected are now out of businesses or without jobs that support a livelihood for their families.

These opposition groups to the aquarium fishery, have engaged in the wrongful practice of creating a false negative perception to the public of the fishery through lies and misinformation. They are unethically ignoring true scientific data from previous research and field monitoring of the fishery by Hawaii's Dept of Land and Natural Resources (DLNR) reef biologists. I ask that you thoroughly review all testimony presented by the DLNR reef biologists and the scientific community and make your decision based on true factual data on the fishery.

DLNR has done an exemplary job managing the fishery for decades with regulations which allow reef fish to be collected in a sustainable manner. Their research data and fish population monitoring values have shown a continued stable reef fish population and a sustainable fishery. Aquarium reef fish species catch counts have not exhibited a declined throughout the years and the observed reef fish populations have not declined as claimed by the opposition but have increased significantly in locations where fish reproduction management protocols are in place.

The local fishers targeting aquarium fish all hold a Commercial Fishing License and adhere to strict guidelines and regulations on catch limits and regulations. Despite the fabricated public perception by the opposition groups, the local aquarium fishers have many incentives and a vested interest into protecting Hawaii's reef habitat and fish populations so that the fishery will continue to provide towards their livelihood. I ask that you continue to allow the Aquarium fishery to exist as it has and to understand that this fishery will continue to be well managed in a sustainable manner.

From: Raffy Jacinto
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Aquarium Fish Industry EIS Hearing 10/8/21
Date: Friday, October 1, 2021 7:44:32 PM

Aloha,

My name is Rafael Jacinto and I would like to state that I support the approval of this EIS. I believe it is the right of the people of Hawaii to be able to live off the land and the sea as long as it is done in a sustainable manner and managed by the DLNR.

As a child, I grew up fascinated by aquatic creatures and was able to make a lasting connection with the ocean through my care of home aquariums. I now have children of my own, who are equally interested in learning more about these things, but have lost the opportunity to even try sharing this experience with my kids because of a one-sided position held by others in the community about a shared natural resource.

I would like for there to be a balanced solution to this issue that is fair for all the stakeholders involved and not just giving attention to whoever shouts the loudest. Please give your fair consideration in the evaluation of this EIS and help those who support it work towards a fair solution.

Mahalo!

Rafael Jacinto

Sent from my iPhone

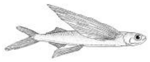
From:	GARY JOHNSON
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] SHOCKING THAT OURS SCARCE SEA CREATURES ARE BEING SOLD !
Date:	Saturday, October 2, 2021 12:23:28 PM

It is hard to believe that our scarce rare sea creatures are being sold to corporate businesses... I live on Maui and we have had a similar problem it seems to have gotten better however please don't let this happen on Oahu and of course not on Maui.

Mahalo nui

Gary Johnson
108 Kanani Street
Kihei Hawaii 96753
808-385-8040

From: Thomas Jung
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Hearing for Aquarium fishing in the state of Hawaii
Date: Friday, October 1, 2021 9:44:58 PM



von Wussow Importe *GmbH*

Haderslebener Str. 4a, 25421 Pinneberg, Germany, Tel.: +49 4101 789890 Fax.: +49 4101 789891, Mobil +49 171 5304060

Handelsregister Pinneberg HR B 5689 Geschäfsführer Thomas Jung, UStNr. 31/284/44459 UStID. DE813626383

Internet: www.vonwussowimporte.de Kunden: sales@vonwussowimporte.de shipper: import@vonwussowimporte.de

Dear Sir, Dear Madame,

pls let me introduce myself shortly. My Name is Thomas Jung and I am an graduated Fisheries biologist. After my studies I took over the aquarium fish wholesale "von Wussow Importe " in Germany. We bought fish from Hawaii since approx. 30 years.

We see a highly professional industry with a close to zero loss rate in our shipments! This is leading for the world industry !

The population is , after my information , monitored by the University of Hawaii and there was no impact on population size over all this years. That means it was a sustainable fishery!

We face reagrding fishing effort only price changes due to noraml price increasing all over the world until the regulation suffered catch!

We never faced no availability due to population crashes!

We always buy only 1 to 1.5 year old young fish, because it lives long in the aquarium and we do NOT want to suffer brood stock in the sea by harvesting spawning ready adults!

The endemic fishes of Hawaii do have a worldwide community of lovers who now are suffert from the regulation.

The USA is a developed country so that export control is no issue and electronic position tracking of boats to make sure the fishing grounds is also simple.

Please excuse my bad english writing and take in mind that Hawaii is a worldwide loved island! Let people overseas also take part in enoying Hawaiian underwater world!

Yours sincerely Thomas
Jung

Mālama Kaiaulu ʻo Kahaluʻu Your Roots

KAIAULU ’O KAHALU’U

KAHALU‘U, HI 96744 | KAIAULUOKAHALUU@GMAIL.COM | WWW.FACEBOOK.COM/KAIAULUOKAHALUU

October 6, 2021

TO: Board of Land and Natural Resources

RE: **Agenda Item F1**: Determination of whether the Final Environmental Impact Statement (FEIS) complies with applicable law and adequately discloses the Environmental Impacts of Proposed Issuance of Commercial Aquarium Permits and Commercial Marine Licenses for the Island of O’ahu, for the purpose of accepting the FEIS; dated August 20, 2021, Applicant Pet Industry Joint Advisory Council (PIJAC); Island of O’ahu, State of Hawaii.

Aloha Chair Case and Honorable Members of the Land Board,

On behalf of Kaiaulu ‘o Kahalu’u, a grassroots community organization based in Kahalu’u, we ask the Board to reject the O’ahu Aquarium Collection FEIS for the issuance of 15 aquarium permits and commercial marine licenses for failing to meet the legal requirements of HEPA and the corresponding Cultural Impact Analysis (CIA).

The FEIS proposes take of 461,190 fish from 31 fish species and 1,002,975 invertebrates from 4 invertebrate species by 15 collectors over 5 years on O’ahu. This amounts to nearly 1.5 million species being removed from our island’s reefs and oceans. Kāne’ohe Bay currently does not have capacity to accommodate the extraction of that many species.

While the sheer number of specific instances of noncompliance of applicable laws within the FEIS are shown in other testimonies such as the Earth Justice, we focus on one critical law. The FEIS clearly does not comply with the applicable Kapa’akai O Ka Aina Hawaii Supreme Court Law (Kapa’akai). For any Cultural Impact Analysis to be completed, the petitioner – in this case, the PIJAC, must complete the Kapa’akai O Ka Aina[1] Analysis.

[1] **Ka Pa‘akai O Ka Aina v. Land Use Commission, State of Hawai‘i, 2000, Supreme Court of Hawai‘i**

The Kapa'akai Analysis is used in determining whether traditional and customary practices would be impacted by petitioners.

<u>Findings of Fact and Conclusions of Law of the Kapa'akai Case</u>

- Identification and scope of "valued cultural, historical, or natural resources" in petition or impacted area, including the extent to which traditional and customary native Hawaiian rights are exercised in the petition area;

- The extent to which those resources, including traditional and customary native Hawaiian rights, will be affected or impaired by the proposed actions;

- The feasible action, if any, to be taken to reasonably protect native Hawaiian rights if they are found to exist.

The petition area in this case are all the marine coastal and ocean areas of the entire Island of O'ahu. These ocean and coastal areas have traditionally and continue to be used for cultural practices that would be seriously and critically impacted by this flawed Environmental Impact Statement with a Cultural Impact Analysis that is fundamentally wrong.

In order to comply with Kapa'akai, the petitioner (PIJAC) should have consulted with the generational families of each of the 88 ahupua'a that comprise O'ahu. Each one is distinct in its cultural practices in coastal areas, deeper ocean, land, wetlands and mauka summits. No generational practitioner from any specific ahupua'a was consulted. Even within the public notice that was put into the Ho'olaha Lehulehu article in July 2019, no practitioner from any specific ahupua'a was notified. Not one was consulted who is a lawai'a or cultural generational practitioner.

The people are comprised of their beliefs and are themselves an integral part of the natural resources and cannot be separated from them because the Akua, the land, and the people are one. They are the whole entity and not separate compartments. In this traditional protocol, the Kupuna of the 'Ohana, with their life experience, generational knowledge and wisdom are the guardians of their family knowledge and customs. This belief system is often not comprehended within the western thought process, yet it is the core of Hawaii State constitutional protection of the traditional and customary practices (TCP) of Hawaii.

We do not believe that the FEIS complies with the Kapa'akai Hawaii Supreme Court Law. Its CIA is an insult to the native Hawaiian culture and its practices – all of which are protected by the Hawaii State Constitution. But most importantly, this petitioner, as shown by this faulty FEIS, does not understand the core of the people of Hawaii. There is no mention of how they will give back to the people of Hawaii – the Public Trust through which native Hawaiians are included. We believe PIJAC only sees opportunities for monetary profit in this endeavor.

For these reasons, we ask that the Land Board REJECT the FEIS.

Me ka ha'aha'a,

Hi'iaka Jardine, Founding Member
Kaiaulu 'o Kahalu'u
(808)953-0307
kaiauluokahaluu@gmail.com

From:	liko kaluhiwa
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Fwd: FW: Testimony FEIS Aquarium Fish
Date:	Thursday, October 7, 2021 9:01:52 AM

---------- Forwarded message ---------
From: **Kahale CIV Kristi M** <Kristi.Kahale@usmc-mccs.org>
Date: Thu, Oct 7, 2021, 9:00 AM
Subject: FW: Testimony FEIS Aquarium Fish
To: kaluhiwaliko@gmail.com <kaluhiwaliko@gmail.com>

From: Kahale CIV Kristi M
Sent: Thursday, October 7, 2021 9:00 AM
To: kahalekristi@gmail.com
Subject: Testimony FEIS Aquarium Fish

VIA ELECTRONIC MAIL

Suzanne D. Case, Chairperson

Board of Land and Natural Resources

State of Hawaiʻi, Department of Land and Natural Resources

P.O. Box 621

Honolulu, HI 96809

blnr.testimony@hawaii.gov

RE: AGENDA ITEM F.1. Final Environmental Impact Statement (FEIS) regarding the Issuance of Commercial Aquarium Permits and Commercial Marine Licenses for the Island of Oʻahu; dated August 20, 2021, Applicant Pet Industry Joint Advisory Council (PIJAC); Island of Oʻahu, State of Hawaiʻi

Aloha Chair Case and Board Members,

Thank you for the opportunity to provide testimony regarding the Final Environmental Impact Statement (FEIS) submitted by the Pet Industry Joint Advisory Council (PIJAC) for the issuance of 15 aquarium permits and commercial marine licenses. I strongly urge the Board to **REJECT** the FEIS for failing to meet the legal requirements of Hawaiʻi Revised Statutes Chapter 343, specifically with regard to its Cultural Impact Assessment (CIA).

My family and I have been residents of the Koʻolaupoko ahupuaʻa for over 200 years. We are kupaʻāina and lifelong stewards of this place. I am a cultural practitioner. My ʻohana and I are lawaiʻa and we have passed on our cultural knowledge and practices to our keiki and our moʻopuna, who are also active cultural practitioners.

I am also a member of the Kāneʻohe Bay Regional Council (KBRC). The KBRC was established in statute by the 1993 State Legislature. It is administered by the Department of Land and Natural Resources and is charged with, in part, implementation of the Kāneʻohe Bay Master Plan as it relates to ocean use activities, to serve as the public advocate for Kāneʻohe Bay, and to advise and make recommendations to the State and the county on matters regarding use of Kāneʻohe Bay by the general public, marine research programs, and commercial ocean use activities, including legislative matters.

PIJAC's FEIS regarding the issuance of 15 aquarium permits and commercial marine licenses was never brought before the KBRC prior to today's deadline to submit written testimony. At no point during the EIS pre-consultation or cultural impact assessment consultation processes did ASM ever reach out to the Council for consultation on this matter. Because of the lack of early consultation and the failure to bring this issue before the KBRC, the Council is unable to fulfill its duty to fully advocate for Kāne‘ohe Bay with regard to this issue. Further, we are unable to fulfill our duty to advise the State on matters related to the proposed action's use of and potential impacts on Kāne‘ohe Bay. As such, I submit this testimony in my personal capacity.

I strongly urge the Board to **REJECT** PIJAC's FEIS for failing to meet the legal requirements of Hawai‘i Revised Statutes Chapter 343, specifically with regard to its Cultural Impact Assessment (CIA).

KANE‘OHE BAY MASTER PLAN (1992)

The proposed action in the FEIS directly conflicts with Kāne‘ohe's community-based management plans and objectives. In 1990, my ‘ohana participated in the Kāne‘ohe Bay Task Force Committee that drafted the Kāne‘ohe Bay Master Plan – a comprehensive master plan for Kāne‘ohe Bay developed through extensive public participation. The Master Plan recognizes that Kāne‘ohe Bay "is a recreational resource, an economic resource, a cultural and traditional Hawaiian resource, and a natural ecological treasure." (Master Plan, p. iv.) The Master Plan also recognizes that the Bay "is in serious jeopardy of being despoiled by over-exploitation" and there is an urgent need to address, among other things, "the decline of the fishery and coral reefs, and the preservation of qualities that allow the continuation of Hawaiian cultural traditions and uses." (Master Plan at iv.) The goal of the Master Plan, therefore, was the "preservation and protection of the unique natural resources of Kane‘ohe Bay for the continued use and enjoyment of the general public and future generations." (Master Plan, p. 14.)

With that goal in mind, the Task Force's Water Use Committee put forth a commercial recreation plan focused on placing limits on the scale and intensity of commercial uses in Kāne‘ohe Bay. Many public participants called for an outright ban on any commercial activities. Following many lengthy and often heated discussions, a compromise was reached. The committee agreed that no new commercial uses could be introduced on Kāne‘ohe Bay without demonstrating consistency with the long-term management goals for the Bay. Existing commercial activities that were allowed to continue operation on the Bay were recorded, and the number of commercial permits for Kāne‘ohe Bay would be limited. The intent of the Master Plan prohibition was to prevent new commercial activities on the Bay and to prohibit growth of existing commercial activities, with the understanding that eventually, all commercial activities on Kāne‘ohe Bay would be phased out. Aquarium collection would represent a new commercial activity and is strictly prohibited under the Kāne‘ohe Bay Master Plan. Moreover, commercial aquarium collection for the aquarium pet trade directly conflicts with the long-term management goals for the Bay, which call for the preservation and protection of our limited natural and cultural resources.

KOʻOLAU POKO SUSTAINABLE COMMUNITIES PLAN (2017)

The Koʻolau Poko Sustainable Communities Plan (KPSCP), adopted in August 2017, is founded on principles of sustainability that promote the long-term health of Oʻahu, its people, and its community resources for present and future generations. The KPSCP expressly focuses on the long-term protection of community resources, including the protection and enhancement of Koʻolaupoko's "natural, cultural, historic, agricultural, and aquacultural/fishpond resources." Commercial collection of reef wildlife for the aquarium pet trade is contrary to the principles articulated under the KPSCP.

COMMUNITY BOARD RESOLUTIONS (2021)

Kāneʻohe Bay continues to be increasingly targeted by commercial aquarium collectors. Beginning in March 2021, the following community boards and organizations passed resolutions urging the legislature to take action to end the commercial harvesting of reef wildlife for the aquarium pet trade and specifically, to prohibit commercial aquarium collection in Kāneʻohe Bay:

Kāneʻohe Neighborhood Board

Kahaluʻu Neighborhood Board

Kailua Neighborhood Board

Waimānalo Neighborhood Board

Kāneʻohe Bay Regional Council

Koʻolaupoko Hawaiian Civic Club

Koʻolau Foundation

Our community has made resoundingly clear that the commercial harvesting of reef wildlife for ornamental purposes outside Hawaiʻi is neither compatible with the local values and lifestyles of Hawaiʻi's residents, nor does it significantly contribute to the quality of life or economy in Hawaiʻi. This enterprise can no longer be justified in our community.

CULTURAL IMPACTS ARE NOT ADEQUATELY ADDRESSED IN THE FEIS.

The FEIS fails to adequately assess cultural impacts of the aquarium pet trade on cultural practices on the Island of Oʻahu, and specifically on Kāneʻohe Bay, which has become, by far, the most heavily collected area on Oʻahu. Public outreach and consultation in the Windward community appears to be non-existent. This raises serious questions regarding the actual efforts made to seek input from cultural practitioners in our community.

Of the cultural practitioners interviewed as part of the CIA consultation effort, not one was from the Kāneʻohe-Kahaluʻu community – the one community on the Island of Oʻahu that has been most targeted by commercial aquarium collectors. The cultural knowledge from lifelong cultural practitioners is here, but the drafters of this FEIS and CIA did not seek us out. Fishing was and continues to be an important part of Hawaiian culture and the wide-scale and wholesale removal of reef wildlife for ornamental purposes has been and continue to be an issue of profound cultural harm.

With regard to the cultural impacts of the aquarium pet trade on cultural practices on the Island of Oʻahu, the FEIS merely states that "the Preferred Alternative would impact cultural practices, but the extent of the impact is unknown." (FEIS at 144.) This is unacceptable and does not provide the Board with the information it needs to engage in the *Ka Paʻakai* analysis required to ensure the protection of traditional and customary native Hawaiian rights. Moreover, the FEIS's wholesale dismissal of the scope of cultural impacts is an affront to our Kānaka Maoli culture and the many cultural practitioners that have kept our customs and traditions alive since time immemorial.

The aquarium trade has broader cultural impacts beyond just impacts to subsistence fishing. Many of the species targeted for the aquarium trade are a part of our Kānaka Maoli origin story – they are embodiments of our akua, they are our ʻaumākua – a spiritual and familial link between Kānaka Maoli and the beginning of time. *He aliʻi ka ʻāina, he kauwā ke kanaka.* We as kānaka have a kuleana to mālama ʻāina and its resources and in exchange, the ʻāina momona will sustain the kānaka. There is a delicate balance between all life forms that must be maintained – a symbiotic relationship exists between the land and the ocean and their inhabitants. The taking of our cultural resources, our ʻaumākua, to be shipped off to live and die in a tank is an affront to our culture, our traditions, and our traditional and customary Kānaka Maoli practices regarding resource management. While the FEIS acknowledges that all of the proposed alternatives would impact cultural practices, it does not quantify or discuss the impacts, and proposes no mitigation, even though impacts have been significant for decades and could increase under this failed FEIS.

The FEIS also includes a major discrepancy between the Proposed Alternatives and the CIA. The CIA study area purported to exclude nearly 80% of Oʻahu's Windward coast, noting on several pages that aquarium collection will be prohibited in four areas: zones 405, 406, to the north of Kāneʻohe Bay and zones 408, and 418, to the south of the Bay, which encompasses the majority of the windward side. The FEIS, however, contains no such alternative, nor does it contain even a discussion of this possibility in the section on alternatives that were considered and dismissed. Furthermore, the potential for collection pressure to increase in Kāneʻohe Bay as a result of the closure of those areas, and/or how collection pressure in Kāneʻohe Bay impacts surrounding areas, was not discussed and consultation on these specific issues was not sought. Instead, the public notice published in the OHA Ka Wai Ola newspaper named the areas where collection would be restricted and sought consultation with those who had knowledge about places *outside* those "restricted areas." Because the CIA fails to adequately assess impacts along the entire Oʻahu coastline where collection could occur, the FEIS is inadequate.

Ultimately, the FEIS and its corresponding CIA fail to meet the most basic requirements of HEPA. The FEIS's analysis of cultural impacts is grossly inadequate and dismisses the cultural impacts and harms that would result from the removal of nearly 1.5 million reef animals. The entire community of cultural practitioners from the Kāneʻohe-Kahaluʻu communities were excluded from the CIA process. Cultural practitioners from surrounding ahupuaʻa were misled into believing that aquarium collection would be prohibited in their communities. We should have been consulted and we were not. The Board has an independent duty and obligation under HEPA, its implementing rules, and the Ka Paʻakai framework to analyze and consider cultural impacts and to make specific findings regarding the extent to which cultural and natural resources will be impaired by the proposed action and feasible actions to take to reasonably protect native Hawaiian rights. The lack of information in the CIA prevents the Board from fulfilling this kuleana. I strongly urge the Board to **REJECT** the FEIS.

Mahalo for the opportunity to testify,

/s/ Liko Kaluhiwa

October 7, 2021

<u>VIA ELECTRONIC MAIL</u>

Suzanne D. Case, Chairperson
Board of Land and Natural Resources
State of Hawaiʻi, Department of Land and Natural Resources
P.O. Box 621
Honolulu, HI 96809
blnr.testimony@hawaii.gov

RE: AGENDA ITEM F.1. Final Environmental Impact Statement (FEIS) regarding the Issuance of Commercial Aquarium Permits and Commercial Marine Licenses for the Island of Oʻahu; dated August 20, 2021, Applicant Pet Industry Joint Advisory Council (PIJAC); Island of Oʻahu, State of Hawaiʻi

Aloha Chair Case and Board Members,

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My family and I have been residents of the Koʻolaupoko ahupuaʻa for over 200 years. We are kupaʻāina and lifelong stewards of this place. I am a cultural practitioner. My ʻohana and I are lawaiʻa and we have passed on our cultural knowledge and practices to our keiki and our moʻopuna, who are also active cultural practitioners.

In the Koʻolaupoko community, I wear many hats. I am the President of the Koʻolaupoko Hawaiian Civic Club and have been an active member for over 60 years. I have served on the Kahaluʻu Neighborhood Board for over 30 years. I am the former President and current board member of the Koʻolau Foundation. I am the Vice President of the Board of Directors for Kākoʻo ʻŌiwi. I serve on the Board of the Heʻeia National Estuarine Research Reserve. I serve as the Kahu Nui o Kakuhihewa (Oʻahu Island) for the State of Hawaiʻi Aha Moku. I am a member of the William Claude and Mae Mae Jones ʻOhana organization of Heʻeia, which represents over 350 members with roots in the Heʻeia community spanning more than 30 generations. In these many capacities, I have been a staunch advocate for the preservation and protection of our natural and cultural resources for present and future generations.

I strongly urge the Board to **REJECT** PIJAC's FEIS for failing to meet the legal requirements of Hawaiʻi Revised Statutes Chapter 343, specifically with regard to its Cultural Impact Assessment (CIA).

KANEʻOHE BAY MASTER PLAN (1992)

The proposed action in the FEIS directly conflicts with Kāneʻohe's community-based management plans and objectives. In 1990, my ʻohana and I were participants in the Kāneʻohe Bay Task Force Committee that drafted the Kāneʻohe Bay Master Plan – a comprehensive master plan for Kāneʻohe Bay developed through extensive public participation. The Master Plan recognizes that Kāneʻohe Bay "is a recreational resource, an economic resource, a cultural and traditional Hawaiian resource, and a natural ecological treasure." (Master Plan, p. iv.) The Master Plan also recognizes that the Bay "is in serious jeopardy of being despoiled by over-exploitation" and there is an urgent need to address, among other things, "the decline of the fishery and coral reefs, and the preservation of qualities that allow the continuation of Hawaiian cultural traditions and uses." (Master Plan at iv.) The goal of the Master Plan, therefore, was the "preservation and protection of the unique natural resources of Kaneʻohe Bay for the continued use and enjoyment of the general public and future generations." (Master Plan, p. 14.)

With that goal in mind, the Task Force's Water Use Committee put forth a commercial recreation plan focused on placing limits on the scale and intensity of commercial uses in Kāneʻohe Bay. Many public participants called for an outright ban on any commercial activities. Following many lengthy and often heated discussions, a compromise was reached. The committee agreed that no new commercial uses could be introduced on Kāneʻohe Bay without demonstrating consistency with the long-term management goals for the Bay. Existing commercial activities that were allowed to continue operation on the Bay were recorded, and the number of commercial permits for Kāneʻohe Bay would be limited. The intent of the Master Plan prohibition was to prevent new commercial activities on the Bay and to prohibit growth of existing commercial activities, with the understanding that eventually, all commercial activities on Kāneʻohe Bay would be phased out. Aquarium collection would represent a new commercial activity and is strictly prohibited under the Kāneʻohe Bay Master Plan. Moreover, commercial aquarium collection for the aquarium pet trade directly conflicts with the long-term management goals for the Bay, which call for the preservation and protection of our limited natural and cultural resources.

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KAHALUʻU NEIGHBORHOOD BOARD #29 RESOLUTION (2021)

Kāneʻohe Bay continues to be increasingly targeted by commercial aquarium collectors. Recognizing the importance of the long-term protection of our community's resources, on May 12, 2021, the Kahaluʻu Neighborhood Board passed a resolution urging the legislature to take action to end the commercial harvesting of reef wildlife for the aquarium pet trade. Kāneʻohe Bay falls within the jurisdiction of both the Kahaluʻu and Kāneʻohe Neighborhood Boards. Both boards have agreed that the commercial harvesting of reef wildlife for ornamental purposes outside Hawaiʻi is neither compatible with the local values and lifestyles of Hawaiʻi's residents, nor does it significantly contribute to the quality of life or economy in Hawaiʻi. This enterprise can no longer be justified in our community.

In recent years, Kāneʻohe Bay has been a hotspot for commercial aquarium collection. In 2018, more than 9,000 reef animals were taken from Kāneʻohe Bay. In 2019, that number increased to more than 36,000 animals and in 2020, to more than 52,000 animals. The FEIS fails to discuss or disclose the tremendous pressure that has been exerted in this catch zone (Zone 407) and would continue to be exerted if the proposed action is ultimately approved and permitted. Nothing proposed in the FEIS would mitigate the impacts of the trade's intense collection efforts in Kāneʻohe Bay. Nothing in the FEIS prevents collectors from specifically targeting Kāneʻohe Bay for the 1.5 million animals it proposes to harvest from our island's reefs over the course of 5 years. This is not pono and directly conflicts with the management goals and objectives of our community.

CULTURAL IMPACTS ARE NOT ADEQUATELY ADDRESSED IN THE FEIS.

The FEIS fails to adequately assess cultural impacts of the aquarium pet trade on cultural practices on the Island of Oʻahu, and specifically on Kāneʻohe Bay, which has become, by far, the most heavily collected area on Oʻahu. Public outreach and consultation in the Windward community appears to be non-existent. Although the CIA specifically lists my name as someone that was contacted for consultation, I never received any communication from ASM staff requesting consultation. This raises serious questions regarding the bona fide efforts made to seek input from cultural practitioners in our community.

Of the cultural practitioners interviewed as part of the CIA consultation effort, not one was from the Kāneʻohe-Kahaluʻu community – the one community on the Island of Oʻahu that has been most targeted by commercial aquarium collectors. The cultural knowledge from lifelong cultural practitioners is here, but the drafters of this FEIS and CIA did not seek us out. Except for perhaps Mr. Aila, none of the persons interviewed as part of the CIA consultation efforts purported to be life-long lawaiʻa, cultural practitioners of the kai, intimately familiar with the traditional and customary resource management practices of our estuaries and nearshore fisheries. Fishing was and is still an important part of Hawaiian culture and the wide-scale and wholesale removal of reef wildlife for ornamental purposes has been and continue to be an issue of profound cultural harm.

With regard to the cultural impacts of the aquarium pet trade on cultural practices on the Island of Oʻahu, the FEIS merely states that "the Preferred Alternative would impact cultural practices, but the extent of the impact is unknown." (FEIS at 144.) This is unacceptable and does not provide the Board with the information it needs to engage in the *Ka Paʻakai* analysis required to ensure the protection of traditional and customary native Hawaiian rights. Moreover, the FEIS's wholesale dismissal of the scope of cultural impacts is an affront to our Kānaka Maoli culture and the many cultural practitioners that have kept our customs and traditions alive since time immemorial.

The aquarium trade has broader cultural impacts beyond just impacts to subsistence fishing. Many of the species targeted for the aquarium trade are a part of our Kānaka Maoli origin story – they are embodiments of our akua, they are our ʻaumākua – a spiritual and familial link between Kānaka Maoli and the beginning of time. *He aliʻi ka ʻāina, he kauwā ke kanaka.* We as kānaka have a kuleana to mālama ʻāina and its resources and in exchange, the ʻāina momona will sustain the kānaka. There is a delicate balance between all life forms that must be maintained – a symbiotic relationship exists between the land and the ocean and their inhabitants. The taking of our cultural resources, our ʻaumākua, to be shipped off to live and die in a tank is an affront to our culture, our traditions, and our traditional and customary Kānaka Maoli practices regarding resource management. While the FEIS acknowledges that all of the proposed alternatives would impact cultural practices, it does not quantify or discuss the impacts, and proposes no mitigation, even though impacts have been significant for decades and could increase under this failed FEIS.

The FEIS also includes a major discrepancy between the Proposed Alternatives and the CIA. The CIA study area purported to exclude nearly 80% of Oʻahu's Windward coast, noting on several pages that aquarium collection will be prohibited in four areas: zones 405, 406, to the north of Kāneʻohe Bay and zones 408, and 418, to the south of the Bay, which encompasses the majority of the windward side. The FEIS, however, contains no such alternative, nor does it contain even a discussion of this possibility in the section on alternatives that were considered and dismissed. Furthermore, the potential for collection pressure to increase in Kāneʻohe Bay as a result of the closure of those areas, and/or how collection pressure in Kāneʻohe Bay impacts surrounding areas, was not discussed and consultation on these specific issues was not sought. Instead, the public notice published in the OHA Ka Wai Ola newspaper named the areas where collection would be restricted and sought consultation with those who had knowledge about places *outside* those "restricted areas." Because the CIA fails to adequately assess impacts along the entire Oʻahu coastline where collection could occur, the FEIS is inadequate.

Ultimately, the FEIS and its corresponding CIA fail to meet the most basic requirements of HEPA. The FEIS's analysis of cultural impacts is grossly inadequate and dismisses the cultural impacts and harms that would result from the removal of nearly 1.5 million reef animals. The entire community of cultural practitioners from the Kāneʻohe-Kahaluʻu communities were excluded from the CIA process. Cultural practitioners from surrounding ahupuaʻa were misled into believing that aquarium collection would be prohibited in their communities. We should have been consulted and we were not. The Board has an independent duty and obligation under HEPA, its implementing rules, and the Ka Paʻakai framework to analyze and consider cultural impacts and to make specific findings regarding the extent to which cultural and natural resources will be impaired by the proposed action and feasible actions to take to reasonably protect native Hawaiian rights. The lack of information in the CIA prevents the Board from fulfilling this kuleana. I strongly urge the Board to **REJECT** the FEIS.

Me ka haʻahaʻa,

/s/ Frances Leialoha "Rocky" Kaluhiwa

October 6, 2021

Testimony in SUPPORT of BLNR Accepting the Aquarium Fish Fishery EIS.

John Kaneko

Sustainable fisheries are those that are science-based, adaptive and are managed to 1) control overfishing (catch rate and total catch), 2) prevent overfished fish populations (depleted, no longer to replenish what is taken) and 3) control adverse environmental impacts.

The EIS concludes that the Aquarium Fish Fishery is sustainable. This conclusion is supported by many reputable scientists who study Hawaii reef fish, fisheries and reef environments. Reliance on credible science is a hallmark of fisheries managed for sustainability, including Hawaii's Aquarium Fish Fishery. I strongly support the acceptance of the EIS and the continuation of this fishery.

From:	Loea Keanaʻāina
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1 Testimony
Date:	Monday, October 4, 2021 9:01:02 AM

Aloha,

My name is Loea Keana'aina and I am a Native Hawaiian resident. I ask BLNR to reject the EIS. The survival of Oʻahu's dwindling marine species is on the brink of extinction. Decades of unlimited aquarium collection on Oʻahu have led to a 90% reduction of the most heavily targeted species. Yet, the FEIS still ignores this, proposing levels of take that far exceed reported historical catch for most species. A paper describing the collapse of the aquarium fishery on Oʻahu's southwest reefs 35 years ago -- which have yet to recover, and research documenting that Hawai'i residents receive ZERO benefits from the trade, but suffer ALL the costs. Additionally, the required Cultural Impact Assessment claimed the EIS proposal would close 21% of Windward coast to collection.

Please reject this EIS proposal, for the sake of Hawaii's sacred marine life.

Sincerely, Loea

From: Damien Kenison
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Reject EIS
Date: Wednesday, October 6, 2021 12:59:48 PM

Aloha my name is Damien Kenison, a resident of Hookena South Kona Hawaii Island. The aquarium trade benefits a few and and detracts from the wellbeing of the majority. Climate change, overfishing, pollution, all contribute to the depletion of our reef fish but together they cannot match the significant destruction and degradation of our reefs by the aquarium trade which had annually removed hundreds of thousands of fish from west hawaii.
Our families here depend on those fish for sustenance to help offset the high cost of living. Those fish play a key role in maintaining a healthy reef and removing them will negatively impact our families, our lifestyles, and our environment. Please reject the EIS for the majority of the people on Oahu who depend on those fish for the same reasons we do

Mahalo Nui
Damien Kenison
Kauhako Ohana Association
PO box 38, Honaunau, Hi. 96726

From: Knell, Bernadette P
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Aloha!
Date: Tuesday, October 5, 2021 1:03:52 PM

Aloha!

I hope you're having a great day so far. My name is Bernadette Knell and I support this EIS. I am a true believer that the people in Hawaii would truly benefit from living off of the land and sea as long as it is done in a sustainable manner and managed by DLNR.

Mahalo!

Bernadette

Sent from iPhone

BERNADETTE KNELL, REALTOR-ASSOCIATE®
Assistant to Chance Knell (RA), RS-76603
Coldwell Banker Realty
Cell Phone: 808.391.2328
Agent License: #RS-82215
1314 S. King Street 2nd FL | Honolulu, HI 96814
| Bernadette.Knell@cbpacific.com
teamknelledit.cbintouch.com

From: Go Pako
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1
Date: Thursday, October 7, 2021 6:23:05 AM

Dear Hawai'i BLNR:
Re: Agenda item F.1

I oppose the Environmental Impact Statement as invalid, and illegitimate, and in disregard of the Hawai'ian culture as ruled by the Supreme Court of the State of Hawai'i. The Pet Industry Joint Advisory Council prepared the document seeking permits on behalf of 10 individuals. The Board of Land and Natural Resources has the discretion and authority to prevent the issuing of aquarium permits" through the Hawai'i Constitution.

The claim of "sustainability" has been used for too long, at the expense of Hawai'i public trust, for the benefit of commercial interests. The aquarium trade only takes reef wildlife from Hawai'i and leaves nothing. People around the world have Hawai'i in their hearts and spend a billion dollars annually on reef activities that take nothing from the reef. Hawai'ian reef wildlife should remain in the waters of Hawai'i, not in glass tanks globally.

Sincerely,
Paul Kohman
Former resident of Hawaii and frequent visitor to witness reef wildlife

From:	Blake Kolona
To:	DLNR.BLNR.Testimony
Cc:	fishybuissnesshawaii@gmail.com
Subject:	[EXTERNAL] Oahu Aquarium EIS testimony
Date:	Wednesday, October 6, 2021 5:33:45 PM

Aloha,
My name is Blake Kolona and I am in support of this Aquarium EIS!
I have owned a salt water aquarium for the past 20 years and currently own a 150-gallon saltwater aquarium. I'm also looking to add another sometime soon. I can Honestly say saltwater fish brings me so much peace and joy when I come home from a long day of work. The peace and comfort from relaxing Infront of my aquarium has gotten me thru some really tough times in my Life. I am currently sharing this hobby with my children who have come to love the same fish hobby as I have. I am a Hawaiian who loves the ocean and saddened to be forced to bring in saltwater aquarium fish from other parts of the world due to the Hawaii shutdown. I prefer fish from my own island that I know is caught the right and sustainable way. I believe in Sustainability and believe the limits in this EIS brings just that.
Please Pass this EIS

Mahalo!
Blake Kolona

Sent from my iPhone

From:	Luary Kong
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Testimony Regarding O’ahu EIS being heard on Oct.8th
Date:	Monday, October 4, 2021 2:13:23 PM

Aloha my name is Luary Kong and I support the Aquarium EIS! I believe it is the right for people in Hawaii to live off the land and the sea along as it's done in a sustainable manor and managed by the Department of Land and Natural Resources (Dlnr).
Mahalo!

Sent from my iPhone

From: Colin Kop
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] FEIS Ornament Aquarium Fishery
Date: Wednesday, October 6, 2021 9:55:58 AM

Aloha,

I am an applicant of the FEIS for the Ornament Aquarium Fishery and I would like to see it passed.

Thank you and Mahalo,
Colin K

From:	Keynin Kretz
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Aquarium Fishery support Section F. Item 1. DAR
Date:	Friday, October 1, 2021 11:48:44 AM

Aloha Land Board Members,
I am a student at UHM This was to be my senior year. I have had to stop my last year of college at UHM due to my job loss. My degree will be in education if I can ever finish it if get my job back.
As an aquarium fish packer and delivery person I have years of hands on experience with the aquarium fishery. I lost my job to misinformation generated in the EIS lawsuit which shut down the aquarium fishery. Please do the right thing and pass the Oahu FEIS. Science proves the fishery to be a humane one.

The hardship on me for paying my bills and remaining employed are at stake. I could understand the loss of my job due to real facts and real environmental issues, but the science does not support that!
There are extremely low death rates in the handling of reef fish for aquariums. Here is the scientific proof.
Let's look at this science.
Emily Munday Dr. Veterinary Medicine DVM and master's thesis researcher in ornamental aquarium trade. Unpublished study followed several hundred fish from capture to destination and their holding in captivity for 2.5 years and the results were 0% dead.

Munday E.t al. 2015 publication:
The effects of venting and decompression on Yellow Tang (*Zebrasoma flavescens*) in the marine ornamental aquarium fish trade.
Emily S. Munday,

1 Brian N. Tissot,2 Jerry R. Heidel,3 and Tim Miller-Morgan3,4
Academic Editor: Robert Toonen

Common collection methods in the fishery, ascent without decompression stops coupled with venting, or one long decompression stop coupled with venting, resulted in no mortality. Histopathologic examination of heart, liver, head kidney, and swim bladder tissues in fish 0d and 21d post-collection revealed no significant barotrauma- or venting-related lesions in any treatment group.

In our study, we seek to: (1) Determine short- and long-term mortality of reef fish caught for the aquarium trade subjected to the barotrauma prevention and/or mitigation practices of decompression and venting, respectively; (2) Examine sublethal effects of collection that could result in delayed mortality

"In conclusion, we determined that the methods commonly used by aquarium fishers in Hawaii do not cause mortality in Yellow Tang".
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4338794/

Cesar Study 2002
Quote from a Cesar 2002 study "Mortality rates of aquarium fish are low and have gone down considerably since the last survey in 1984. Currently, mortality rates from collection to wholesaler are estimated at 0 to 1 percent. In the wholesalers tanks, mortality rates range from close to 0% up to 2%. During shipment, rates range from 0.75% to 2%. This give a current total of between 1% and 5%, down from a range of 5% to 8% in the early 1980's (van Poolen and Obara, 1984; estimates of wholesalers and collectors, own study)."

After reviewing the studies done on Hawaii marine fish health one can conclude that Aquarium fish collectors seem to be improving with regards to reaching a 0% death rate for captivity capture to end use holding.

Furthermore in 2009:
Dr. Dan A. Polhemus PhD marine Biology DAR sent Rene Umberger a letter stating the low mortality number, but she and others opposing the fishery continue to this day incorrectly claim most of the fish taken in Hawaii die. December 23, 2009

More on Fish Health Humane treatment:
Aquarium fisherman take great care at much personal risk, to maintain the health of the tropical fish they catch, in order to deliver a healthy product. Delivering quality fish is good for business.

1. Proper needling of fish swim bladder does not harm the fish. It creates a healthy outcome for the fish, reduces possible injury to the fish, and this practice, along with the hours and hours of slowly decompressing the fish while at sea, as they slowly raise the fish from the depths of the ocean, ensures fish safety.

1. Clipping of the needle-like spines and razor-sharp flanges on large fish is done during packing, not before, and it ensures the fish does not pop the multi-layered plastic/paper lined bag they are packed in, so they can arrive at their new home safely- without suffocating from the bag being popped. They do not flinch in pain when they are clipped, it does not hurt the fish. The procedure is certainly dangerous to the person doing the clipping, who risks being sliced, but not to the fish. The spines are like fingernails and they regrow. The receiving aquarist will put clipped fish with other friendly fish species, so it doesn't need to stress or aggressively fight.

1. Regarding not feeding the fish the day before shipping - no one wants a fish breathing "poopy" water including the *Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Transport Guidelines* which state that fish shipments should be packed " in order to minimize pollution of the water, fishes should not be fed for 24 hours prior to shipment."

As you can see from all the above research the fishery is very humane in it's handling of reef fish. This along with sustainable collection and low coral impacts make it a "Model" fishery.

Thanks for your time,
Keynin Kretz UHM student

THE LABORATORY OF INTEGRATIVE NEUROSCIENCE
THE ROCKEFELLER UNIVERSITY
1230 YORK AVENUE • NEW YORK, NEW YORK 10021-6399
http://sur.rockefeller.edu/ http://m2c2.net (212) 327 8542

Testimony in SUPPORT of the Final Environmental Impact Study (FEIS).

Board of Land and Natural Resources
State of Hawaiʻi
Honolulu, Hawaiʻi

Esteemed Board Members,

The indifference of the many is often far worse than the malice of a few. In trying to preserve our natural world, we attack indifference by educating the public, so our people know and understand what is at stake and what we will lose by inaction. Also central to preservation is to study our charges, for we cannot steward what we do not understand. This education and study **cannot** be carried out in vacuum; we need to bring the species to the public and to the laboratory, and we do not know how to do this without a modicum of disturbance. We all understand that this is not ideal, but that as long as we treat our specimens humanely, as long as they are taken sustainably, and as long as we work hard to make their lives matter by learning from them, we're still doing far more good than harm. We often say these specimens are "ambassadors for their species".

I have for many years been involved in studying the intelligence of dolphins, and in my capacity as a researcher, I find myself often educating the public about these magnificent creatures and supporting animal welfare causes; at National Aquarium, where I used to carry my research, no less than 400 schoolchildren *a day* visited the dolphinarium. During the pandemic, I decided to study a species I could humanely keep in my laboratory, and opted for the octopus. While we initially studied *Octopus vulgaris*, we have decided to switch our study to *Octopus cyanea*, the day octopus endemic to Hawai'I, due to its high level of intelligence and its uncanny ability to build dens. It is not an endangered species and I understand it can be fished for food. I applied for a permit to secure two specimens in April; the application was somehow lost and I reapplied in June. I still have no answer.

Some of the people offering testimony against FEIS offer no other argument than "these are my fish and I do not like them being taken by the pet industry". They conflate all fish together regardless of endangerment status and they conflate all destinations regardless of the importance of their use: specimens that are at major Aquaria lighting up the faces of schoolchildren every day; specimens in scientific laboratories, from which we learn in detail and depth. **This is unprincipled and unscientific, but even worse, it is selfish and short-sighted.** The Hawai'i I know and adore is not just a magnificent scenery and amazing reefs, it is also a magnificent and generous people who would never tell me to my face "the schoolchildren of the world have no right to ever see Octopus cyanea in person" or "you cannot study how this octopus builds structures"; never mind that you can actually eat them at the corner sushi.

Please approve the FEIS. It is hard work, I understand, and it would be easier just to ban the whole thing, but it would do far more damage than good. The Board can keep a keen eye on the species and the sustainability, and on the need for use of the specimens. But above all, remember that there are extremely legitimate reasons why the world needs some of Hawai'i's wonders brought to it, for the benefit not just of the world but also of the species itself and of Hawai'i.

Yours most respectfully,

MAGNASCO, M.O.

Marcelo O. Magnasco
Professor, and Head of Lab
Laboratory of Integrative Neuroscience

From:	Joan Lander
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1 Testimony
Date:	Saturday, October 2, 2021 10:12:10 AM

Aloha mai,

I am a resident of Ka’u on Hawai’i island.

For the life of me, I can’t figure out how the aquarium pet trade benefits anyone or any ecosystem in Hawai’i. At a time when the world is reconsidering the practice of capturing wild animals for nothing other than display, we seem to be moving backward.

Please do your duty as protector of Land and Natural Resources and reject the FEIS regarding the Issuance of Commercial Aquarium Permits and Commercial Marine Licenses for the Island of O’ahu.

Mahalo,

~Joan Lander

PO Box 29
Na’alehu, Hawai’i 96772-0029

From: Teresa Landreau
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Stop taking wild fish from Hawaii
Date: Saturday, October 2, 2021 6:18:05 PM

The special interests who have for decades been allowed to remove wild fish from Hawaiian waters to sell to collectors for profit must finally be stopped. Our ocean life is threatened more than ever by acidification, warming, pollution, and accumulation of ghost nets, plastics, and trash. Our sealife needs protection. With economic hardships locally caused by COVID shut-downs, more locals must turn to our sea to feed their families. Please stop the raiding of local sea creatures for foreign profiteers. I can only ask why the Governor vetoed prior legislation that was passed to accomplish this. End out-of-state lobbying influence at the expense of local sea life. Mahalo and aloha.

TESTIMONIAL FOR FINAL ENVIRONMENTAL IMPACT STUDY – FISH COLLECTING

Steven Leong

98-2042 E Kaahumanu St.

Pearl City, Hawaii 96782

I am 25% native Hawaiian and was born in Hauula about a block from the ocean. I grew up loving fishing and anything to do with the sea. At five, I got my first saltwater aquarium. My mother and father would take me out and using my red net, I would catch fish for my aquarium from the Hauula tidepools. I graduated later to a cracked 70 gallon aquarium that could only be filled a quarter way up. My father would help me fill one gallon glass water jugs from the ocean to use for my aquarium which we hauled in the back seat of our car. This interest in marine aquarium fish progressed till I got to high school where I had the opportunity to use the library, and really study Hawaiian reef fish, their names, behaviors and how they fared in captivity. My friend Dennis and I would go out on the weekend, to go collecting fish. It wasn't easy. We would catch one or two red and white coris wrasses then catch the bus to Kapahulu to sell them to a pet shop. We poured our earnings into buying aquarium supplies so we could set up more aquariums. My love and interest in collecting, housing and studying our local reef fish progressed through the years. I learned the ways of fishing and mastered the art of collecting reef fish.

My uncles were fishermen in Kahana, and I would watch them go out and bring back so many fish. I wanted so much to do what they did. I learned from my tutu how to ask permission from God and the Hawaiian Ocean deities before diving, and then thank them upon leaving. I took only what was needed, and no more. In 1973 I started collecting reef fish commercially. In 1975 I started a business with a partner and sold fish to pet shops overseas. In 1977, I had a wonderful opportunity when Japan sponsored me to collect (new to science) fish from around the world. I dove and collected in Easter Island, Egypt, Culebra, Rapa, Tubuai etc.

The reason for all this background, is to illustrate the opportunity that our Hawaiian reefs provide for all our keikis who are drawn like I was to the sea's wonders. Prohibiting the collection of reef fish, is the first step in banishing these opportunities.

There are a lot of emotional opinions and theories about how collecting Hawaiian fish is detrimental to our environment and the local fish populations. In all my years of diving and fishing here, I haven't experienced once any of our reef fish species shrinking or disappearing. There are seasons when there are a lot. Seasons when they are over abundant, and seasons when they don't show up. These seasonal population changes have gone on for years.

It is all too easy in this "internet age" to read theories, judgments, and emotional opinions of the poor reef fish being exploited. People sit behind their computers/phones and read these articles, then pass judgments without really knowing the facts. I will give the example of the fish most being spoken about, the yellow tang, Zebrasoma flavascens. Studies have been done on them by DLNR that shows each yellow tang female is capable of laying 5,000 + eggs per spawning*. Now you multiply this by the several thousand adult females that are outside of Kaneohe. Then you add on the thousands from

Waimanalo, Waikiki, Sand Island etc. By the time you multiply the female yellow tang population in Oahu, then add the other islands as well as the Northern Hawaiian Archipelago you are looking at billions of yellow tang larvae being distributed in the currents throughout our islands. The problem is not the collection of these fish, the problem lies in keeping their environment healthy so that these larvae will have a place to settle.

This law is another example of how Hawaii State Judicial system caved to the pressure of those screaming emotional conspiracy theories, rather than listen to scientific facts, and in the process, stripped away our keiki's possible livelihoods, as well as destroyed on of Hawaii's thriving economies. Presently, with our sugarcane, pineapple and tourist (pandemic result) industry shrinking, I believe that the Hawaiian aquarium fish business, if regulated well, will be a great way to bring money into our islands, as well as give our local people job opportunities derived from the trade.

*Report on the findings and recommendations of effectiveness of the West Hawaii Regional Fishery Management Area. DLNR State of Hawaii December 2014

From:	Leslie G
To:	DLNR.BLNR.Testimony
Cc:	snorkelbob@snorkelbob.com
Subject:	[EXTERNAL] I oppose the EIS...
Date:	Monday, October 4, 2021 5:46:21 PM

The pet industry doesn't need another barbaric and abominable aquarium extraction. As a frequent visitor to Maui and a supporter of its local people, animals, culture and environment, I am begging you to DISAPPROVE this extraction.

Thank you.

From:	Keneke Lesperance
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1 Testimony
Date:	Saturday, October 2, 2021 6:03:33 AM

In the past, I considered harvesting fish for aquarium use to be barbaric. When I became a Conservation Officer on Oahu, I learned aquarium fish help educate people to the beauty of the sea and was potentially useful in conservation efforts.

As I watched inshore fish populations plummet over 12 years, I have learned the truth. Many of our reefs are suffering neglect from poor environmental laws, inadequate enforcement of the laws we do have, lack of public outreach, and a failure of the judicial system to enforce the mandatory penalties, especially for repeat offenders.

The potential for education of conservation in aquarium fish pales in comparison to our reef crisis. I hold a Master's Degree in Business. Industry responds to supply change (Business Principles 101). The aquarium fish industry will react to a halt in harvesting our dwindling resources as all industries react to change in supply. Incentive will improve FOWLR, Frag, and other techniques to achieve a sustainable industry.

In order to save our inshore fish populations, we must ban all aquarium fish gathering, including the unenforceable non-licensed, small harvest for "personal use." Our deeply rooted concept of gathering rights must not apply to non-traditional activities, such as removing and killing wild animals for amusement.

If we do not improve regulations and demand strict enforcement, Hawaii's inshore fisheries will be gone for our future generations. Auwe, what a legacy.

Ken Lesperance

Waimanalo, Oahu, Hawaii
, Hawaii

From: Kelly Levenda
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Comment on F.1. Aquarium Fish Collection
Date: Wednesday, October 6, 2021 2:09:07 PM

Hello,

I am a visitor to Hawaii who loves to snorkel and enjoy the wildlife. I am also an attorney who focuses on animal law, with a special interest in aquatic animals.

I have some thoughts on agenda item F.1. I would like to share. The EIS completed by the aquarium trade should be rejected. It will harm Hawaii's reefs and those animals who call the oceans there their home.

Thank you,
Kelly Levenda, J.D.

From:	dlinehan114
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Testimony regarding Oahu EIS being heard on Oct 8th
Date:	Monday, October 4, 2021 2:46:41 PM

Aloha, my name is Daniel Linehan and I use to own Tropical Fish Emporium on Oahu. I have since sold the Business but am still very much involved with the fishermen who use to dive for me as we became close friends and family. I am very much in support of the aquarium EIS and believe Hawaii has always been a model for sustainability for fisheries around the world. Most of the fishermen are Hawaii born and deserve the opportunity to support themselves off the land and sea, and with direct support and cohesion with DLNR it can once again be the beacon of sustainability for global fisheries.

Mahalo for your time.
Daniel Linehan

--
DJ Linehan

Northwest Aquatics Inc.

Tel: 808-754-7100

From: ANDREW LUK
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda item F.1
Date: Tuesday, October 5, 2021 4:44:42 PM

Dear Hawai'i BLNR:
Re: Agenda item F.1

I oppose the Environmental Impact Statement as invalid, and illegitimate, and in disregard of the Hawai'ian culture as ruled by the Supreme Court of the State of Hawai'i. The Pet Industry Joint Advisory Council prepared the document seeking permits on behalf of 10 individuals. The Board of Land and Natural Resources has the discretion and authority to prevent the issuing of aquarium permits" through the Hawai'i Constitution.

The claim of "sustainability" has been used for too long, at the expense of Hawai'i public trust, for the benefit of commercial interests. The aquarium trade only takes reef wildlife from Hawai'i and leaves nothing. People around the world have Hawai'i in their hearts and spend a billion dollars annually on reef activities that take nothing from the reef. Hawai'ian reef wildlife should remain in the waters of Hawai'i, not in glass tanks globally.

Sincerely,
Andrew J. Luk, MD, MPH
Seattle, WA

From: Luken, Alan
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Oahu FEIS Testimony
Date: Wednesday, October 6, 2021 4:30:37 AM
Attachments: image001.png

To whom it may concern,

In regards to the Oahu FEIS, I strongly support the FEIS and urge the board to accept the study.

The science and the data are clear that the fishery is sustainable and will continue to be sustainable under the quotas within the FEIS. Expert marine scientists back this data. The collection areas are not in areas where coral reefs are prevalent, thus preventing any collateral damage from collecting marine aquarium species. The benefit to the local communities in Hawaii is that not only does all of the money raised from exporting fishes stay within the community to support the local economy, but also the fishes from Hawaii help inspire hobbyists and public aquaria guests from all over the globe to visit and support Hawaiian reefs. Accepting this FEIS would be of great benefit to both the Hawaiian community as well as the reefs.

Best Regards,
Alan

Alan Luken
Brand Manager

P.O. Box 758 | Gibsonton, FL 33534
O 800.237.9317 ext. 1253 **M** 513.815.1449 **SEGRESTINC.COM**

From:	becca mann
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Vital reef fish protection
Date:	Tuesday, October 5, 2021 6:57:25 PM

To the distinguished members of the Board,
It is vitally important that you reject the seriously flawed environmental impact statement that suggests opening up Oahu's reefs to the aquarium trade.
You simply can not allow that. It would cause irreversible damage to our waters and wildlife. We can not allow our fish to be pillaged for the trade. We can not allow our economy to collapse by allowing the capture of our fishes. Our healthy oceans are the lifeblood of Hawaii. We must respect the ocean and fishes if we want to ensure a vibrant economy and environment.
Thank you and Mahalo.
All my best,
Becca Mann

From: Marsha
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] I oppose the EIS
Date: Tuesday, October 5, 2021 5:18:49 AM

Please stop the attempt to ramrod aquarium extraction.   These precious native fish need to be safely left in their natural habitat.

Marsha

Keep on Keepin on

From:	Ashley Mason
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Re: Please Protect Hawaii"s Fish
Date:	Wednesday, October 6, 2021 1:14:36 PM

Apologies for the typos in my original email, thanks!
Ashley Mason

On Wed, Oct 6, 2021 at 1:12 PM Ashley Mason <ashley.lynn.mason113@gmail.com> wrote:

> Aloha,
> I'm a Hawaii State resident and I'm writing to provide testimony against Agenda Item F1 regarding the aquarium trade ban. I do not think the most recently submitted EIS is neither accurate nor trustworthy and I beg you to please continue to protect Hawaii's fish from the aquarium trade.
> Mahalo,
> Concerned Citizenthahbh
>
> --

--
Ashley Mason

From: Dorothy McCorriston
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1 Testimony
Date: Monday, October 4, 2021 2:19:10 PM

Aloha nui,

For my children and my grandchildren, I write to ask BLNR members to please reject the EIS regarding mainland collectors collecting Hawaiian reef fish for pet stores.This does not benefit Hawaii in any way and will break down the eco-balance of Hawaii's reef systems. All the reefs in the world, and specifically in Hawaii, are dead and dying at an alarming rate. This FEIS disregards the science, the data and research documenting the disastrous impacts of fish collecting in the past. Because of past aquarium fish collecting, research has documented a 90% reduction of key species, 35 years ago O`ahu's southwest reefs collapsed and have yet to recover, and research shows Hawai`i residents reap no benefits but suffer all the disastrous results of reef collapse. There are also serious concerns about the impact of the Windward coast being left unprotected.

Culturally, biologically, and socioeconomically, citizens of Hawai`i have everything to lose and nothing to gain when we add more imbalance to the health of our reef life. It is past time to think about the future. Think about the world our mo`opuna will inherit. BLNR must be wise, be responsible and be pono stewards of our oceans and land.

Thank you,

Dorothy McCorriston
P.O. Box 551743
Kapa`au, HI 96755
(808) 896-7311

From: David McGuire
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Oppose Fish Collection: Agenda item F.1
Date: Wednesday, October 6, 2021 10:02:08 AM

Dear Hawai'i BLNR:
As a part time Kona resident, marine conservationist and Director of an international non profit representing over 10,000 members, I oppose the Environmental Impact Statement submitted by the Aquarium Trade industry as invalid, and illegitimate, and in disregard of the Hawai'ian culture as ruled by the Supreme Court of the State of Hawai'i. The Pet Industry Joint Advisory Council prepared the document seeking permits on behalf of 10 individuals. The Board of Land and Natural Resources has the discretion and authority to prevent the issuing of aquarium permits" through the Hawai'i Constitution.Coral reefs are already impacted in Kona by climate change and nutrient run off causing algal growth. Good science and reef management does not support the removal of these important algavores.

The claim of "sustainability" has been used for too long, at the expense of Hawai'i public trust, for the benefit of commercial interests. The aquarium trade only takes reef wildlife from Hawai'i and leaves nothing. People around the world have Hawai'i in their hearts and spend a billion dollars annually on reef activities that take nothing from the reef. Hawai'ian reef wildlife should remain in the waters of Hawai'i, not in glass tanks globally.

Sincerely,
David McGuire, MEH
Director, Shark Stewards
--
Follow the Adventure on our National Geographic Field Notes
Save Sharks and ocean health with your Donation
Urge the US Congress to Stop the Shark Fin Trade.

Shark Stewards is a project of The Earth Island Institute

m:415 350-3790 | e:sharkfilms@gmail.com | w:www.sharkstewards.org

From:	MadeleineMatisse
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] REJECT the EIS
Date:	Saturday, October 2, 2021 9:28:39 AM

Thank you for taking the time to read and consider the following testimony:

1. I am a resident of the State of Hawaii and have been for nearly 20 years. I love this state and believe all of its resources need the highest level of protection.

2. In or about 2005 I began snorkeling nearly every morning at Hanauma Bay with a group of friends who were adamant about not touching or harassing any wildlife, marine or otherwise, at the Bay. We snorkeled quietly and only observed at a distance, enjoying all that we saw. Within a few years we witnessed the number of fish dwindling drastically.

3. A number of our snorkeling group (me included) stopped going to the bay to snorkel because the fish population and quality of the water and surroundings had seriously deteriorated. We then began snorkeling around Waimanalo.

4. Within a few short years, the fish populations at Waimanalo also fell. In fact, the numbers fell so drastically that I stopped snorkeling altogether. Yes, there were the effects of climate change and overwhelming numbers of tourists (as well as a group of fisherman who decimated the turtle population) but the drop in the number of fish was exacerbated by the aquarium trade.

Please! This state needs to preserve what little it has left. In 2020 when Hanauma Bay was closed, the marine scientists were amazed to see the resiliency of the Bay once it was left to rest and regenerate. We are all stewards of the natural resources in our state, but in your position you can have a direct and immediate effect by REJECTING the EIS.

Please act now before our fish populations disappear before our very eyes.

Thank you.

Bonnie B. McMullen

From: ShaylaMassage
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] AGENDA ITEM F.1
Date: Monday, October 4, 2021 2:27:05 PM

Aloha Friends-

I am a Hawaii resident and I oppose the approval of aquarium reef fish extraction based on the most recent EIS in Kona.

Reef fish collection is not sustainable as 99% die within a year of capture. This is an industry akin to cut flowers, we must not allow an endless supply of our endemic fish to be sold and tanked only to shortly perish.

We on Maui have seen our reefs recover since the ban a few years ago.

I am against approving reef fish extraction on any Hawaiian island.

Thank you,
Shayla Middleton
Resident
Kihei, HI
96753

From: Lisa marie Minor
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Testimony regarding Oahu EIS being held on Oct.8,2021
Date: Tuesday, October 5, 2021 8:06:52 PM

Aloha my name is Lisa Marie Minor and I support the Oahu Aquarium EIS, I believe it is the right for people in Hawaii to live off the land and sea, as long, as it’s done in a sustainable manner and managed by the department of land and natural resources.

Mahalo for your time,

Lisa Marie Minor

3517 Kilauea Ave, Honolulu, HI 96816
808-777-9813

Board of Land and Natural Resources
Meeting of October 8, 2021, Item F-1

Testimony in **support** of a Board Determination that the Final Environmental Impact Statement (FEIS) complies with applicable law and adequately discloses the Environmental Impacts of Proposed Issuance of Commercial Aquarium Permits and Commercial Marine Licenses for the Island of Oʻahu, for the purpose of accepting the FEIS; dated August 20, 2021

Mr. Alton Miyasaka, DAR Acting Commercial Fisheries Program Manager (retired)

Comment

Each Board member represents a group larger than just themselves. As a representative of that group, each member is asked to put aside their own personal agendas, biases, and pre-conceived ideas of the matters before it. Each member is asked to make fair, rational, and objective decisions based on the information it has received on each agenda item. To do otherwise would be a betrayal of the public trust placed on each Board member and contrary to the ideals that created the Board.

Those who still believe that the aquarium fishery is not sustainable; you are supporting a false narrative. Those who want to ban the fishery based on this false narrative; you need to critically examine the scientific data or risk damaging the Board's credibility. Those who want to use the EIS process as a means to ban the aquarium fishery will corrupt the process.

Summary
The Board is strongly urged to determine the Oahu aquarium fishery FEIS complies with applicable laws and accept the FEIS for the following reasons: 1) the Oahu aquarium fishery is currently biologically sustainable, based on the best available information; 2) any significant impacts would be social rather than biological; 3) resolving these social conflicts would be outside of the EIS process; 4) closing the aquarium fishery would be contrary to Legislative intent; and 5) the Department already has the authority to appropriately manage the fishery should it find such measures necessary.

My testimony urging the Board to determine this FEIS complies with applicable laws and accept the FEIS is based on the following facts: 1) the aquarium fishery, at its current levels of harvest, is sustainable; 2) the Department has provided this determination of sustainability in several official, written testimonies to the Legislature; 3) the data the Department used to make this determination has been collected and analyzed since before the 1970s (a period of over 50 years); 4) since this determination of sustainability, the fishery has been essentially closed due to the Supreme Court decision in 2017; 5) with the 2017 closure of the fishery, any negative impacts the fishery might have had on the resources would have been greatly reduced, as there is currently little to no aquarium collecting activity now; and 6) prior to 2017, the fishery was already contracting due to the national economic downturn of 2008.

My testimony urging the Board to determine this FEIS complies with applicable laws and accept the FEIS is also based on the following information: 1) the Oahu aquarium fishery collects fewer individuals from many species compared to the Hawaii Island aquarium fishery that collects many individuals from fewer species; 2) this spreading out of the catch amongst a wider variety of species means that the threat of overfishing any one species is greatly diminished, and 3) the characteristics of the Oahu, multi-species, aquarium fishery make it more likely to be a manageable fishery compared to a single-species fishery.

DLNR testifies the aquarium fishery is sustainable

The Department's official testimonies on proposed bills in the 2017 Legislature stated that they believed the aquarium fishery was operating sustainably at the time of the Supreme Court's decision. By the Department's own admission, the data it had indicated that the fishery was a well-managed fishery. I was in a unique position, being the DAR Acting Commercial Fisheries Program Manager and the lead biologist overseeing the aquarium fishery at the time, to have direct access to the aquarium fishery data and information behind the Department's testimonies.

In the case of a fishery, the most important effect is, arguably, whether the fishery is sustainable. If sustainable, then the Oahu aquarium fishery would have no significant biological impact. Those opposed to aquarium collecting are raising the question of sustainability as justification to close the fishery. The Department has determined that it currently has no sustainability concern for this fishery and the justification for fishery closure, based on biological reasons, doesn't exist.

Worldwide Market Conditions Were Contracting the Local Aquarium Fishery

Since the economic collapse of 2008, the worldwide demand for aquarium species from Hawaii has experienced a dramatic change. Hawaii has a reputation for having the gold standard in terms of quality marine life but along with this high quality product comes a higher price point. This higher price point, compared to other countries with lesser quality, has made it much more challenging for Hawaii to stay competitive in the global marketplace. The lack of demand resulted in a number of professional, full-time collectors to stop collecting and a number of dealers in aquarium species have gone out of business. This downturn in market demand for aquarium species caused a contraction of aquarium collecting around Oahu that is not based on any resource concern.

The Oahu Aquarium Fishery is Different from the Hawaii Island Fishery

The nearshore habitats around Oahu are older compared to Hawaii Island. This reef maturity provided more time for more species to become established. The Oahu aquarium fishery has therefore specialized on species variety but less numbers per species and a smaller total take of marine life. The Oahu reef maturity also supports a well-developed invertebrate community with hermit crabs and feather duster worms being collected in large numbers compared to Hawaii Island where the invertebrate community is not as diverse or developed. Invertebrates generally reproduce at much faster rates and in greater numbers than vertebrate species, allowing them to recover from harvest better.

Comments on the Cultural Impact Assessment (CIA)

The Aquarium Fishery is a Conflict of Values and Not a Question of Sustainability
In my 30+ years of overseeing the Statewide aquarium fishery at the Division of Aquatic Resources (DAR), I have spoken to many native Hawaiians about their thoughts and concerns regarding aquarium collecting activities and fishing in general. The comments provided in the CIA are typical of the wide range of comments I've heard over the years. The CIA represents a small sampling but an accurate report of the thinking that exists within the Hawaiian community. In my opinion, cultural impacts would be most notable in specific areas, involving specific species, with specific individuals. As noted in the CIA, certain individuals would have concerns if specific species were taken in specific locations. This seems more like a user conflict rather than a fisheries level sustainability concern. The regulatory measures would be focused in limited locations with certain species and likely not have statewide application.

In the cultural impact assessment, some individuals expressed their personal opposition to the collection of any marine life for aquariums. Some believe aquarium collecting should be banned. The public policy question of whether aquarium collecting should even exist was already answered when the Legislature authorized the permit for aquarium purposes. The Legislature decided that aquarium collect should exist. The Board is being asked to consider if the FEIS complies with applicable environmental laws. In this light, the opposition to aquarium collecting may be viewed more as a clash of social values, rather than one based on any biological concern.

For those who believe that aquarium collecting should not occur, to close the aquarium fishery through the HEPA process would be contrary to Legislative intent. This leaves those native Hawaiians who believe that some level of aquarium collecting would be acceptable, as the remaining source of potentially significant cultural impacts. This perspective would essentially be "Not in my back yard (NIMBY). They would have no opinion unless it starts to impact native Hawaiian use of the resource. My experience has been that the range of thoughts about what level of collecting would be acceptable is so wide that there is no one thought that I would consider a significant impact. Even if a significant impact was to arise, the Department has the authority to regulate such impacts. Those cultural impacts would likely be to individuals that might be concerned about the take of specific species in specific areas.

Comments on Sustainability of the Oahu Aquarium Fishery
During my whole career with DAR, the question of determining sustainability of any fishery has undergone a number of changes. The shift from species management to ecosystem management was one of the most significant changes in recent years. This question, at what level does sustainable fishing becomes unsustainable, is especially difficult to answer when there is insufficient data on which to form a defensible position. DAR has had to depend on what little

data it had, recognize certain fishery indicators, and then determine if regulatory measures are warranted. Limits to acceptable change is the concept that there is a limit to the amount of change the public is willing to accept. In order to answer the question of how much is enough, science needed to provide an objective measure to begin the discussion of defining sustainability. Catch per unit of effort (CPUE) has and continues to be a useful scientific indicator of fishery performance in data poor conditions. CPUE is the number of fish collected per hour of fishing effort.

1. Catch Per Unit of Effort is Stable

The CPUE over time was trending upward during the 1990s and 2000s but has remained level since the economic crash of 2008 to 2017. A rising CPUE indicates a positive and expanding fishery while a level CPUE indicates the fishery is stable. A declining CPUE would be an indication that something has changed in the fishery and a closer examination at what might be causing this change is warranted. The steeper the curve, the faster change is occurring. Not all declines indicate that there is a problem with resource abundance. As there are insufficient fishery data to determine sustainability using current assessment modeling, CPUE is the most practical tool, given the data poor situation. In my opinion, based on the best fisheries data available, the CPUE estimate indicates the aquarium fishery is currently well managed.

The CPUE estimate was one of the science based indicators the Department used to make its 2017 determination that the aquarium fishery was operating at a level that was likely sustainable. The level CPUE rates over time indicated the fishery was stable. Invertebrates make up a large proportion of Oahu aquarium catch, which are known to reproduce quickly and occur in high densities. The majority of Oahu's coastline is not used to collect aquarium species. The total reported commercial aquarium catch is matched by the reported aquarium dealer purchases indicating the reported commercial catch numbers are likely accurate. There was a reduction of fishery participants due to the reduced demand for aquarium species since 2008. The extensive studies along West Hawaii also indicated that the overall status of the aquarium fishery statewide was good. These and other information resulted in the Department providing written testimony to the Legislature indicating the fishery was likely sustainable.

2. The Reported Commercial Aquarium Catch Accurately Represents the Whole Fishery

I conducted an analysis in the 1980s to determine what percentage of the reported catch was being provided by the non-commercial collectors. The non-commercial collectors were contributing about 3% of the total report catch but were responsible for over 90% of the catch reports received by the Department. This large number of reports with little fishery information on them, the time needed to process these "no catch" reports, and the costs of printing report forms lead to the cancellation of the requirement for non-commercial aquarium permits holders to submit monthly catch reports. A follow-up DAR study around 2016-2017 suggested that the non-commercial segment of the aquarium fishery on Oahu continues to still be less than 3% of the total reported aquarium catch. Claims that the non-commercial take in this fishery might be the same as the commercial take are not consistent with the data that DAR has. In addition, the collector reported catch is supported by the reported dealer purchases. Based on this information, the reported commercial aquarium collection data likely represents an accurate accounting of the fishery.

Thank you for the opportunity to provide these comments.

From:	Harlan Miyoshi
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1 Testimony
Date:	Wednesday, October 6, 2021 3:29:37 PM

Aloha esteemed members of the BLNR,

My name is Harlan Miyoshi and I am a resident of Kealakekua on the Big Island and an avid snorkeler and volunteer at a local beach on the island.
I humbly ask the board to reject the FEIS as many of the species on the White List may have the level of abundance that is asserted on a macro level but, if they are allowed to take the numbers that have been proposed, it could wipe out entire schools and decimate localized populations of fish. Many of the key species are considerably depleted according to a paper I have read but the FEIS makes no mention of it. I have witnessed a decrease in some of these species at our local beaches, even during this moratorium on aquarium fishing, which shows that these fishes are already facing significant pressures and threats (global warming, runoff, coral bleaching, etc.) so to add to that by allowing the aquarium industry to deplete our resources is not right and it could become the straw that ultimately broke the camel's back. Many of the fish on the list are some of the most beautiful fishes that we have here in Hawaii and taking them out of our oceans would also deplete the appeal of our oceans.
As the stewards of Hawaii's natural resources, I hope that the BLNR will make the right decision to reject the FEIS and protect our ocean resources for all to enjoy.

Mahalo,
Harlan Miyoshi

From:	David Monasevitch
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1 Testimony
Date:	Monday, October 4, 2021 7:54:11 PM

Aloha BLNR,

I am a 26 + year resident of Kaua'i.

I am urging you to reject the FEIS aimed at reopening Oahu's deadly aquarium trade.

The science is irrefutable. We are in the midst of a MASS EXTINCTION EVENT.

It is totally amoral and unconscionable to even consider opening up the aquarium trade again.

It is strikingly disheartening to think that the environmental, regulatory systems of checks and balances in this state is completely captured, corrupted and perhaps ignorant of the reality of what is happening to the biosphere.

Believe it or not, human beings are a part of the biosphere.

REJECT THE FEIS AIMED AT REOPENING OAHU'S DEADLY AQUARIUM TRADE!

Thank you and Mahalo for reading this email.

David Monasevitch M.Ed., BA Environmental Biology

From: Nina Monasevitch
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Reject the flawed Aquarium trade FEIS
Date: Wednesday, October 6, 2021 5:59:28 PM

To BLNR,

I am a 43 years resident of Kauai, scuba diver and long distance ocean swimmer. The decline of the marine ecosystem I have witnessed is catastrophic.
I have witnessed a massive reduction of key species. The EIS is ignoring this critical fact—shockingly irresponsible! Our oceans are dying and over extraction is one of the main reasons.

The ocean is our life support system, particularly here in Hawaii. Please REJECT the flawed FEIS aimed at re-opening Oahu's deadly aquarium trade.

Malama Pono.

Sincerely,
Nina Monasevitch
Lihue, Kauai

From: Eric Morgensen
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Testimony regarding Oahu EIS being heard on Oct 8th
Date: Monday, October 4, 2021 2:25:42 PM

Hello my name is Eric Morgensen and I run an aquarium shop in Washington State called The Shark Reef.

The banning of tropical fish collecting in Hawaii has not only hurt my collector friends in Hawaii but has hurt my business as well. It makes no sense to me that almost 4000 commercial fisherman can kill the fish for food and sell them for a fraction of what we do and we are keeping them alive. And how many aquarium fisherman are there? Only about 40. How are the 40 hurting the fish and reefs more than the 4000 commercial fisherman.

I have followed this since it went it effect and I SUPPORT this EIS! I believe it is the right for people in Hawaii to live off the land and the sea along as it's done in a sustainable manor and managed by the DLNR.

Please let them fish again and help the Hawaiian locals have their jobs again as well as helping the many businesses throughout the US who rely on their products.

Thank you
Eric Morgensen
3656 NW Munson St
Silverdale WA 98383
360-662-1313

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From: Arthur Mori
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] FEIS re opening of aquarium trade
Date: Monday, October 4, 2021 11:46:47 AM

I am a resident of Hawai'i and strongly oppose the reopening of the aquarium trade. Scientific data and plain good sense certainly mean that we should protect this special resource of the islands. As a volunteer at the Waikiki Aquarium I have heard many times from our visitors that when they came to Hawai'i 10 or 15 years ago they saw many more reef fish than at this time. Allowing this business to continue has absolutely no positive value for the islands. Please allow these wonderful creatures to live and thrive. Have you considered how many die on the stressful transport to the mainland?
Val Mori

From: Mike Nakachi
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] F1
Date: Monday, October 4, 2021 5:22:18 PM

Subject F1: Reject this Oahu EIS, PIJAC continues to want to degrade ‘aina. They continue to NOT listen to the Kanaka Maoli voice, continue to change the goal lines in a smoke and mirror act, this is against the LAW a direct violation of HEPA. Direct Violation of Hawaiian Kingdom Law to have commercial exploits before the people civically engaged of Malama aina first. BLNR, do the right thing and reject this EIS, that has no foundational CIS. Mahalo nui, Mike Nakachi

Mike Nakachi
PO Box 4454
Kailua Kona, HI 96745
mike@moanaohana.com
808-640-3871

From:	Joan O"Brien
To:	DLNR.BLNR.Testimony
Cc:	Joan OBrien
Subject:	[EXTERNAL] Re: Agenda item F.1
Date:	Wednesday, October 6, 2021 5:46:30 PM

Dear Hawai'i BLNR:

I oppose the Environmental Impact Statement as invalid, and illegitimate, and in disregard of the Hawai'ian culture as ruled by the Supreme Court of the State of Hawai'i. The Pet Industry Joint Advisory Council prepared the document seeking permits on behalf of 10 individuals. The Board of Land and Natural Resources has the discretion and authority to prevent the issuing of aquarium permits" through the Hawai‘i Constitution.

The claim of "sustainability" has been used for too long, at the expense of Hawai'i public trust, for the benefit of commercial interests. The aquarium trade only takes reef wildlife from Hawai'i and leaves nothing. People around the world have Hawai'i in their hearts and spend a billion dollars annually on reef activities that take nothing from the reef. Hawai'ian reef wildlife should remain in the waters of Hawai'i, not in glass tanks globally.

Sincerely,

Joan O'Brien
Reef Wildlife Lover

Joan O'Brien
Humane Policy Volunteer Leader
New Hampshire Congressional District 2

joanlobrien@yahoo.com
P 603-554-1544 C 978-758-2967
humanesociety.org

Ocean Tourism Coalition

The Voice for Hawaii's Ocean Tourism Industry
1188 Bishop St., Ste. 1003
Honolulu, HI 96813-3304
(808) 537-4308 Phone (808) 533-2739 Fax
timlyons@hawaiiantel.net

October 8, 2021

Suzanne Case, Chairperson
Board of Land and Natural Resources
1151 Punchbowl Street; Room 131
Honolulu, HI 96813

RE: OTC Testimony
DLNR Board Meeting
10/8/2021
Agenda Item J-1

Via e-mail: blnr.testimony@hawaii.gov

Chair Case and Members of the Board:

The Ocean Tourism Coalition ("OTC") is writing in strong support of the Department's decision to deny the petition for contested case hearing. Several of our members depend on the Commercial Use Permits ("CUPs") for the Mala boat launch ramp for their livelihood, and the loss of these CUPs would be catastrophic to their businesses.

OTC agrees with the Department that the issues at the Mala boat launch ramp should be addressed through discussion among the user groups and by the possible addition of parking stalls near the ramp. The CUP holders have not violated any laws, and the termination of their permits would be both premature and inconsistent with the intent of current administrative rules.

Resources are limited in our State, but only through discussion and compromise are conflicts between competing users reduced. Canceling the CUPs is unnecessary when avenues of cooperation can still be pursued. For these reasons, we humbly request that the Board affirm the denial of petition for a contested case hearing.

Sincerely,

Glen for Tim Lyons

Tim Lyons, CAE
Executive Director

Board Of Land And Natural Resources
RE: Pet Industry Joint Advisory Council FEIS

We're writing to express our strong **opposition** to the Environmental Impact Statement. The statement is deeply flawed, inadequately supported by available scientific data; lacking in critical species-specific information at points, and prioritizes the profits of one small group of collectors over:

- the health of Hawai'i's already threatened reefs and biodiversity
- reef wildlife's cultural importance to Native Hawaiians
- the local economy that benefits from people visiting from all over the world to see Hawai'i's reef wildlife

The EIS has failed to address many of the issues that the industry has been continuously criticized for like cultural and socioeconomic impacts, lack of input from Native Hawaiian cultural practitioners, environmental risks, and providing zero analysis for some of the species they intend to take. It also heavily relies on data that NOAA has publicly acknowledged as flawed and continuously claims fish populations are “possibly being underestimated” when NOAA has insisted it is quite the opposite.

The EIS ignored DLNR's request for proposed enforcement measures despite multiple collectors being charged with poaching in recent years, providing no incentive for collectors to follow the regulations proposed.

Above all, the proposed EIS fails to comply with HEPA requirements which alone should result in its rejection.
Due to the aforementioned reasons, we highly encourage the board to **REJECT** PIJAC’s FEIS.

Courtney Vail
Oceanic Preservation Society
Strategic Campaigns

Natalie Parra
Keiko Conservation
Co-Founder

From: Perry Olson
To: DLNR.BLNR.Testimony
Cc: Mom
Subject: [EXTERNAL] Agenda Item F.1 Re Aquarium Trade Havesting
Date: Tuesday, October 5, 2021 11:44:39 AM

Ladies and Gentlemen,

We are Hawaii residents on the Big Island. We have witnessed first hand the recovery of native Hawaiian fish as a result of harvesting moratoriums. The fish populations bounce back!

One of Hawaii's true treasures are its reef fish. They promote tourism and also native Hawaiian fishing.

There is simply no way that the Final Environmental Impact Statement accurately reflects the impact of reef fish harvesting. Please reject this dubious report on the real impact…..we have seen it first hand.

Mahalo,

Perry and Lynne Olson

Sent from Mail for Windows

From:	shantelmacalino01
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Oahu FEIS Final environmental impact statement
Date:	Tuesday, October 5, 2021 9:06:19 AM

Aloha, my name is Shantel O'Neil and I stand against the ban of commercial fishing. My Uncle has been a commercial Diver for over 30 years, just a few years short of being able to retire. With this ban, he has lost not only his passion, but his lively hood. My brother has been diving and fishing for 20 years. He has also loss his income, lively hood and his career in his passion. My family used nets according to the law, being sure not to catch tiny fish. They see plentiful fish in our ocean, not a depletion. They've been in the water for many years, and I trust their expertise when they say, they are not depleting the fish from our oceans. During these trying times, in the middle of the pandemic where financial hardships are already dire, I strongly urge you to reconsider, stop the ban, or at least put a pause on it before you make your final decision. This decision you're making can mean the difference between having a home and food, versus government assistance and homelessness for these local fisherman, a problem that is already too great in Hawai'i. I trust you will hear the people of Hawai'is voice and come up with a better solution.

Respectfully,

Shantel O'Neil

From: Mayako XO
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] REJECT opening up reefs to aquarium trade
Date: Tuesday, October 5, 2021 3:19:32 PM

To the distinguished members of the Board,
It is vitally important that you reject the seriously flawed environmental impact statement that suggests opening up Oahu's reefs to the aquarium trade.
You simply can not allow that. It would cause irreversible damage to our waters and wildlife. We can not allow our fish to be pillaged for the trade. We can not allow our economy to collapse by allowing the capture of our fishes. Our healthy oceans are the lifeblood of Hawaii. We must respect the ocean and fishes if we want to ensure a vibrant economy and environment.
Thank you and Mahalo.
Sincerely,
Mayako

From:	Tiffani Parker
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] EIS support
Date:	Monday, October 4, 2021 5:42:41 PM

Aloha my name is Tiffani and I support this EIS! I believe it is the right for people in Hawaii to live off the land and the sea along as it's done in a sustainable manor and managed by Dlnr.

Sent from my Verizon, Samsung Galaxy smartphone
Get Outlook for Android

From:	Robert Pecoraro
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Tropical Fish Collection in West Hawaii
Date:	Wednesday, October 6, 2021 12:45:05 PM

Dear Hawai'i BLNR
Re: Agenda item F.1

I don't understand how your agency can support the resumption of tropical fish collection in West Hawaiian waters. The reefs are already stressed due to climate change and algae growth in some areas, and you are looking to allow collectors to harvest the very creatures that can keep algae growth under control. People visit Hawai'i to enjoy water activities such as snorkeling and diving. It is what drew me and my wife to choose Kailua Kona as the place for us to retire and spend the rest of our lives. I have seen first hand the devastation caused by warming oceans. Dead reefs are seen up and down the coast. There will be no hope for recovery if collectors are allowed to take our reef fish. The collection of tropical fish benefits no one except for the collector. The fish are pulled from the reef, depriving all others the joy of observing these beautiful animals in their natural environment. And what becomes of the fish once they are harvested? Many die before they reach their destinations or shortly thereafter. The stress is just too much for them. This is animal cruelty hands down, and for what? So some fisherman can make a few bucks and one person, thousands of miles away, can hold this fish in a tank until it dies. Please listen to the public outcry. There has not been legal tropical fish collecting for years on the Kona Coast. These fishermen should have already moved on and found other ways to make a living, which does not contribute to the destruction of our reefs. I am aware of the reputation of some of those involved in this trade. They are not exactly what one would consider to be upstanding citizens. I know that some were caught collecting while it was illegal and I am sure that they will not be prone to follow the rules if it becomes legal again.

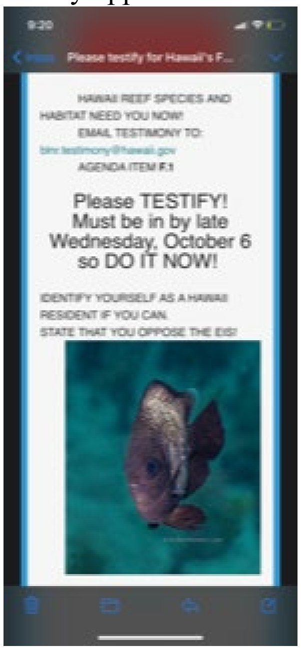
I oppose the Environmental Impact Statement as invalid, and illegitimate, and in disregard of the Hawai'ian culture as ruled by the Supreme Court of the State of Hawai'i. The Pet Industry Joint Advisory Council prepared the document seeking permits on behalf of 10 individuals. The Board of Land and Natural Resources has the discretion and authority to prevent the issuing of aquarium permits" through the Hawai'i Constitution.

The claim of "sustainability" has been used for too long, at the expense of Hawai'i public trust, for the benefit of commercial interests. The aquarium trade only takes reef wildlife from Hawai'i and leaves nothing. People around the world have Hawai'i in their hearts and spend a billion dollars annually on reef activities that take nothing from the reef. Hawai'ian reef wildlife should remain in the waters of Hawai'i, not in glass tanks globally.

Sincerely,
Robert Pecoraro

From: Chanel Phillips
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Firmly oppose
Date: Monday, October 4, 2021 6:21:46 PM
Attachments: image0.png

Firmly oppose   Save our reefs. Our fish and our lives. Save the oceans.



Sent from my iPhone

From:	David Pinilla
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda F.1 testimony
Date:	Wednesday, October 6, 2021 7:59:17 AM

Dear Sir or Madam,

As a resident of Hawaii, and a professional in the dive tourism and education industry, I hope you will **REJECT the EIS**. The aquarium trade is an inhumane industry that **exploits Hawaii's natural resources with no real benefit to its people or economy**, no connection to traditional Hawaiian harvest and resource management practices, and significant detriment to its environment. A fish is worth so much more on the reef! Please don't let this wasteful, cruel, and exploitative practice continue. We must strive to be good stewards of the land (and sea).

Mahalo for your attention to this matter.

David Pinilla
Course Director
davidp@jacksdivinglocker.com
Cell: 8083584492
Jack’s Diving Locker
75-5813 Ali’i Drive | Kailua-Kona, HI 96740
tel (808) 329-7585 | fax (808) 329-7588
https://www.jacksdivinglocker.com/

From:	muirbean@gmail.com
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F-1: Aquarium trade
Date:	Thursday, October 7, 2021 8:12:18 AM

Hi please accept my input as a Hawaii resident speaking for many of my Hawaii family and friends you will not be hearing from, but are nonetheless, equally opposed to the aquarium trade resuming their take.

These animals are needed in their natural habitat as part of a very delicate ecosystem that is already threatened in so many ways. In addition to performing an important environmental role, taking of a public resource for private gain is wrong. These animals should be left alone to be viewed in their natural habitat. The aquarium industry should not be allowed to cause harm to these animals which is what happens to the fish that survive. They are harmed by being removed from their family and habitat, and they are subjected to inhumane treatment at the hands of humans. It is animal abuse. And for the many that don't survive the inefficient process of taking fish from their natural habitat, it is torture and death.

Erin Pinto
Paia, HI

From: Elisa Plauche
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda ítem F1 testimony REJECT the FEIS
Date: Sunday, October 3, 2021 9:13:30 AM

Dear BLNR,
I am a Hawaii resident and an avid snorkeled. I believe that Aquarium Collecting Should NOT Be Allowed to Resume on Oʻahu!

Because the Final Environmental Impact Statement (FEIS) proposed by the mainland pet trade to allow 15 unidentified aquarium collectors to annually take hundreds of thousands of reef animals from Oʻahu's reefs is deeply flawed.

Please REJECT the FEIS aimed at reopening Oahu's deadly aquarium trade!

The very survival of Oʻahu's dwindling marine species is at stake. Decades of unlimited aquarium collection on Oʻahu have led to a 90% reduction of the most heavily targeted species. Yet, the FEIS totally ignores this, proposing levels of take that far exceed reported historical catch for most species.

The FEIS ignores data and research documenting the impacts of their actions, such as:

- research documenting the 90% reduction of key species described above
- a paper describing the collapse of the aquarium fishery on Oʻahu's southwest reefs 35 years ago -- which have yet to recover
- research documenting that Hawai'i residents receive ZERO benefits from the trade, but suffer ALL the costs.

Additionally, the required Cultural Impact Assessment claimed the EIS proposal would close 21% of Windward coast to collection, YET the FEIS proposes no such closures.

The entire FEIS is designed to facilitate their forgone conclusion that taking large numbers of marine animals and selling them to the aquarium pet trade outside Hawaiʻi has no significant impact on cultural, biological, and socioeconomic resources. They do so by claiming that aquarium trade operations would take a small percentage of the entire island-wide populations of the species they target, yet nothing would prevent the collecting of species to the point of collapse in specific places, such as occurred in the past!

Sincerely,
Elisa Plauche
(808)870-3861

From:	Cynthia Potter
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] FEIS
Date:	Wednesday, October 6, 2021 12:13:40 PM

I am a Hawaii resident since 1999, bought my own home on the Big Island in 2003 therefore am a tax paying citizen.
Please Please do not let the FEIS take our fishes from the ocean! I snorkel and many of my friends do as well. I also have friends that free dive and scuba dive. Over the 20+ years I have had the honor to live in this beautiful place, I have seen the amount of fishes slowly decrease. I know this has to do with environmental damage to the coral reefs. We cannot afford to let any of our fishes be taken.

Thank you for your consideration in this manner,

Sincerely, Cynthia Potter

From: Jeff Preble
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Please Approve Oahu Aquarium FEIS
Date: Thursday, October 7, 2021 8:37:52 AM

Dear Board members,
I am a former fish collector that now grows native plants and teaches kids about Hawaiian culture and agriculture. I am deeply offended by dive tour operators from the mainland who chose this small specialized fishery to attack in an attempt to look like they are helping with marine conservation. The hobby of marine aquariums is fun and educational, and it launched the careers of many of our top marine biologists.
Thanks for your time,
Jeff Preble
47-136 Mapele Way
Kaneohe HI 96744
808-551-1376

Board of Land & Natural Resources
Testimony on F3
October 8, 2021

Testimony of Richard L. Pyle, PhD

Chair Case and Members of the Board:

Thank you for the opportunity to speak with you today. My name is Richard Pyle, and am currently the Senior Curator of Ichthyology at Bishop Museum, although my testimony represents my own views, and not necessarily those of the Museum.

I was born in Hawaiʻi and am the fourth generation of my family to live here. I have been passionate about coral-reef fishes my entire life. I kept saltwater aquariums when I was a kid, collected aquarium fishes when I was in high school, and my first job was at Waikiki Aquarium, so I am familiar with the aquarium industry and how it operates. I have worked extensively to promote marine protected areas in Hawaiʻi, including the Papahānaumokuākea Marine National Monument, and have given presentations around the world (including two TED talks) on the importance of protecting biodiversity.

The aquarium fish industry has been studied and documented more extensively in Hawaiʻi than anywhere else on Earth. The take in terms of number of individuals and biomass is tiny compared to other fisheries. Moreover, collection targets juveniles of most species, so many of the collected fishes would likely not have survived in the wild to a reproductive age. Furthermore, the bycatch and collateral damage from the aquarium collecting activity is much smaller than for most other fisheries.

This robust scientific foundation has, since the 1970s, consistently shown that aquarium fishing in Hawaiʻi is among the best, if not *the* best-managed nearshore fishery in the world. We can say with high confidence that among the many threats to Hawaiian reefs and other marine life, the impact from the aquarium fishery is near the bottom of the list in terms of likely harm to the natural ecosystem.

Unlike many other activities that impact Hawaiian reefs more severely, such as climate change and its effect on coral bleaching, land-based run-off and pollution (especially plastics), invasive alien species, many different kinds of food fishing, and most other threats, the aquarium industry has positive impacts that may more than offset any impacts to the reef. I have met very few people as passionate about protecting coral reefs as the people around the country and around the world who invest thousands of dollars and thousands of hours maintaining healthy aquariums in their homes. Aquarium fishes serve as ambassadors for coral reefs, helping to instill passionate concern for their future well-being in the wild. In my opinion, the net positive impact of the marine aquarium industry in terms of motivating people around the world to care about our oceans exceeds any small impact that the industry has on the reefs.

I have reviewed this FEIS and find it to be among the most robust documents summarizing the aquarium fish industry that I have ever seen. The science included in the report is sound, and the regulation of the fishery it proposes is far more than adequate to ensure that Hawaiʻi's reefs are well protected.

I'd like to comment on one particular point mentioned in the report, which may not be widely understood or appreciated. The population figures provided by NOAA research are actually substantially underestimated. These numbers are based on surveys down to a depth of 30 meters, and use habitat area down to that depth to extrapolate population sizes. My particular area of expertise is the exploration and documentation of deep coral reefs, below 30 meters. Many, if not most of the species targeted for aquarium fish collecting extend to much greater depths than either the NOAA surveys, or the reach of aquarium fish collectors. For example, I have seen reefs with robust populations of Potter's angelfishes at depths of nearly 400 feet off O`ahu. Some of the targeted species, such as the Hawaiian Flame Wrasse, have their largest populations below 30 meters, so are inadequately represented in shallow-reef surveys. The point is, not only is the available habitat area for most of these species much larger than what was considered for the population density estimates, but some of the species are grossly under-represented based on surveys that were limited to depths shallower than 30 meters.

In closing, despite what many people probably assume, my role here is not to advocate for the marine aquarium fishery. My role is to advocate for implementing policies that are based on sound science. When the science supports stricter regulations, as it did for expanding the Papahānaumokuākea Marine National Monument, or for preventing the destructive commercial fishing practices and deep-sea mining, then my testimony has strongly supported increased protections. But when the science clearly supports a fishery, as it does in this case, it is my duty to encourage policies to be structured accordingly.

I am happy to address or comment on any questions you may have.

From:	David Ramos
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL]
Date:	Monday, October 4, 2021 7:37:51 PM

Aloha,

My name is Dave Ramos, I was born and raised in Oahu, My Father is from Honoka'a on the Big Island.
I've been aquarium fishing since 1986, and spent 35 years learning and observing fish behavior in our underwater ecosystem. The first 3 years I made barely enough to put gas in my truck, boat and a little left for air in my scuba tank. When I finally learned to catch fish one day I thought,wow I'm going to go back there and collect some more tomorrow. When I went back to the same area the fish saw me and took off. I then thought I needed to move to another area. This is why you can't fish out an area.

Unless you are in the ocean here for years and observing the fish you won't be able to understand how it works.Few people other than Aquarium Fishermen have the water time it takes to learn the reefs.I think 35 years in the ocean qualifies me to let you know how the reef fish collecting works.

This is how aquarium fishing works. Each reef structure contains a certain community of fish. These communities are fiercely guarded by the reef enforcers. They are the Palani, Mamo, and a host of aggressive fish.Any new fish that tries to move in are immediately pushed out to keep the population stable and make sure that only the amount of fish that can be sustained with the amount of food that is in the area can stay.

Let's say for example you have 100 fish on a particular reef. If we collect 40 of them, then the reef enforcers will allow only 40 more back on that reef. This is why after about 3 months of leaving the area alone you will have the same amount of fish there again.We have learned to rotate areas so we can collect year around.

I'm not blaming the environmentalists for how they feel but they have no clue how our eco system works. I have offered to take a few of them out to show them how we collect but it seems they aren't interested in the truth. 35 years of sustainability. There might not be a lot of aquarium fishermen (due mostly of the hazards of this job) but there alot of people with families that are affected by the closing down of this industry.

Mahalo for your time
Dave Ramos

From: Leatrice Ramos
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Oahu EMIS,
Date: Tuesday, October 5, 2021 1:10:05 PM

Aloha,

My name is Leatrice K. Ramos, and my husband is David Ramos who is a Tropical Fisherman.
I would like to tell you some background of my husband,
When I met him he was doing inverts first, then a couple years later he got into Tropical Fishing.
It was very difficult the first two years, he had to learn the fish. The thing you have to know is while you are learning you have to be safe and respect the ocean at all times. It is not a easy task to become a Tropical Fisherman.
I wad born and raised on the island of Oahu and my Ancestors are full blooded Hawaiian and I'm so proud to be one of them.
We have been going to court a lot of years dealing with the Tropical Fishing and I Pray and hope
the committee for once and for all to let Tropical Fishing go on.

Much Mahalo,
Leatrice K. Ramos
10-05-221

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From: Leatrice Ramos
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Fwd: Oahu EMIS,
Date: Wednesday, October 6, 2021 10:10:16 AM

revised:
Aloha,

My name is Leatrice K. Ramos, and my husband is David Ramos who is a "Tropical Fisherman
I would like to tell you some background of my husband.
When I met him he was doing inverts first, then a couple years later he got into Tropical Fishing.
It was very difficult the first two years, he had to learn the fish. The thing you have to know is while you are learning you have to be safe and respect the ocean at all times. It is not an easy task to become a Tropical Fisherman.
I was born and raised on the island of Oahu and my Ancestors are Pure Hawaiian and I'm so proud to be one of them.
We have been going to court a lot of years dealing with the Tropical Fishing and I Pray and hope the committee for once and for all to let the Tropical Fishing go on

Much Mahalo,
Leatrice K. Ramos
10-06-2021

---------- Forwarded message ---------
From: **Leatrice Ramos** <kauhilanialoha@gmail.com>
Date: Tue, Oct 5, 2021 at 1:09 PM
Subject: Oahu EMIS,
To: <BLNR.testimony@hawaii.gov>

Aloha,

My name is Leatrice K. Ramos, and my husband is David Ramos who is a Tropical Fisherman.
I would like to tell you some background of my husband,
When I met him he was doing inverts first, then a couple years later he got into Tropical Fishing.
It was very difficult the first two years, he had to learn the fish. The thing you have to know is while you are learning you have to be safe and respect the ocean at all times. It is not a easy task to become a Tropical Fisherman.
I wad born and raised on the island of Oahu and my Ancestors are full blooded Hawaiian and I'm so proud to be one of them.
We have been going to court a lot of years dealing with the Tropical Fishing and I Pray and hope
the committee for once and for all to let Tropical Fishing go on.

Much Mahalo,
Leatrice K. Ramos

10-05-221

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From: Dulice Reden
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Please reject the EIS
Date: Monday, October 4, 2021 4:02:39 PM

I am a resident of Hawaii Island, our Ocean resources should not be exploited with damaging aquarium collection. This atrocity is against protecting our valuable natural resources, irreplaceable wildlife and upsets our reef systems. Please ban aquarium fishing on our precious island . Not only is it a cruel practice, but it robs our oceans and Ruth have a very precious resource.
Respectfully,
Dulice Reden
Sent from my iPhone

From:	ron.rehkemper@gmail.com
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] EIS Support Testimony
Date:	Wednesday, October 6, 2021 11:26:43 AM

I would like to protest the cancellation of permits allowing established aquarium collectors to collect fish from our oceans around Oahu and the rest of the state. As a person born and raised in Hawaii, I believe that there is science proving that these small group of REGISTERED collectors do not harm the environment and should be allowed to continue their livelihood. There are much more pressing issues that should be address in terms of over fishing rather than wasting valuable resources going after the wrong people. The ones that are registered are NOT the ones that are overfishing the area. The collected aquarium fish that are not for consumption and they reproduce rather rapidly if you look at the SCIENCE. This is a sustainable business that features Hawaii around the world and also assists our tourism industry. To ignore the science and bow down to a very vocal MINORITY is just wrong and is hurting hard working people. Please look at the science and spend your efforts where they will make a difference. The registered aquarium collectors are business people trying to earn a living and have been doing for many, many decades, to take away their livelihood is just wrong.
Please reconsider.
Mahalo for your time, please do the RIGHT thing.
Ron Rehkemper
1324 Kuuna Street, Kailua, HI 96744

HOUSE OF REPRESENTATIVES

STATE OF HAWAII
STATE CAPITOL
HONOLULU, HAWAII 96813

October 06, 2021

Board of Land and Natural Resources
1151 Punchbowl St.
Honolulu, HI 96813

Suzanne D. Case, Chairperson
Christopher Yuen, Hawaiʻi Member
Doreen Nāpua Canto, Maui Member
Thomas Oi, Kauaʻi Member
Samuel "'Ohu" Gon III, Oʻahu Member
Vernon Char, At-Large Member
Wesley "Kaiwi" Yoon, At-Large Member

Re: Opposition to Agenda Item F.1. Determination of whether the Final Environmental Impact Statement (FEIS) complies with applicable law and adequately discloses the Environmental Impacts of Proposed Issuance of Commercial Aquarium Permits and Commercial Marine Licenses forthe Island of Oʻahu, for the purpose of accepting the FEIS; dated August 20, 2021, Applicant Pet Industry Joint Advisory Council (PIJAC); Island of Oʻahu, State of Hawaiʻi.

Aloha Chair Case and Honorable Members of the Board,

As an elected official who has taken an oath to uphold the state constitution, I have a duty to protect public trust resources. With that kuleana in mind, I beseech you to recognize the gaping holes that this Environmental Impact Statement fails to address. For years, the aquarium fishing industry has claimed they are "sustainable" but there are no accurate baseline studies to show how much this industry has actually impacted fish stocks compared to 100 years ago.

This unabashed commercialism is destroying our reefs, our ocean, and our marine wildlife. People all over the world are pressing their faces against glass prisons to look at fish that belong on our reefs. We are leaving our sea life floundering on the brink of extinction, which will have disastrous ripple effects on the corals and nearshore ecosystem.

I appreciate the May 2020 decision by this body that rightfully rejected the previously proposed DEIS, please uphold the same decision in this case. While they have included a catch limit in this proposal, there is precious little enforcement. The fact remains that they have not clearly demonstrated necessity nor public benefit of allowing the unmitigated take of this public trust resource.

Office of Representative Tina Wildberger
Proudly serving the 11th House District
415 S. Beretania St. Honolulu, HI 96813, Room 327
Phone: 808.586.8525 | Fax: 808.586.8529 | email: repwildberger@capitol.hawaii.gov

Permitting the aquarium trade to profit so highly with so little oversight is an enormous inequitable giveaway of a public trust resource. Please allow the fish a chance to return to their rightful population density.

Mahalo,

Tina Wildberger

Representative Tina Wildberger
House District 11 - South Maui
Kīhei · Wailea · Mākena

From: Frederick Reppun
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Testimony on agenda item F-1 Aquarium Fishing
Date: Thursday, October 7, 2021 9:00:59 AM

As a resident and long-time recreational user of Kane'ohe Bay, I urge the Board to consider the specific impacts of aquarium fishing to Kane'ohe Bay. The final EIS does not disclose specific impacts to the Bay, which may be significant given the ease of collecting in the Bay and lack of population connectivity with other areas (and corresponding inability to repopulate from protected areas outside the Bay).

Mahalo,
Frederick Reppun

--
Frederick Reppun
Education Coordinator
He‘eia National Estuarine Research Reserve
freppun@hawaii.edu
(808) 779-9411

From: A Roman
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] I Support this EIS study
Date: Tuesday, October 5, 2021 8:33:39 PM

Aloha my name is Aaron Roman and I support this eis! As a commercial food fisherman myself I believe it is the right for people in Hawaii to live off the land and the sea along as it's done in a sustainable manor and managed by the Dlnr.

Mahalo!
Aaron

Sent from my iPhone

From:	Shirlie Rose
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Attention: OAHU FEIS
Date:	Monday, October 4, 2021 2:04:35 PM

Attention. OAHU FEIS
I am writing this letter in hopes that someone somewhere with some authority will understand the point that I'm trying to make. I have many family members as well as friends that were involved in the saltwater fishing industry. Particularly tropical fish. The beauty of our islands is something that is without compare. I want to express my sadness in the fact that this fishing has been brought to a hault. Those that I know of who are tropical fishermen have the utmost respect for the ocean and it's reefs and the environment found within the oceans' depths. Using a little common sense will allow someone to understand that these fishermen do not destroy the reefs nor the environment. To the contrary they protect it and they hold it close to their hearts. If they see any type of trash or anything that doesn't belong in the ocean they'll grab it and they'll bring it out of the water to protect all species that are found in the waters. Why would anybody believe that these fishermen would not have such respect for the ocean as that's their livelihood! It's what feeds their families. Now we have Covid and this has disrupted their income in ways that are not even explainable. They're having to deliver pizza, mow people's lawns, work on peoples cars etc. This is just to try to gather pennies together to be able to feed and take care of their families. With all due respect I hope and pray that you will reconsider and open up the tropical fish industry once again. Please help our ohana continue to show you that they LOVE the ocean and wouldn't do anything to harm the environment. Please allow then to take care of their families !!!!

Respectfully,
Shirlie Rose

808-861-7306

Sent from AOL Mobile Mail

BLNR Meeting, October 8, 2021

Testimony in support of the Oahu Aquarium Fishery FEIS

I am writing in support of the finel environmental impact statement (FEIS) for the Oahu aquairum fishery.

Please let these fishermen get back to work. We need all the jobs we can get in Hawaii. Every year, more of our children are forced to move to the mainland because there are no opportunites. Diving for aquarium fish is sustainable and hurts nobody. With the restrictions posed by the FEIS, it would be impossible for any of these species to be overfished. Please listen to the science, approve the EIS, and let these local families continue to earn a living from the ocean, as they were doing for decades prior to the lawsuit that forced the fishery to close.

Thank you for the opportunity to testify,

Matthew Ross

Tropical Fish Emporium LLC
PO BOX 725 , Kaneohe, HI 96744
tel: (808) 222-7559 email: ryan.tfehi@gmail.com

Aloha Land Board Members,

My name is Ryan Rothwell, owner of Tropical Fish Emporium a fish exporter here on Oahu. I am a 6th generation local born and raised on this island and am a member of the Hawaii Sustainable Reef Fisheries.

In addition to the other points others have made, I ask that you accept the EIS so that we can get our fisherman back to work. A small sustainable fishery with low impact is a valuable asset to the state and its residents. Aquarium fish are ambassadors for Hawaii, because the fish are handled by experienced fisherman using only hand collection and the best practices people worldwide KNOW the quality and beauty of fish that come from Hawaii, and this is something that we should be proud off. Allowing the sustainable collection of fish in Hawaii allows us to show the world what Hawaii has to offer outside of a tourism brochure, while being good stewards of the environment. Sustainable collection has always been and will continue to be our goal and we can continue to be the model fishery that other countries have based their collection laws and practices of. Our EIS shows that this is a low impact, ecologically friendly business that is in-line with the DAR's 30x30 initiative.

Fish that are collected and sold bring joy to private residents, research institutions, public aquarium and aquaculture facilities that will care for them for years to come and money directly into the state. Since I am not a collector, my business handles the husbandry of the fish before shipping along with the logistics of carefully packing and moving these fish around the world and I know first-hand that the money from these fish STAY in Hawaii with the exporters, box and bag supply companies, dive shops, veterinarians, boat repair and maintenance, collectors, and my employees and their families that have been out of work since January.

Thank you for your time,
Ryan Rothwell

From:	Steve Saito
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Please Accept Aquarium EIS
Date:	Wednesday, October 6, 2021 12:10:56 PM
Attachments:	kiimplibjkcajkfe.png

Aloha Kakou,

I am born and raised in Hawaii and I am writing in support of Pisces Pacifica as a responsible business in order for reinstatement of their fishing permit. There is little impact of an individual private businesses on the Hawaiian environment in comparison to commercial businesses throughout our island chain. The responsibility of maintaining a small business is difficult enough without over zealous commercial enterprises and environmental opposition restricting local small businesses. The problem is every effort placed onto our environment has a effect. This dilemma is a challenging task as we are all part of our environment and this small business does contributes to our economy and community in order to survive. This business I am in support is part of our local community and has earned and maintained the knowledge and careful guidance that provides their livelihood. We need to support our responsible homegrown business community.

Respectfully,

--
Steve Saito

Allied Machinery Corporation
Construction & Heavy Equipment Sales and Rentals

94-168 Leoole St., Waipahu, HI 96797 | Office Ph:(808) 671-0541
Direct:(808) 687-2157 | Cell:(808) 271-1353
http://alliedmachinerycorp.com

October 7, 2021

Board of Land and Natural Resources

P.O Box 621

Honolulu, Hawai‘i 96809

Submitted via e-mail: blnr.testimony@hawaii.gov

Re: Testimony Regarding Item F1 Final Environmental Impact Statement for Issuance of 15 Commercial Aquarium Permits on O‘ahu

Dear Chairperson Case and BLNR Board Members:

My name is Siena I. Schaar and I hold a Master's degree in Environmental Management. In 2021 I co-authored and published a cost-benefit analysis (CBA) that specifically analyzed Hawai‘i's marine aquarium fishery to provide necessary information to decision makers. This report was published in the peer-reviewed Marine Policy journal, and is entitled "The future for Hawai‘i's marine aquarium fishery: A cost benefit analysis compared to an environmental impact assessment" (2021) (*Please find attached with this testimony*.)

The Pet Industry Joint Advisory Council's [hereinafter "PIJAC's" or "Applicant's"] Final Environmental Impact Statement (FEIS) fails under HEPA standards two-fold – both procedurally and in insufficiency of content. **First**, the Applicant's FEIS has deployed an entirely new preferred action that was not included in the DEIS published May 2020 and thus the new preferred action was never subject to public question and comment as required under HEPA. **Second,** and perhaps as a result of the entirely new proposed action, the FEIS fails to adequately analyze the environmental and socioeconomic impacts of the proposed commercial aquarium collection across O‘ahu, and therefore, is not in compliance with HEPA requirements. Thus, **I strongly encourage the Board to reject PIJAC's FEIS.**

A. <u>As to the second fatal flaw, PIJAC failed to accurately analyze the costs and benefits and their distribution across relevant stakeholder groups, thereby ignoring the "Precautionary Principle" adopted by Hawai‘i's Supreme Court, and failing to meet the HEPA requirement of assessing and discussing *reasonably foreseeable* impacts.</u>

Properly conducted CBAs are used in environmental impact studies to provide decision-makers "the balance required in complex regulatory decisions." Our independently conducted CBA was undertaken to analyze the costs and benefits of Hawai‘i's marine aquarium industry for various scenarios and their distribution across stakeholder groups. Four past, current, and proposed management scenarios were explored and the CBA results were compared to the recommendations and conclusions of the WHRFMA FEIS before it's revision – which is comparatively similar to the O‘ahu FEIS.

Our CBA of the statewide aquarium trade determined that ending the trade was the only option that yielded positive annual benefits, and negatively impacted the fewest stakeholders.

- We found that the **annual net positive benefit** of banning the aquarium trade was between $442.1M–$478.9M – factoring in potential costs, including **on-reef tourism** impacts to Big Island and Oʻahu which the FEIS chose to exclude due to "limited data."
- It is important to note that, most of the state's on-reef tourism value accrues from the island of Oʻahu – with an estimated annual value of $440 M.

Our CBA included potential impacts on on-reef tourism – deferring to the precautionary principle articulated by the Hawaiʻi Supreme Court, where the Court concluded that, related to public trust resources, "where [scientific] uncertainty exists, a trustee's duty to protect the resource mitigates in favor of choosing presumptions that also protect the resource." The RFEIS chose to omit these potential impacts and costs, while our CBA followed the precautionary principle set-forth by the Hawaiʻi Supreme Court and erred on the side of caution when making these critical assessments that ultimately impact public trust resources.

Here, in comparison to the findings of our CBA, PIJAC's Oʻahu FEIS fails to assess the costs and benefits of the aquarium trade and their distribution across stakeholder groups. Again, our CBA deferred to the judicial authority of the Hawaii Supreme Court, which reaffirmed "that all public resources are to benefit Hawaiʻi's people and that private or commercial use should receive a "*high" level of scrutiny*" making "the size of the stakeholder group" of interest. While the estimated market *benefits* of the aquarium trade were similar between the CBA and the EIS, the estimated costs were not:

- The FEIS estimated the *costs* of the trade to Native Hawaiians and other stakeholder groups were negligible, and the EIS provided no justification for that estimation.
- Additionally, the FEIS failed to take a serious look at other *reasonably foreseeable* socioeconomic impacts, instead only considering the estimated gross annual sales if all fifteen fishers caught max quotas on all thirty-one species – which PIJAC estimated would max out at $746,000 (*FEIS*, Table 5-3, p93).

In PIJAC's FEIS, the comparatively low market benefit of the aquarium trade in Hawaiʻi accrued to a small group of collectors, wholesalers and dealers, including fifteen unnamed collectors in the FEIS. However, 1,415,872 residents – 83% of whom want to see an end to the trade due to environmental, cultural, and ethical concerns with capturing marine life for the pet trade outside Hawaiʻi – bore the losses.

Our CBA concluded that sustainable management requires that the costs and benefits accruing to all stakeholder groups be investigated to ensure policies are equitable. Relying on EIS recommendations that aim to support one group of stakeholders at the expense of others to determine policy could be considered biased.

B. <u>Additionally, PIJAC omitted key information regarding the true market dynamics of the fishery and thus, is **misleading decision makers** on to whom the market value of the fishery actually accrues.</u>

PIJAC strategically omitted key discussion and explanation about the percentage of market benefits that actually accrue to economies outside of Hawaiʻi. For example, one of PIJAC's main supporting arguments for continuing the trade in Hawaiʻi is the assertion that Hawaiʻi benefits from "millions of dollars" in gross sales, again citing to the estimated gross annual sales of all fifteen fishers catching max quotas on all thirty-one species – which they estimated would max out at $746,000 (*FEIS*, Table 5-3, p93). This table shows that for Yellow Tang, if the fifteen collectors caught 23,524 individuals and sold them for $6.49/each (strangely different from $4.29/each in the WHRFMA FEIS), the average annual sales would create $152,670.76 in market benefits presumably added "to the state's economy."

What this discussion, and the entire FEIS, ignores is the reality of this export industry and who is actually realizing the large market benefits. At least 95% of the fish caught from our public trust resources are being <u>exported</u> and sold to mainland dealers who mark up the prices before selling the fish again to a retailer or a final consumer. This market supply chain was analyzed in our CBA and we found that U.S. mainland dealers may have a 500% mark-up or higher. In the case of the Yellow Tang, a survey of online U.S. aquaria retailers revealed that Hawaiian Yellow Tangs are being sold for an average price of $74.41 – a **1,146% mark-up** from the $6.49 base price that Hawaiʻi sellers retail them for. Even if Hawaiʻi fishers sell their Yellow Tang to the mainland for $16, the number we used in our CBA, the mainland retailers may sell that same fish for $74.41 – which still is a **465.1% mark-up**.

This larger market benefit never reaches Hawaiʻi's economy and accrues in the U.S. mainland states where the fish are resold. Thus, outside stakeholder groups, such as the national and international pet industry retailers, are realizing the largest market benefits of all stakeholder groups. Again, the stakeholder groups who are losing the most are Native Hawaiians, residents of Hawaiʻi, and Hawaiʻi's tourist industry. **This is not equitable**.

As stated in our CBA, relying on an FEIS that is funded and produced by an industry stakeholder group is likely to produce a document aimed at justifying the position of the funder, as is the case here. Sustainable management requires that the costs and benefits accruing to all stakeholder groups be investigated to ensure that policies are equitable. Given the above reasons, and many others outlined in our seven-page CBA report – **the Board <u>must reject</u> PIJAC's flawed and procedurally fatal FEIS.**

Mahalo,

Siena I. Schaar, MEM

(*Please find 2021 CBA attached with this testimony*)

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The future for Hawai'i's marine aquarium fishery: A cost benefit analysis compared to an environmental impact assessment

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ABSTRACT

Conflict has surrounded Hawai'i's commercial marine aquarium fishery since its inception in the late 1940s. In 2019, the Hawai'i Supreme Court requested that an environmental impact statement (EIS) analysing the ecological and cultural impacts of Hawai'i's marine aquarium fishery be completed for Hawai'i Island (Big Island) and O'ahu. The costs and benefits associated with the fishery and their distribution across stakeholder groups was however not addressed in the EIS. This paper presents a cost-benefit based analysis of four policy scenarios using existing secondary data for Hawai'i's marine aquarium fishery. From the analysis, a state-wide collection ban was the option that yielded positive annual net benefits and negatively impacted the fewest stakeholders. In contrast, the EIS recommends ten permits for fishing off the coast of Big Island be issued.

1. Introduction

Some view the marine aquarium fish trade as a path to expanding the conservation of reef environments based on the assumption that owning aquarium fishes cultivates awareness and interest in the conservation of their source habitats [46,6,31,47]. While conservation groups have promoted the aquarium trade as a means of enhancing livelihoods in developing countries, others are concerned that the profit motive of commercial fishers serves as an incentive to overharvest species commonly found in marine aquariums [37,39,59]. If marine aquarium fisheries are not properly regulated and the regulations are not promulgated, a common-pool resource dilemma will result in economic profitability prevailing over long-term sustainability – a tragedy of the commons scenario [43].

Hawai'i's commercial marine aquarium fishery has been a source of debate among various stakeholder groups including aquarium fishers and hobbyists, marine scientists, Native Hawaiians (Kānaka Maoli), resource managers, policy makers and community members [2,36,46]. The fishery's costs and benefits are distributed differently among these stakeholders, resulting in years of conflict. As has been observed in many fisheries around the world, fishers in Hawai'i under report their catches and mortality rates [23,48,52,56], which further exacerbates conflicts. The fishery is comprised of two geographically distinct zones. The first is the West Hawai'i Regional Fishery Management Area (WHRFMA) that extends the length of the west coast of Hawai'i Island (Big Island) from Ka Lae, Ka'u¯ (South Point) to 'Upolu Point. The second encompasses North Kohala, and the main Hawaiian Islands excluding all zones that are designated as Marine Protected Areas (MPAs) [57].

Residents and Native Hawaiian cultural practitioners have pushed to ban aquarium fishing in Hawai'i citing the lack of sustainable and humane harvesting methods, inadequate enforcement, inaccurate catch reporting and poor alignment with Kānaka Maoli ideals of resource management [23]. In 2017, the Hawai'i Supreme Court placed a moratorium on aquarium fishery permits, citing a need for a Hawai'i Environmental Policy Act (HEPA) review [15–17]. The court concluded that the permitted use of fine mesh nets involves the public's use of state land and therefore requires discretionary approval from the state [15–17]. The court's request in 2019 for an environmental impact statement (EIS) analysing the ecological and cultural impacts of the marine aquarium fishery came after Environmental Assessments (EA) for Big Island and O'ahu were submitted by the Pet Industry Joint Advisory Council (PIJAC) and deemed insufficient by the State's Department of Land and Natural Resources (DLNR) Chair Suzanne D. Case [15–17]. The final environmental impact statement (EIS) funded by PIJAC and conducted by a consulting firm, which concluded that DLNR should issue permits to ten commercial aquarium fishers in the WHRFMA, was unanimously rejected by the Board of Land and Natural Resources (BLNR) after concluding that the EIS did not adequately disclose the potential environmental impacts of the proposed action [14]. PIJAC appealed BLNR's decision to the Environmental Council who affirmed BLNR's rejection of

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Table 1
Description of policy scenarios analysed in CBA.

Scenario	Characteristics
A. Status quo (2019)	AQ Permits void and fishery continues without use of fine mesh nets on O'ahu, Big Island and no collecting in WHRFMA Voluntary catch report data Majority of catch is exported Unknown impacts to other fisheries, the environment, cultural resources and on-reef tourism State funds monitoring and management of fishery Potential for non-compliance Provides industry income Provides tax and fee revenue to state
B. Permitting system (2016)	Administrative rules and bag limits apply across the State Voluntary catch report data Majority of catch is exported Unknown impacts to other fisheries, the environment, cultural resources and on-reef tourism State funds monitoring and management of fishery Potential for non-compliance Provides industry income Provides tax and fee revenue to state
C. State-wide collecting ban	No aquarium species from Hawai'i state waters can be collected Collection exemptions possible for research, educational institutions and managers Wild-captured aquarium exports banned No impacts on other fisheries, the environment, cultural resources or on-reef tourism State avoids costs associated with managing the fishery Potential for non-compliance Loss of industry income Loss of tax and fees revenues to state
D. Captive breeding collection	Permits issued to fishers with facilities for captive breeding Opportunity to export from Hawai'i Unknown impacts on other fisheries, cultural resources, the environment and on-reef tourism State funds monitoring and management of fishery Potential for non-compliance Provides income opportunity for industry Provides tax and fee revenue to state

the EIS [27].

The 2019 state-wide moratorium allows commercial aquarium fishing to continue without commercial aquarium permits, as long as fine-mesh net equipment is not used and fishers possess a commercial marine license (CML), whereas, all collection has been outlawed regardless of gear-type for the WHRFMA [20]. A November 2020 order from Hawai'i's First Circuit Court requires environmental review for issuance of new or renewed annual CMLs to be used for aquarium fishing purposes, allowing aquarium collecting by CML holders to continue until their CML expire one year after issuance [18,21]. A January 2021 order from the same court further strengthened the November 2020 order by issuing an injunction to halt aquarium collection under existing CMLs, completely banning commercial aquarium fishing in the State of Hawai'i pending environmental review by the industry [13].

Many U. S. government agencies use cost benefit analysis (CBA) in addition to or in place of environmental impact assessment to assist in management decision-making. The U.S. Environmental Protection Agency [54] concluded that cost benefit analyses used to determine environmental regulations increased net benefits to society and "provide the balance required in complex regulatory decisions." International non-profit organizations also rely on CBAs in managing natural resources. Verdone [55] used CBA to analyse landscape forest restoration in Rwanda for the International Union for Conservation of Nature and Natural Resources.

This paper presents a cost benefit (CBA) based analysis using published information and existing data to provide evidence to assist decision makers considering the future of this fishery. Four policy scenarios were developed, the relevant costs and benefits for each scenario are described and/or estimated and their distribution across stakeholder groups are assessed. The CBA results are compared to the EIS recommendations and conclusions in order to determine how the two differ and which one provides a more accurate appraisal of maintaining the aquarium fishery.

2. Methods

Four past, current or proposed scenarios for managing this fishery are described (Table 1) in order to identify the associated costs and benefits, along with stakeholders impacted. Scenarios A and B assume that the aquarium fishery continues, though the number of fishers in the industry is not mandated in either one. Scenario A involves maintaining the 2019 status quo that restricts the use of fine mesh nets and no collecting in the WHRFMA. Scenario B assumes that the 2016 bag limits would be applied across the State. These were considered here because they both attempt to limit the catch. Scenario C involves a state-wide ban, which has been suggested by many stakeholders who do not benefit from the fishery. Scenario D allows the fishery to continue only to facilitate the establishment of captive breeding operations. This option is considered as one that protects wild fish in the long run, while also encouraging an industry that cultivates awareness and interest in the conservation of their source habitats by producing aquarium fish. The environmental impact statement (EIS) funded by PIJAC recommends limiting the number of permits, rather than limiting the catch.

The stakeholder groups who were identified in each scenario are described (Table 2) and the acronym used for the group throughout the

Table 2
Codes and descriptions for stakeholder groups.

Code	Stakeholder Group Description
S1	Native Hawaiians
S2	Residents of Hawai'i
S3	Tourists
S4	Collectors and wholesalers from O'ahu
S5	Collectors and wholesalers from Hawai'i Island excluding the WHRFMA
S6	Collectors and wholesalers from the WHRFMA
S7	All collectors and wholesaler in the State
S8	State government agencies

paper is identified. Previous research [2,23,36,46], various media reports, hearings and litigation surrounding the ongoing conflict in this fishery provided details about the stakeholder groups. A description of the methods used to estimate or describe each cost/benefit and their expected sign follow. While CBA normally involves discounting to ensure that net present value of costs and benefits are calculated, annual point estimates are used in this CBA. Since the estimates do not vary over time, discounting adds nothing to the analysis.

2.1. Cost and benefit estimates and descriptions

2.1.1. State management costs

Since both Scenarios A and B involve limiting the industry's catch and require voluntary reporting, the State will have to enforce these regulations. Therefore, to estimate this cost, DAR personnel in DLNR were contacted and asked to estimate DAR's 2019 management cost for Hawaiʻi's marine aquarium fishery including salaries of employees who work directly with the fishery, aquarium fish surveys and any other costs associated with the fishery that DAR funds. DAR officials provided a low estimate of USD 300,000 annually covering the time spent by 20 or more individuals in the aquarium fishery along with their supplies and equipment. Their high estimate of USD 500,000 annually includes costs, such as fringe benefits that are not included DAR's annual 2019 budget, but are found in DLNR's overall budget. For Scenario C, these management costs should be eliminated overtime. Scenario D would likely involve management costs, which could be reduced as the policies and regulations that support this scenario are refined.

2.1.2. Tourism value

According to the Hawaiʻi Tourism Authority [29], the State's economy relied on tourism for its largest source of private capital. Spalding et al. [50], estimated the "on-reef" tourism value for the entire state of Hawaiʻi at USD 550.8 million per year. Spalding was contacted and estimated, using the existing data base the annual "on-reef" values for Oʻahu and Hawaiʻi Island to be approximately USD 442,496,000 and USD 16,921,000 respectively, for an annual upper bound of USD 459, 417,000. This was inflated to 2019 USD for a total annual value of USD 478,891,356.77. Cesar and Beukering [7] estimated the value of tourism to be USD 304 million and inflating this value to 2019 USD yields a low estimate of approximately USD 442.1 million.

This estimated tourism value between USD 478,891,356.77 and 442,100,000 USD represents the direct and indirect market value of on-reef tourism to the State in 2019. Maintaining this value over time is partially contingent on maintaining the health and beauty of Hawaiʻi's reefs. The aquarium fishery may reduce this over time as fish are removed from the reefs in Scenarios A and B because the limits are not calculated based on the productivity of the fishery and are difficult to enforce. Evidence also suggests that catches are underreported. Therefore, if the fishery continues, overharvesting of this public resource will likely occur and as a result, the value of tourism will decrease. Uncertainty exists as to how quickly this decline will occur. Researchers predict that unmitigated bleaching events could lead to the loss of shallow coral cover in Hawaiʻi by the year 2050 [35], which indicates that a 30 year time frame could be considered in making marine resource management decisions and would result in an extremely large total cost of continuing this aquarium fishery by 2050.

2.1.3. Industry income

In order to determine the market value of the aquarium fishery in Hawaiʻi, the methods used by Dierking [22] were updated with recent data to conservatively estimate 2019 gross revenue for the industry. Unpublished 2019 catch report summary information, unpublished 2019 dealer purchase information, unpublished 2019 individual catch reports, and unpublished permit lists from 2015 to 2018 were obtained from DAR. The 2019 price and cost information from dealer websites, retail price lists on websites, and industry structure information provided the data used for the estimation. The lower bound for total revenue accruing to fishers was calculated by multiplying the "diver price" for each species by the number sold to estimate annual revenue of USD 1,676,982 in 2019.

Wholesale revenue could not be estimated due to the lack of price information among local fishers who are also wholesalers. In order to estimate the upper bounds, the 2016 catch report data for "number sold" was used with retail prices on the website of a Hawaiʻi based fisher retailing fish. The "number sold" on the 2016 catch report for each of 12 species was multiplied by the 2019 retail price listed by the primary collector/retailer. The total revenue across all the species represents the upper bounds of USD 8,343,896, which includes the value of the fish after they were exported.

2.1.4. License fees

The State does collect license fees for the aquarium fishery. Commercial aquarium permits are USD 50 and recreational aquarium permits have no cost [20]. Commercial aquarium collectors must also purchase USD 100 commercial marine fishing licenses annually from DAR. Scenario A, which represents the status quo in 2019 only accounts for the cost of the commercial marine fishing license since all commercial aquarium permits are void. Scenario D assumes that a permit is required to collect for captive breeding. This scenario explores an option that would raise the permit cost to USD 500 and cap the number of permits issued at 100 state-wide.

2.1.5. Export values

The industry values also include the value of fish exported, which were investigated to determine how much of this value accrues to the State. Catch reports for 2016 are the most recent, complete annual data set and thus are used to estimate exports. Twelve species commonly targeted in Hawaiʻi's marine aquarium fishery (*Table a1*, appendix) were included. The data for six out of the twelve species discussed in this study (*Naso lituratus, Forcipiger flavissimus, Chaetodon multicinctus, Zanclus cornutus, Centropyge potteri, Coris gaimard)* indicated that the fish sales on initial catch reports by licensed fishers was lower than numbers of fish reportedly purchased by licensed dealers from licensed fishers on dealer sales and export reports. This suggests that a percentage of the catch was not reported on catch reports or was sold to dealers by fishers who do not report their catch to the state.

Dierking [22], reported that roughly 95% of the aquarium fish caught from the West Hawaiʻi fishery were exported. Two criteria were used to identify retailers from which price information was obtained. The first criteria requires that the species' primary and sole collection origin had to be Hawaiʻi, and the second requires the species be one of the 12 species described in this study, not including captive bred fish. Retail prices for 2019 were collected from 11 online aquaria retailers with 10 on mainland U.S.A. and one from Hawaiʻi. Species name, price, retailer name, city of operation and website information were used to generate an average out-of-state retail price for each of the 12 species and were compared to online retail prices offered by the local aquarium fishers/retailer. Retail price differences were 1.5–5.1 times higher in mainland markets compared to the local market.

The profits made on the mainland and the taxes on the value added accrues to the area in which the fish is retailed. Since these profits and taxes occur from the sale of a Hawaiʻi public resource, a negative impact occurs in comparison to keeping the fish in the reef to ensure that the State's tourism sector and/or residents continue to benefit from these fish. This is consistent with a 2019 decision by the Hawaiʻi Supreme Court that "all public natural resources are held in trust by the State for the common benefit of Hawaiʻi's people and the generations to come" ([8], p. 1150).

2.1.6. Environmental costs

Hawaiʻi's marine aquarium fishery almost exclusively targets herbivores and corallivores. The development of a State Coral Bleaching

Table 3
Cost and benefits associated with each scenario.

Scenario	Impacted Stakeholder Groups	Annual Estimates (USD)	
		Low	High
A. Status Quo (2019)			
- State management costs	S8	-300,000.00	-500,000.00
- Tourism value	S2, S3, S8	-442,105,806.46	-478,891,356.77
+ Industry income	S4, S5	1,784,936.43	8,343,896.00
+ License fees	S8	17,400.00	17,400.00
Total valued net benefit		-440,603,470.03	-471,030,060.77
Costs/benefits not valued			
- Losses from exports	S2, S8		
- Environmental costs	S1, S2, S3, S7, S8		
- Social costs	S1, S2, S8		
- Other fisheries' indirect costs	S1, S2, S7, S8		
- Captive breeding costs	S4, S5		
B. Permitting System (2016)			
- State management costs	S8	-300,000.00	-500,000.00
- Tourism value	S2, S3, S8	-442,105,806.46	-478,891,356.77
+ Industry income	S7	1,784,936.43	8,343,896.00
+ License fees	S8	26,100.00	26,100.00
Total valued net benefit		-440,594,770.03	-471,021,360.77
Costs/benefits not valued			
- Losses from exports	S2, S8		
- Environmental costs	S1, S2, S3, S7, S8		
- Social costs	S1, S2, S8		
- Other fisheries' indirect costs	S1, S2, S7, S8		
- Captive breeding costs	S7		
C. Statewide AQ Collection Ban			
+ Tourism value	S2, S3, S8	442,105,806.46	478,891,356.77
- Industry income	S7	-1,784,936.43	-8,343,896.00
- License fees	S8	-26,100.00	-26,100.00
Total valued net benefit		440,294,770.03	470,521,360.77
Costs/benefits not valued			
+ Environmental costs	S1, S2, S3, S7, S8		
+ Social costs	S1, S2, S7, S8		
+ Other fisheries' Indirect costs	S1, S2, S8		
D. Captive Breeding Collection			
- State management costs	S8	-300,000.00	-500,000.00
- Tourism value	S2, S3, S8	-442,105,806.45	-478,891,356.77
+ Industry income	S7	1,784,936.43	8,343,896.00
+ License fees	S8	50,000.00	50,000.00
Total valued net benefit		-440,570,870.03	-470,997,460.77
Costs/benefits not valued			
- Losses from exports	S2, S8		
- Environmental costs	S1, S2, S3, S7, S8		
- Social costs	S1, S2, S7, S8		
- Other fisheries' indirect costs	S1, S2, S8		
- Captive breeding costs	S7		

Recovery Plan, in collaboration with the National Oceanic and Atmospheric Association (NOAA), DLNR, and DAR concluded that the establishment of a combination of Marine Protected Areas (MPAs) and Herbivore Fishery Management Areas (HFMAs) across the main Hawaiian Islands ranked among the most preferred actions to address the State's coral reef recovery from climate change induced bleaching events [19]. The State's decision to employ spatial herbivore management, highlights the importance of herbivores as a critical tool for reef recovery and resiliency, thus increasing their value and importance in Hawaiʻi's coral reef ecosystems.

Past studies have indicated that climate change impacts coupled with local, human-induced stressors can retard coral reef resilience, resulting in regime shifts from coral to algal turf dominated systems if left unchecked [1,8,9,26,30]. Herbivores have been found to play critical roles in resisting these regime shifts [26]. While the long-term impact of the aquarium fishery on herbivore management is uncertain, the potential exists for the fishery to prevent the State from realizing its reef recovery goals.

2.1.7. Social costs

A 2017 survey of Hawaiʻi residents concluded that 90% of respondents support further regulation of Hawaiʻi's marine aquarium fishery, and that 83% of respondents support ending the trade altogether [4]. From the fishers' perspective, Stevenson et al. [51] found that 20.7% of all fishers disliked the bureaucracy and 17.2% disliked the poor reputation of the West Hawaiʻi aquarium fishery.

No secondary information about the overall social impacts is available. However, the Pet Industry Joint Advisory Council [44] did summarize several interviews in a Cultural Impact Statement found in Appendix A that describes the contentious nature of the fishery and its lack of alignment with Native Hawaiian values and fishing/management views/traditions [44].

While the impact of the fishery on the long-term social well-being of State's residents is uncertain, the majority appears to conclude that continuing to operate this fishery reduces their social well-being.

2.1.8. Indirect costs for other fisheries

While some studies have indicated that fish populations have increased in open areas and Fish Replenishment Areas (FRAs) where no aquarium collecting occurs, other studies have argued that many marine aquarium fish stocks in Hawaiʻi are still relatively data poor [41]. The Hawaiʻi Supreme Court has adopted a precautionary principle associated with the public trust with a ruling concluding that "where (scientific) uncertainty exists, a trustee's duty to protect the resource mitigates in favour of choosing presumptions that also protect the resource" ([32], p. 466)).

Overfishing is the primary driver of reef fish declines across the main Hawaiian Islands and the populations of food-fish species that overlap with some commonly collected aquarium species are particularly affected [24]. Specific concern regarding the sustained abundance of some commonly targeted food-fish species in the West Hawaiʻi aquarium fishery exists due to some species exhibiting declining populations [57]. Concern regarding the aquarium fishery's impact on the commercial and recreational nearshore reef fisheries has arisen due to overlap in target species [46,57]. This concern supports the conclusion that the aquarium fishery is likely to have negative impacts on other fisheries in the long-run.

2.1.9. Captive breeding costs

Scenario D involves allowing the aquarium fishery to continue in order to support captive breeding efforts. In order for this scenario not to have negative impacts on Hawaiʻi reefs, a detailed policy and supporting regulations would be required. Descriptions of the costs paid by wholesalers and collectors by Dierking [22] can be used to infer the cost categories associated with local collection and wholesale business operations. Captive breeding and husbandry would result in similar costs

Table 4
A comparison of procedures and recommendations for the CBA to those for the 2020 Hawai'i Island EIS.

Cost Benefit Analysis	Big Island 2020 EIS[a]
Explores four policy alternatives, including a ban.	Rejected considering a ban since it did not meet PIJAC's purpose. Considered three scenarios that involved no permit limits and one with a permit limit.
Provided evidence-based recommendations based on impact estimates, descriptions, and the distribution of them among stakeholder groups.	Provided a recommendation based on direct market benefits of the industry.
Recommends a statewide ban on the collection and export of marine aquaria. Suggests that captive breeding collection might hold potential if properly managed.	Recommends reducing the number of permits to ten across the State.
Completed as a student project using existing secondary data and not funded by any industry, government agency or non-profit organization.	Funded by the PIJAC.

[a] [44]

as wild collection, along with some additional costs to accommodate more technologically advanced equipment required to stimulate spawning [40,58].

Marine ornamental species can be categorized as demersal spawners or pelagic spawners. Most demersal spawners produce clutches of eggs in nests or on substrates and tend to form strong breeding pairs, often displaying parental care which makes them the preferred choice for captive breeding aquarists [40]. The specialized knowledge and equipment required for rearing marine aquarium fish that are pelagic spawners will make them more expensive to produce compared to wild collection [49]. This increase in costs would primarily impact those that purchase these captive bred fish. Currently, nearly all of these people live outside of the State and therefore likely have no particular interest in protecting the public resources of residents. Rhyne [49] also argues that promoting access to breeding information could result in more successful ornamental rearing and help conserve populations of wild aquarium fish.

3. Results and discussion

The results indicate that Scenario C, a state-wide ban on aquarium collecting, is the only scenario that produced positive net benefits (Table 3). Because point estimates in 2019 USD were the only quantitative data presented here, this conclusion is based on one annual estimate of costs and benefits. The stakeholder groups negatively impacted by a state-wide ban include a small group of local fishers, wholesalers, and dealers that comprise Hawai'i industry while benefits accrue to larger populations of stakeholders.

The status quo policy in Scenario A would allow collection to continue with methods other than fine-mesh nets. In the WHRFMA, where all permits are now void, poaching has been observed, resulting in vessel, aquarium gear and fish take seizures [5]. Thus, monitoring costs may increase if this scenario occurs. Scenario B, which represents what took place in 2016 does not put a cap on the issuance of permits, though it does provide for the collection of fees by the State. Overall, market benefits would still accrue only to aquarium collectors and wholesalers, though the distribution of net benefits between these industry members varies between Scenarios A and B because Scenario A excludes fishers in the WHRFMA.

Scenario D allows collection for captive breeding with a permit similar to DAR's Special Activity Permit system which allows research, education or management institutions to collect marine organisms with specific gear restriction exemptions [18,21]. However, all existing permit holders can claim to be engaged in breeding. Further research may be needed to identify potential regulatory and enforcement solutions for Scenario D. Fishers could be required to prove their capacity to captive breed species and stricter live-fish export regulations could be developed. While this would increase costs, the potential indirect and non-market benefits associated with not removing fish from the reefs in the long-run would also increase and provide the positive benefits associated with consumers having access to aquarium fish. Militz et al. [38] found that 90.5% of consumer respondents were willing to pay more for fishes that were certified as harvested in an environmentally sustainable way. This type of certification could be considered for captive bred fish to create a mechanism that convinces the customers to absorb some of the costs associated with switching to a sustainable practice [38]. In addition, captive breeding facilities could become attractions for residents and visitors. If captive breeding attractions included educational content designed to inform people about protecting fish and the surrounding reefs, the carrying capacity of Hawai'i's near shore ecosystems may increase.

A comparison of this CBA with the PIJAC funded EIS found that the procedures and overall recommendations were significantly different (Table 4). Both the CBA and the EIS relied on existing data to complete the analysis and the market benefits of the industry estimated by the CBA and the EIS are similar. The EIS did not consider a ban because it did not meet PIJAC's purpose to continue fishers' livelihoods [44]. The EIS considered three scenarios that involved unlimited permits and one that limited permits on the Big Island to ten. The costs for Native Hawaiians and other stakeholder groups of continuing to operate the fishery were considered negligible and no justification is provided as to why this decision was made [44]. No recommendations on compliance enforcement relative to the proposed bag limits or oversight to prevent poaching were included. No caveat was included that oversight and enforcement expenses might increase if permits were limited [44]. One individual who was allegedly named as one of the proposed permit holders [45] was also cited in a February 2020 poaching incident (R. Umberger, personal communication; [5]) which indicates the need for such a caveat. Overall the EIS puts forth a recommendation that supports the industry.

Because Hawai'i's Supreme Court reaffirmed that all public resource are to benefit Hawai'i's people [32] and that private or commercial use should receive a "high" level of scrutiny, the size of the stakeholder groups is also of interest. The resident population, including Native Hawaiians, was 1,415,872 in 2019 [53] and Pet Industry Joint Advisory Council [44] indicates that their preferred plan would directly benefit ten resident fishers with permits and their employees. Visitors, which numbered 10,424,995 in 2019 [28], will also likely pay a cost if marine aquarium fish are removed from the State's reefs. Tourists can also decide to travel elsewhere should the reefs become degraded, which will result in significant market costs for Hawai'i in the long-term.

4. Conclusion and recommendations

The analysis presented here determined that a state-wide ban on collection is likely to produce impacts of positive annual net benefits. The EIS funded by PIJAC recommended that collection permits be limited to ensure that the fishery remains in existence. Relying on EIS recommendations that aim to support one group of stakeholders at the expense of others to determine policy could be considered biased. CBA is used globally for evidence-based decision-making.

When considering the "sustainability" of any system, distributional and equity issues over a long-time frame must be considered [10]. The CBA presented in this paper explores these distributional issues that this fishery poses to a variety of stakeholder groups and the environment using the available evidence. While modern economic systems often focus on gross domestic product to track economic progress and guide policy, tracking environmental and social indicators has been identified as important to ensure sustainability in certain economic sectors specific to Hawai'i [42].

Other fisheries, which pose similar environmental problems [3,11,12,25,33,34], should consider employing CBA in order to inform decision-making. Relying on an EIS funded by an industry stakeholder group is likely to produce a document aimed at justifying the position of the funder. Stakeholders that receive cultural ecosystem services from resources that are also being harvested for market benefits often include relatively large populations of disadvantaged minorities and indigenous populations. Businesses interested in protecting their market benefits likely have an advantage if an EIS is the only source of management recommendations. Sustainable management requires that the costs and benefits accruing to all stakeholder groups be investigated to ensure that policies are equitable.

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CRediT authorship contribution statement

Siena Schaar: Investigation, Formal analysis, Writing - original draft. **Linda J. Cox**: Conceptualization, Methodology, Supervision, Writing - review & editing.

Declaration of Competing Interest

none.

Data availability

The majority of data used for this research came from secondary sources. Relevant pricing data was collected from public websites and catch data was retrieved by UIPA from the Hawai'i Department of Aquatic Resources (DAR).

Appendix

See Tables A.1–A.3.

Table A.1
The 12 common marine aquarium species included in this report.

Common Name	Scientific Name	Hawaiian Name
Yellow Tang[b]	*Zebrasoma flavescens*	Lau'ipala, Lauī pala, or Lā'ī pala)
Goldring Surgeonfish[a]	*Ctenochaetus strigosus*	Kole
Achilles Tang[b]	*Acanthurus achilles*	Paku'iku'i
Orangespine Unicornfish[b]	*Naso lituratus*	Umaumalei, Kala, Ume, Mahaha, Pakala, Pakalakala or 'Ohua
Chevron Tang[b]	*Ctenochaetus hawaiiensis*	n/a
Longnose Butterflyfish, (Forcepfish)[b]	*Forcipiger flavissimus*	Lau wiliwili nukunuku 'oi'oi
Multiband (Pebbled) Butterflyfish[a]	*Chaetodon multicinctus*	Kikākapu, Kapuhili
Fourspot Butterflyfish[b]	*Chaetodon quadrimaculatus*	Lauhau
Tinker's Butterflyfish[b]	*Chaetodon tinkeri*	n/a
Moorish Idol[b]	*Zanclus cornutus*	Kihikihi
Potter's Angelfish[a]	*Centropyge potteri*	n/a
Yellowtail Coris Wrasse[b]	*Coris gaimard*	Hinalea 'akilolo

[a] Indicates endemic species
[b] Indicates native species

Table A.2
Average retail prices (U.S Mainland) compared to average retail price (local collector/seller) of 12 common aquarium species, and price difference (%).

Common Name	Scientific Name	Avg. Retail Price (U.S Mainland) n = 10	Avg. Retail Price (Local collector/ seller) n = 1	Mark-up (%)
Yellow Tang	*Zebrasoma flavescens*	$74.41	$16.00	465.1
Goldring Surgeonfish	*Ctenochaetus strigosus*	$71.88	$14.00	513.4
Achilles Tang	*Acanthurus achilles*	$392.32	$150.00	261.5
Orangespine Unicornfish	*Naso lituratus*	$152.71	$37.50	407.2
Chevron Tang	*Ctenochaetus hawaiiensis*	$233.11	$150.00	155.4
Longnose Butterflyfish	*Forcipiger flavissimus*	$46.00	$15.00	306.6
Multiband Pebbled Butterflyfish	*Chaetodon multicinctus*	$35.37	$10.00	353.7
Fourspot Butterflyfish	*Chaetodon quadrimaculatus*	$78.99	$40.00	197.5
Tinker's Butterflyfish	*Chaetodon tinkeri*	$699.99	$350.00	200.0
Moorish Idol	*Zanclus cornutus*	$49.98	$10.00	499.8
Potter's Angelfish	*Centropyge potteri*	$108.06	$30.00	360.2
Yellowtail Coris	*Coris gaimard*	n/a	$30.00	n/a

Table A.3
Comparison of specimens reported sold on licensed aquarium collectors' detailed catch reports (2016) versus specimens reported bought from licensed fishers by licensed dealers, on licensed aquarium dealers' personal sales and export reports (2016).

Common Name	Scientific Name	No. Sold (AQ detailed catch report)	No. Bought (AQ dealer pers. Sale/ export report)	% (no. bought/ no. sold)
Yellow Tang	*Zebrasoma flavescens*	322,651	284,784	88.26
Goldring Surgeonfish	*Ctenochaetus strigosus*	45,765	44,106	96.37
Achilles Tang	*Acanthurus achilles*	6787	5758	84.84
Orangespine Unicornfish[a]	*Naso lituratus*	9966	10,338	103.73
Chevron Tang	*Ctenochaetus hawaiiensis*	5126 (B.I only)	4135	80.67
Longnose Butterflyfish[a]	*Forcipiger flavissimus*	1329	1507	113.39
Multiband Pebbled Butterflyfish[a]	*Chaetodon multicinctus*	314	666	212.10
Fourspot Butterflyfish	*Chaetodon quadrimaculatus*	480	448	93.33
Tinker's Butterflyfish	*Chaetodon tinkeri*	293 (B.I only)	218	74.40
Moorish Idol[a]	*Zanclus cornutus*	805 (B.I only)	970	120.50
Potter's Angelfish[a]	*Centropyge potteri*	6708	8726	130.08
Yellowtail Coris Wrasse[a]	*Coris gaimard*	866	993	114.67

(B.I only) indicates collection and reporting on detailed catch report only from Hawai'i island
[a] Indicates sales or export reporting over 100% of what was reported on initial detailed catch report.

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From:	Kim Schaumburg
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL]
Date:	Tuesday, October 5, 2021 1:54:15 PM

Aloha, my name is Kim.

Until captive breeding of tropical fish can provide a greater number and diversity of species for the aquarium trade, wild collection in Hawaii should be allowed if it is stringently regulated to ensure that environmentally safe collection practices and quotas are being adhered to. It should be noted that if the adverse effects of global climate change were to someday result in a catastrophic loss of marine life, the many dedicated aquarium hobbyists worldwide might prove to be invaluable keepers of some of the oceans’ precious treasures.

Mahalo!

From:	Maile
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Attn: O’ahu FEIS
Date:	Monday, October 4, 2021 2:19:20 PM

Attention: OAHU FEIS

I want to be counted among those who have sent in a request to re-open the tropical fish industry. It saddens me to think that my family and friends are struggling to take care of of their loved ones. The tropical fish industry also affects the dive shops and those who also depend on buying those fish to sell . We are proud of our islands and this industry is a part of OUR lives. This is not the mainland . Culturally we are different. Our environment is different. We RESPECT our oceans and reefs. Please respect our right to support our families.

Respectfully,
Maile S
808-554-1769

Sent from my iPhone

From: Henri Etta Schmitz
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] AGENDA ITEM F.1 TESTIMONY
Date: Monday, October 4, 2021 9:50:27 AM

As a full time Hawaii resident I respectfully request that you reject this flawed EIS. MAHALO, HENRI ETTA SCHMITZ

From: Dean Sensui
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Testimony for O'ahu Commercial Aquarium Permits -- Final EIS
Date: Tuesday, October 5, 2021 7:41:55 PM

Aloha…

In addition to having a BA in Journalism from the University of Hawaii at Manoa, working in the news media business since 1979, and producing a fishing show for TV since 2004, I was a council member with the Western Pacific Regional Fishery Management Council for three years, and am currently serving as the chairman of the Council's Non-Commercial Fishery Advisory Committee. I am also the vice-chairman of the Pacific Islands Fisheries Group which has been doing extensive work with NOAA Fisheries on Hawaii's bottomfish assessments for about 10 years.

I'm very familiar with fishery management principles and processes in both littoral and pelagic zones, as well as what goes into management planning regarding protected species.

Whenever the management of natural resources are discussed, all measures brought up for consideration should be examined with caretully acquired scientific information.

What has been well-established through studies conducted by Hawaii's Division of Aquatic Resources, and confirmed by the latest environmental impact statement, is that the practice of capturing and raising fish by aquarium collectors is sustainable, and does no significant harm to the resource or near-shore habitats.

I have observed and filmed the tropical fish capture process and can attest that claims of excessive take and destructive practices are unwarranted and untrue.

The process of collecting these fish is very low-impact. The fine-meshed net used to corral the fish for close inspection is just a couple of feet high and perhaps 20 feet long. It's a delicate net that is easily damaged if not handled with care, and is specifically designed to avoid damaging the reef.

A couple of small handheld scoop nets, similar to what you'd use inside of an aquarium, are used to capture just one fish at a time so the diver can carefully inspect it. And if it is deemed to be worth keeping, it's secured in a protective collection container.

The collection containers are brought slowly to the surface so the fish inside are allowed ample time to adjust to the change in pressure before being brought aboard the boat.

And after the diver leaves the collection site, there's no evidence they were there. The numbers of remaining fish appear unchanged because the percentage of fish taken from any particular spot is very low. And collectors will rotate among several spots to ensure healthy populations continue to thrive.

People who gather these fish do their utmost to keep them in the best condition possible. They cannot afford a high mortality rate because each one that dies represents a lot of time and effort wasted. If a tropical fish collector develops a reputation for bringing in fish that don't survive, their business wouldn't survive, either.

With reasonable care, the fish can live for years afterward -- despite claims to the contrary.

It should be noted that these, and other fish, live in the wild where they're constantly being preyed upon by other inhabitants of the reef. Of particular concern are invasive species such as roi, toau and taape.

Introduced in the 1950s, the taape population has expanded throughout Hawaii's waters. From shallows to the darkened waters hundreds of feet deep, these large schools of fast-moving carnivores consume anything that will fit into their mouths, 24 hours a day.

Imagine the amount of biomass they are responsible for removing from Hawaii's waters. Then compare that to aquarium fish collectors who are brief visitors taking a few fish at a time.

When given some proper perspective, it's clear that aquarium collecting plays an immeasurably small role in the status of our state's fisheries.

Thank you for your thoughtful consideration.

Dean Sensui
Executive Producer, Hawai‘i Goes Fishing
dean@HawaiiGoesFishing.com
808-265-8875

From:	Shannon Shea
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Agenda Item F.1 Testimony
Date:	Tuesday, October 5, 2021 9:37:20 AM

Dear Sir or Madam,

As a resident of Hawaii, and a professional in the dive tourism and education industry, I hope you will REJECT the EIS. The aquarium trade is an inhumane industry that exploits Hawaii's natural resources with no real benefit to its people or economy, no connection to traditional Hawaiian harvest and resource management practices, and significant detriment to its environment. A fish is worth so much more on the reef! Please don't let this wasteful, cruel, and exploitative practice continue. We must strive to be better stewards of the land (and sea).

Mahalo for your attention to this matter,

Shannon Shea
PADI Course Director #270304
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75-5813 Ali'i Drive
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From: Jim Stauff
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Aquarium Collecting
Date: Tuesday, October 5, 2021 10:55:32 AM

Dear Sir or Madam,

As a resident of Hawaii, and a professional in the dive tourism and education industry, I hope you will REJECT the EIS. The aquarium trade is an inhumane industry that exploits Hawaii's natural resources with no real benefit to its people or economy, no connection to traditional Hawaiian harvest and resource management practices, and significant detriment to its environment. A fish is worth so much more on the reef! Please don't let this wasteful, cruel, and exploitative practice continue. We must strive to be good stewards of the land (and sea).

Mahalo for your attention to this matter.

Sincerely,
Jim Stauff

From: danstearn@thefishstoreseattle.com
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Testimony Regarding Oahu EIS Being Heard On October 8th.
Date: Tuesday, October 5, 2021 9:18:03 AM

To Whom It May Concern-

I am writing to you as both a retailer of aquarium plants and animals and an avid aquarist. I wholeheartedly support the regulation and limiting of collecting animals from Hawaiian waters for the aquarium trade and this is a position I have held for more than two decades when I first found out about the completely unregulated collection that was allowed to anybody with a dip net and a plastic bag.

I have not seen any numbers on the population dynamics or recruitment rates specifically for Hawaiian animals, but it has been well known for many, many years that properly managed plant and animal populations can lead to productive and healthy populations in nature. Here in Seattle, The University of Washington has a lengthy history of studying numerous economically important marine species (e.g. all salmon species, halibut, lingcod, rock fish species, Pacific pollock, razor clams, and geoducks) and could prove to be a useful resource for determining proper management techniques if needed.

Limiting collection times of the year, the number of individual animals to be caught, the areas where collecting can take place, and the number of people who are allowed to collect are all valid ways to help manage virtually any of the species in question. Completely closing collection for the aquarium trade while still allowing limitless food fishing is nonsensical. All aspects of collection, whether for food or live export, must be monitored and controlled; especially when the aquarium trade accounts for 1% of the total number of collection licenses. This is the only way to truly manage Hawai'i's natural resources.

Within the aquarium industry, we already see many examples of regulations for collecting around the world. Two quick examples would be Brazil heavily limiting and restricting the collection and export of many of their most vulnerable species and Indonesia being required to have CITES permits properly filled out and paid for if any of their live corals are exported. There are ways to conserve healthy ecosystems without dire economic consequences.

On my end, the cost of the animals, including collecting, shipping, and a mark up to cover care and staff costs, makes it prohibitive for my customers to view any of the saltwater animals I sell as cut flowers, intentionally bought with the expectation of their quick demise. My shop is not in the business of excessive purchases and sales of animals that will not survive just for the sake of pumping them through some sort of free flowing economic pipeline. Everyone on my end is looking for many years of enjoyment with any animal they purchase. We all want to see the animals that are brought in to live and grow. This is what helps to foster a deeper understanding and empathy for any environment, much more so than a video program or article. We can only achieve this immersion into the natural world by allowing for hands-on husbandry of the animals. Many people cannot travel to Hawai'i, so they would have less of an interest in its environments without being able to witness even a small slice of its splendor in their own home.

Please allow for the responsible limited collection of Hawaiian animals for the aquarium trade.

Thank-you for your time and careful consideration on this matter.

Sincerely,
Dan Stearn
The Fish Store
Seattle, Washington

From: Comcast
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Save Hawaiian Reefs
Date: Tuesday, October 5, 2021 12:53:47 PM

I strongly oppose the EIS. Please stop farming fish to aquariums and other FISH industries. Respect Hawaii and respect the wildlife.

Thank you, Karen

From:	WAYNE SUGIYAMA
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Support for the FEIS for the aquarium fishery on Oahu
Date:	Wednesday, October 6, 2021 11:19:01 AM

Dear Board of Land and Natural Resources Chair and committee members,

I am in support of passage of the FEIS for aquarium fishing on Oahu. The Covid-19 pandemic has destroyed the economy in Hawaii and every little bit of help will be supporting a very small group of fishermen in restoring their livelihoods. Please accept the FEIS.

Thank you very much.

Best regards,
Wayne Sugiyama

From:	Liysa Swart
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] I oppose aquarium fish gathering.
Date:	Thursday, October 7, 2021 8:17:03 AM

I used to work for Aquatic Resources and was aboard the RV Kila in 1985. The waters around the major islands have become so depleted in the last 30 years there should be no question that aquarium fish gathering should NEVER be re-instated. When I was a Junior at UH, I paid my way through school working at a dive shop, and I was offered a job collecting aquarium fish. I did it one time, and realized it was unethical, and stopped. Please, don't sanction the rape and further decimation of our fragile ecosystem.

Mahalo
Liysa Swart

From:	Kenneth Tabulog
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Testimony regarding Oahu EIS being heard on Oct 8th
Date:	Monday, October 4, 2021 3:57:23 PM

Aloha, my name is Kenneth Tabulog and I support the Aquarium EIS! I believe it is the right for people in Hawaii to live off the land and the sea as long as it's done in a sustainable manner and managed by the Department of Land and Natural Resources (DLNR).

Mahalo!
Kenneth Tabulog

From:	Rick Tamez
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Aquarium
Date:	Monday, October 4, 2021 5:09:13 PM

Do not do this, it will ruin the reef. I oppose the eis.

Rick T.

From: Stephen Tchudi
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Aquarium Extraction
Date: Tuesday, October 5, 2021 9:07:00 AM

Please do not permit further extraction of tropical from Oahu. The proposal before you is a sham.

Stephen Tchudi

--

Stephen Tchudi
TurkeyTail Farm
10846 Nelson Bar Road
Yankee Hill, California 95965-9733
N 39 deg. 41.797 min.; W 121 deg. 33.361 min., elev. 1288 ft.
Phone:530-781-4676
SteveTchudi@gmail.com

From: Robert Thompson
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Support for Aquarium fish Industry"s Environmental Impact Study
Date: Tuesday, October 5, 2021 10:41:32 AM

Aloha,

My name is Robert Thompson Jr and I support this Environmental Impact Study! I believe it is right for people in Hawaii to live off the land and the sea as long as it is done in a sustainable manor and managed by DLNR.

Mahalo for your time,
Robert Thompson Jr.

Sent from Mail for Windows

From: Linda Toki
To: DLNR.BLNR.Testimony; Linda Toki
Subject: [EXTERNAL] Agenda Item F.1 Testimony
Date: Wednesday, October 6, 2021 7:15:30 PM

Aloha,
I am a longtime Hawaii resident. Local born in Wahiawa and raised in Honolulu, have been an avid diver & snorkeler for decades. It is my sincere plea to BLNR to please reject EIS! Our oceans and reefs have been decimated by too many local fishermen & spearmen, aquarium hunters, netters, and commercial fishermen. I have seen the destruction of our marine ecosystems and the decimation of large schools of fishes from over fishing through the decades.

Please keep what remains of our Hawaii ocean marine life safe for Hawaii residents to enjoy and appreciate the beautiful marine life for future generations too. We have already lost too much to human greed and carelessness. Please do not give in to the Aquarium Trade Industry- our marine life is more important than money. Once damaged and gone it will not be replaceable. Please stop this terrible action! We need all our leaders to be better stewards of our environments. Thank you for reading my testimony. Please do what is ethical and pono.

Sincerely,
Linda Toki
Conservationist and Marine Life Advocate
lctoki@gmail.com
phone # 808-224-8869

From:	Christopher Tranilla
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] EIS - Sustainability
Date:	Monday, October 4, 2021 11:13:10 AM

Aloha,

My name is Christopher Tranilla and I support this eis! I believe it is the right for people in Hawaii to live off the land and the sea along as it's done in a sustainable manor and managed by the Dlnr.
Mahalo!

Testimony in favor of the Oahu Aquarium Fishery

Please sign me up for Oral Testimony

Oct. 8, 2021 Hearing 9am, Sect. F, Item 1. DAR blnr.testimony@hawaii.gov Aloha Esteemed Members of the Board of Land & Natural Resources,

I'm Mary Beth Tubbs, born and raised on Oahu, where I worked as an educator in Hawaii's public elementary schools for 35 years. I am testifying to give evidence of the professional character and positive contributions the Sustainable Reef Fishermen have made to our community, economy, ocean research, and education of our keiki. They've donated thousands of dollars in aquariums, equipment, fish, time and expertise to my classrooms, school, and community events, where they have taught about Hawaii's amazing marine life and how to RESPECT it. These include family fishing events at Pier 37 for 300 children and families, and STEM Family Night Events in Windward Oahu, for over 1900 students, parents, and families.

The professional character of Oahu's Sustainable Reef Fishermen is best demonstrated years ago, when their prior organization self-monitored, and independently initiated catch and size restrictions on the Oahu aquarium fishery, which became law. Aquarium fishers strive to keep the sea abundant with fish, as we all do, not only because their livelihoods depend on it, but because as aquarists they love fish, and with the devastating aquarium shut down, as the wife of a fisher, it has been heartbreaking to switch from a lifetime of keeping fish alive in aquariums, to catching other fish to eat.

The aquarium fishers make possible scientific oceanic research opportunities, and provide enormous educational and economic benefits to states and citizens thru large aquariums. Over the years, universities and aquariums such as Princeton, Univ. of Hawaii, local aquariums, and the Monterey Bay, and Atlanta Aquariums have requested specific species. These important requests were filled because of the scientific and educational value of these endeavors, despite additional paperwork, lower profit, and long delays in getting paid from these institutions.

Aquariums are valuable educational tools that immediately engage students in learning. They are proven to be calming, can be used to teach responsibility, and motivate students to malama the land and ocean. Aquariums bring relevance to teaching the Science Standards and have been used to teach hundreds of students' skills in observation, description, comparison of traits, prediction of patterns, scientific method, determining volume, and content such as habitat, development of fish structures and processes, eco-systems, global warming, ocean acidification, and the importance of sustainability and curbing the use of plastics. One former student just won the 2021 Junior Division of the Hawaii State Science Fair's Environmental Engineering category, went on to nationals, and credited my teaching methods which included aquariums, as inspiration.

On behalf of teachers, researchers, our community, and the education of Hawaii's keiki, please approve the Oahu's Final Environmental Impact Statement. Thank you.

Mary S. Tubbs, M.ED. maliaoflanikai@gmail.com
Nationally Certified School Psychologist National Education Association, Retired

From:	Maka Tuulima-Cruz
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] ATTENTION O'AHU FEIS
Date:	Monday, October 4, 2021 1:29:26 PM

Aloha,

Attention O'ahu FEIS

My name is Amosa Tuulima-Cruz and your probably guessing why I'm sending this email. Well, I'm here to put a testimony to eradicate the band of Aquarium fishing. Being a Native Polynesian from this island I call home it's very important to talk about the subject at hand.

I understand both sides of the matter at hand from the worries of reef pollution to having aquarium fishing being very sustainable and safe to the aquatic life. That being said, I highly believe being a licensed aquarium fishermen and how long Hawaiian Reef Dwellers has been in business for over 20 plus years, it shows that doing the job the right way and having the knowledge to not only make money which was the main source of my family's income but, to also make sure that the aquatic life was never at stake when handling with care. My grandfather David Ramos always took into consideration the , "Circle of life" very seriously. He always made sure to find ways for his company to make a profit safely and in order to do so, you must make sure that the aquatic life will be able to reproduce within itself and also be sustainable over the years so that he could be able to provide for his family. I ask that the board take this testimony into consideration and eradicate the band of Aquarium Fishing.

With much Mahalo,
Amosa Tuulima-Cruz
--
Amosa Tuulima-Cruz

From: Kaipo Tuulima-Cruz
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Tropical Fish
Date: Monday, October 4, 2021 4:25:33 PM

Please bring back tropical fishing for all of our local companies trying to provide for their family needs. I feel it is wrong that you guys are trynna shut down what's been around longer than you guys been in office. Don't you think it's bad enough COVID has shut down many family company owned companies just so you guys can put money in your own pockets and try to blame others for your greed and mistakes. For FEIS.

Sent from my iPhone

From:	Leionaona Tuulima-Cruz [STUDENT]
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Oahu; FEIS
Date:	Monday, October 4, 2021 4:40:27 PM

I am for FEIS.

Sincerely,
Leionaona Tuulima-Cruz

Sent from Mail for Windows

From: Christian Viernes
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] I SUPPORT THE OAHU TROPICAL FISH EIS!
Date: Monday, October 4, 2021 9:30:41 PM

I, Christian Viernes, support the Oahu Tropical Fish Environmental Impact Statement.

Mahalo for your time,
Christian Viernes

From: Darrell
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] EIS
Date: Monday, October 4, 2021 7:34:21 PM

I oppose the EIS

Sincerely

Darrell Walker
Lahaina, Maui

From:	Patrick Walsh
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Fwd: REJECT opening up reefs to aquarium trade
Date:	Tuesday, October 5, 2021 3:45:01 PM

To the distinguished members of the Board,
It is vitally important that you reject the seriously flawed environmental impact statement that suggests opening up Oahu's reefs to the aquarium trade.
You simply can not allow that. It would cause irreversible damage to our waters and wildlife. We can not allow our fish to be pillaged for the trade. We can not allow our economy to collapse by allowing the capture of our fishes. Our healthy oceans are the lifeblood of Hawaii. We must respect the ocean and fishes if we want to ensure a vibrant economy and environment.
Thank you and Mahalo.

all the best
patrick

From: Diane Ware
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] F1 agenda item regarding AQ fish collection EIS
Date: Thursday, October 7, 2021 8:24:09 AM

In support of rejecting the Pet Industry EIS

Dear Board Members,

The intergenerational impact of Hawai'i colonial based government policy is still felt today. Loss of the indigenous language and cultural injury to governance and sovereignty, and high poverty, poor health, and growing suicide rates continue to harm Hawaiian communities across the state.

> The Hawaiian culture and people have suffered from colonial racial disenfranchisement and profiteering from the resources of these islands for over 200 years. Now with racial injustice reckoning taking place today the State should turn to giving back and protecting resources supposedly guaranteed in Public Trust Doctrines. Repairing relationships and possibly offering reparations are more appropriate than giving fragile, irreplaceable wildlife resources to a $200 million dollar multinational pet industry trade which is the applicant in this case. They purport to represent 20 local collectors never identified in the document.

There can be no excuse for allowing unnecessary (for profit not sustenance) taking and selling of our precious Hawaiian fishes to mostly privileged white hobbyists at the expense of already impoverished, disenfranchised kanaka maloli and residents who overwhelmingly oppose the trade.

Thank you for listening and opposing this faulty, biased EIS. The "host culture" deserves to manage the nearshore resources in a traditional way.

For the fishes and all residents,

Diane Ware
808-967-8642
P. O. Box 698
99-7815 Kapoha
Volcano HI 96785

From:	Brian Weber
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] I oppose the EIS
Date:	Tuesday, October 5, 2021 12:44:44 AM

I oppose the EIS!!

Brian Weber
Sent from my iPhone

Board of Land & Natural Resources
Testimony on F1, Aquarium fish fishery FEIS
October 8, 2021

Chair Case and Members of the Board, good morning.

My name is Kevin Weng, and I am a fish biologist and a fisherman. I have a masters from UH Mānoa and a PhD from a mainland university. I have conducted research on fishes in Hawai'i. I am a freedive spearfisherman and regularly take munu, moano kali, ulua and omilu in the nearshore waters of Oahu. I have bottomfished for pakas and onagas and trolled for pelagics. I believe that the people of Hawai'i have the right to fish, both for personal use and to make a living from the resources of the sea; and just as we have the right to fish, the State of Hawai'i has the responsibility to manage our activities to prevent over-exploitation. We as fishers must accept controls on our activities to keep our harvest at sustainable levels.

I believe **the FEIS fulfills the technical requirements** under HAR § 11-200-16 and the DLNR meeting announcement (https://dlnr.hawaii.gov/wp-content/uploads/2021/10/F-1.pdf). The views expressed here are my own, and do not represent any institution.

- Shortcomings of the draft EIS were addressed in the FEIS, including limits on catch, which allow calculation of percent harvest. The DEIS did not propose catch limits, and without catch limits, the sky is the limit, so even a small number of participants could conceivably over-harvest a species. The FEIS addresses this shortcoming with catch limits for each species.
- The environmental consequences of the proposed action are quantified in terms of the percent of the population harvested per year, which, at 4.5% of population per year, is far lower than the harvest of most commercially exploited species. For context, the slow growing bottomfish fishes of Hawai'i have a sustainable harvest rate of about 7%, while many other species may have sustainable harvest rates up to 25% or more. A conservative approach to management would select a value below the estimated maximum harvest, and 4.5% would therefore be conservative.
- The FEIS uses the available science, though the available science is not perfect. The DLNR letter of 22 June 2020 notes that the NOAA CREP surveys are not ideally suited for assessment of aquarium fish. This is true, but we need to view this in the overall context of how we manage fisheries, and what level of uncertainty we are willing to accept and still permit activities. Uncertainty is not generally a trigger for shutting down a fishery. There is great uncertainty regarding the number of bottomfish fishers in Hawai'i since there is no reporting from the recreational sector. There is great uncertainty regarding the catch and effort in shorecasting and spearfishing since we have no permitting / reporting requirements, nor do we have a recreational / subsistence fishing license requirement, which would provide basic effort data. Speaking as a private fisherman, I do not want to be told that I cannot go spearfishing because there is some uncertainty in our knowledge of fish stocks. I would be open to specific size, species or area restrictions that are based on data and I am willing to accept some limits on my own activities.

- The DNLR letter of 22 June 2020 raises the issue of no-take zones (Waikiki MLCD). In the context of the degraded condition of coral reef ecosystems around much of O'ahu, the expansion of no-take zones and MLCDs is a good strategy, so the establishment of new no-take zones, or the expansion of existing no-take zones, would be beneficial.

Extractive activities must be managed to be sustainable. We know that fishing can cause population declines in target fish species, whether that fishing is for subsistence or for sale. Taking one fish out of the ocean reduces the population by one, whether that fish is eaten, sold, or kept alive in an aquarium. A sustainable fishery is one in which there is a healthy population of the target species that maintains its abundance and age structure through time. For the Hawai'i aquarium fish fishery, the evidence, compiled in the EIS and also in the published literature, indicates that the fishery is sustainable.

Data is one of the most important ingredients of sustainable fishery management. We must be able to track changes in the fish population through time, and ideally compare it with the fishing effort through time. The catch, and the number of people fishing are extremely important. The proposed fishery includes a known number of participants with catch recording. This allows calculation of both catch and effort. Many other fisheries in Hawai'i lack these data.

While I believe that we should take a precautionary approach to natural resource management, and that we should establish no-take zones to allow more pristine ecosystems to thrive, we should not curtail fishing activities when the evidence shows that they are sustainable. Fishing keeps us connected to the oceans, and makes us care about the living organisms that live there. Responsible, sustainable fishing plays an important role in both our economy and our culture.

Thank you,
Kevin Weng

From: Laurel Whillock
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Agenda Item F.1 Testimony
Date: Wednesday, October 6, 2021 6:47:51 PM

As a resident of Hawaii, I urge you to reject the EIS regarding aquarium fish collection in Oahu. As a SCUBA diver who has been diving in Hawaiian waters for over 30 years, I cannot endorse the taking of marine tropical fish for the aquarium trade. As a resident of the Big Island, we have seen first hand the impact of unfettered aquarium collection and implore BLNR to consider the impact of flawed and outdated information.

Aloha,
Laurel Whillock
Sent from my iPad

From:	Paul Williams (via Google Docs)
To:	DLNR.BLNR.Testimony
Subject:	[EXTERNAL] Untitled document
Date:	Tuesday, October 5, 2021 11:47:39 AM

piscespacifica@gmail.com attached a document

piscespacifica@gmail.com has attached the following document:

Untitled document

Snapshot of the item below:

EIS support testimony

I, Paul Williams Arrived in Hawaii in 1967 staging my father for deployment to Vietnam. I am a life long aquarium enthusiast, I have held a DLNR issued Aquarium permit (in good standing) for 40 years. I have three children (the youngest 4) I also have a mortgage! The cancelation of my permit has caused a ripple effect of emotional and financial hardship in my family, and has put us at risk of default. We, Pisces Pacifica, are a community resource volunteering at churches and schools and hosting the same at our learning center. Aquarium fishers contribute to the diversity of Hawaii's economy, at a time of homogenization (i.e. Kaneohe bakery, a landmark of 70 years, is soon to be a Chick-Fil-A). Our slanderous opposition is hysterical, in their disseminating falsehoods, and disregarding our own scientific community! To disregard our own scientific community is akin to denying climate change. We the fishers have come together at great expense to meet the demand for this EIS. I humbly request reinstatement of my fishing permit.

From: Erik J Winkler
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Re: Agenda item F.1
Date: Wednesday, October 6, 2021 7:39:36 PM

Dear Hawai'i BLNR:
Re: Agenda item F.1

I oppose the Environmental Impact Statement as invalid, and illegitimate, and in disregard of the Hawai'ian culture as ruled by the Supreme Court of the State of Hawai'i. The Pet Industry Joint Advisory Council prepared the document seeking permits on behalf of 10 individuals. The Board of Land and Natural Resources has the discretion and authority to prevent the issuing of aquarium permits" through the Hawai'i Constitution.

The claim of "sustainability" has been used for too long, at the expense of Hawai'i public trust, for the benefit of commercial interests. The aquarium trade only takes reef wildlife from Hawai'i and leaves nothing. People around the world have Hawai'i in their hearts and spend a billion dollars annually on reef activities that take nothing from the reef. Hawai'ian reef wildlife should remain in the waters of Hawai'i, not in glass tanks globally.

Sincerely,
Erik J Winkler

From: Stanford Wong
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Oahu's FEIS (Final Environmental Impact Study)
Date: Wednesday, October 6, 2021 12:24:17 PM

Board of Land and Natural Resources,

People keep marine life for different personal reasons. Could be: stress relief; relaxation; distracting children from their electronics; research; the joy of being able to see another world in the convenience of their home; etc. However, not everyone possesses the skills, resources or the desire to collect their own marine fish. The collectors help to fill that gap and bring a much wider variety of fish into our reach, which we may have never seen if we tried to collect our own specimens.

I personally have marine tanks and ponds ranging from 5 gallons to 1,000 gallons and have been keeping and experimenting with various marine organisms (fish, inverts, algae, shells, plankton) for 40+ years. I myself am not a diver or collector, so I've always relied on collectors for my specimens.

I and many other aquarium enthusiasts around the world miss the marine fish that comes from the Hawaiian Islands. In a COVID environment that has severely hurt our economy in Hawaii and caused many businesses to shut down, this could help to reopen part of the economy that is not dependent on tourism.

Please pass the Oahu FEIS.

Thank you for your consideration. Take care.

Respectfully,
Stanford Wong

From: DENNIS YAMAGUCHI
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Acceptance of the Oahu EIS
Date: Wednesday, October 6, 2021 9:26:17 AM

Members of the Board of Land and Natural Resources,

Please accept the Oahu EIS. It has widespread support among the world's leading scientists, support from members of the commercial fishing community such as myself, and represents a compromise from the aquarium fishers themselves concerning species caught, numbers caught, and qualified aquarium fishers applying for commercial aquarium fishing permits.

Thank you for your time and consideration in this matter.

Dennis Yamaguchi
CML #3046

From: Alyssa Yonehiro
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] EIS
Date: Monday, October 4, 2021 11:34:00 PM

I, Alyssa Yonehiro, support the Tropical fish EIS. Please consider their right to work and their families they support.

Thank you for your time.

Sent from my iPhone

From: Austin Yonehiro
To: DLNR.BLNR.Testimony
Subject: [EXTERNAL] Oahu Tropical Fish EIS Support
Date: Monday, October 4, 2021 7:12:42 PM

Aloha,

I, Austin Yonehiro, am writing in to show my support of the Oahu Tropical Fish EIS. Please keep our sustainable local tropical fish industry operating!

Mahalo,

Austin Yonehiro