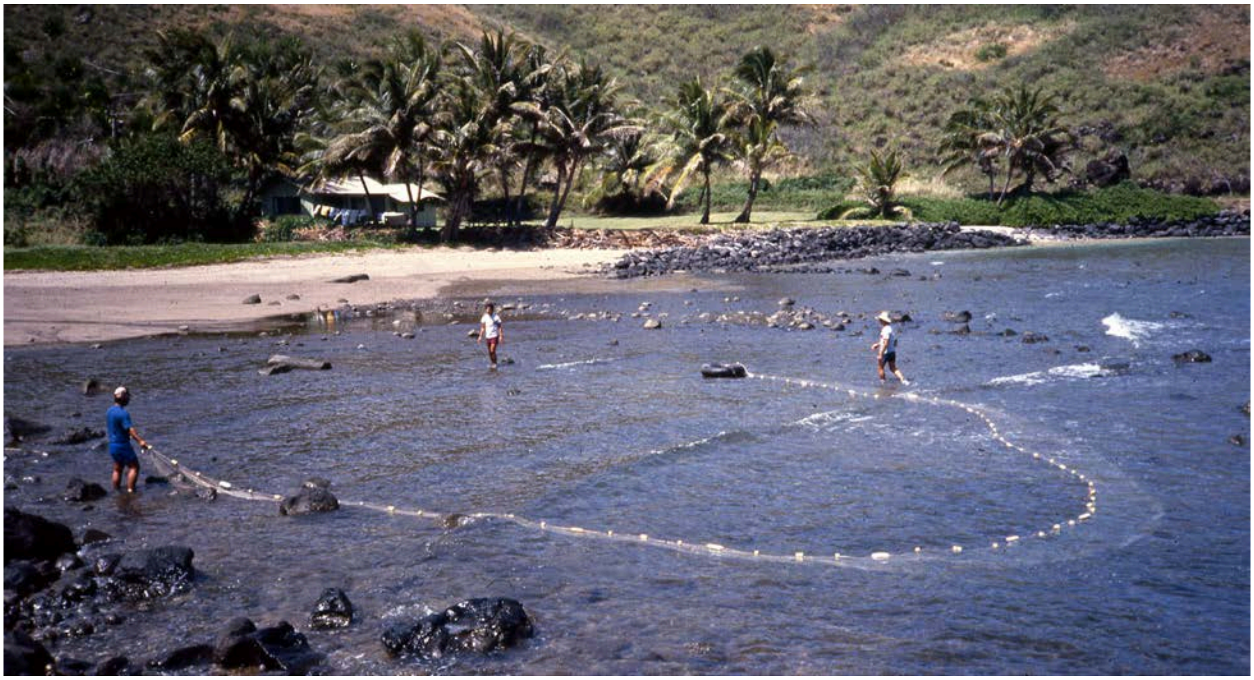
TABLE OF CONTENTS

ACKNOWLEDGMENTS

This project would not have been possible without the due diligence of the following Molokai fishers. Their willingness to endure the rigorous requirments delinated for this project is most appreciated. *Mahalo nui loa* to Noelani Rawlins, Keoki K. Coelho, John I. M. Kalua, Mervin Dudoit, Sr., and August Rawlins, Jr.

William K. Puleloa
Molokai Aquatic Biologist
Division of Aquatic Resources



MOLOKAI ISLAND GILL-NET PROJECT

INTRODUCTION

Monofilament gillnets have been the subject of considerable deliberation since their introduction to Hawaii fisheries in the 1950s. As of late, this debate reached a high crescendo involving the complete gamut of concerned observers.[1] Conspicuously missing from ensuing discussions were essential fisheries data necessary to support relevant points of view.

In an attempt to further objective discussions, several efforts were made by the Division of Aquatic Resources (DAR) to assess gillnet activities on Molokai, an island with a storied history of fishing in this manner.[2] The first endeavor that entailed voluntary catch reports was besieged with problems. It did not take long to realize any attempt to appraise this fishery in this manner was, by nature, fraught with misinformation. To override this problem DAR began a second effort implementing a series of random *in situ* creel inspections. During these investigations DAR approached gillnet fishers and sought their permission to inspect their catch. However, many fishers confronted in such a manner were disinclined to assist, ostensibly critical as to the intentions of governmental inspections. On those few instances when DAR was allowed to examine fish landings, fishers often complained about the time it took to sort and measure their

[1] Randall, J.E., Birkeland, C., Pyle, R. L., Kosaki, R. *The Case Against Lay Gill Nets.* Honolulu, Hawaii, Honolulu Advertiser OpEd, (2006)
[2] Hui Malama O Moomomi. *Proposal to Designate Moomomi Community-Based Subistence Fishing Area*. Hawaii. (1995)

catch. Because of this perceived inconvenience, fishers on more than one occasion unilaterally and prematurely terminated the ongoing sampling process. Additionally because netters customary retrieve their catch incrementally throughout the fishing episode, obtaining the total yield per fishing trip was not always possible during these *in situ* inspections.

The collection of catch-and-effort data from lay netters was additionally hampered by the non-conformity of gear by users to include net length, height, mesh size, and denier among other inherent variables. To further complicate matters, these same monofilament gill nets were being utilized in a variety of ways producing catch results more oftentimes specific to each particular fishing strategy. For example, nets used for passive lay netting were otherwise employed in a more energetic fishing technique known as *pa'ipa'i* in which a myriad of fish species were actively frightened into the nets by the slapping of the water surface. At certain times of the year these same monofilament nets were used to encircle particular schooling species such as Acanthurus unicornis *(kala)*, Acanthurus triostegus *(manini)*, Kyphosus bigibbus *(enenue)*, Mugil cephalus *('ama'ama)*, and Trachurops crumenophthalmus *(akule)* in a long standing fishing practice known as *ka la'au* or surround net fishing. An added gill net technique utilized on Molokai involved several seasoned fishers setting a predetermined length of net in favored locations, all the while standing by during a tidal exchange to collect transitory fish. Another use of monofilament gill nets that may be unique to Molokai involves short pieces of monofilament nets to form baited rings placed on reef flats adjacent to stream estuaries and mangroves to entangle the much sought-after Scylla serrata, an introduced and now permanently established portunid commonly referred to as the Samoan crab.[3]

This being said, it is clear to see that monofilament gill lay nets on Molokai are employed in a variety of ways, each technique producing catch-and-effort results often times particular to each different fishing strategy. Furthermore, the intensity of fishing efforts varied widely from fisher to fisher depending on factors ranging from weather conditions, social obligations, and seasonality of targeted species. For example, people tend to fish harder when there is a need to fulfill cultural obligations associated with traditional social gatherings such as birthday parties, funerals, graduation ceremonies, etc.[4] On these occasions when concerted groups of fishermen were involved, more attention is paid to the logistic placement of nets, tidal dispositions, lunar periodicity, gear configuration, seasonal occurrence of certain species, and such. On the other hand, there were also informal beachside netters seeking merely to compliment their picnic meals. These casual netters more often than not merely set their net paraphernalia very close to shore for easy and immediate retrieval, and seem amply satisfied no matter how modest their catch.

PROCEDURES

In an attempt to gain insight into the use of gill net fishing on Molokai, a concerted monitoring project over the course of twelve months was implemented involving several local fishers. Experienced and actively engaged lay-net fishers living within close proximity of commonly fished areas on Molokai's fringing reef were identified and five were invited to collaborate in a

[3] Brock, V. *The Introduction of Aquatic Animals Into Hawaiian Waters. Int. Revue Hydrobiol* 45: 463-480. (1960)
[4] Baker, M. E., *Backyard Fishing On The South Coast Of Molokai, Master's Thesis, Department of Geography, University of Hawaii at Manoa.* (1987) Honolulu, Hawaii

year-long gillnet monitoring project. Each of these participants were included as assistants on a Scientific Collection Permit as authorized under Chapter 187A-6 of the Hawaii Revised Statutes.

The south shore of Molokai includes the most the extensive and continuous fringing reef in Hawaii.[5] Unfortunately, this area is notorious for soil runoff that extends in some cases to a half-mile offshore. Because of the prevailing winds and ocean currents, inshore reef degradation is most severe in site Kapa'akea (#1) and improves incrementally upon moving from that point eastward, i.e. from site Kapa'akea (#1) to Moa-nui (#5) (Figure 1). This change in habitat cover was found to influence the kinds of marine species encountered from site to site. Not coincidentally landings of benthic feeders such as Albula glossodonta (*'ō'io)* and Upeneus arge *(weke-pueo)*, both species that sustain themselves by sieving organisms from soft bottom substrates, were found much more abundant at Kapa'akea (#1) and One-ali'i (#2). Conversely, Scarus psittacus *(uhu-uliuli)*, a parrotfish species heavily dependent upon live coral, was caught only at Moa-nui (#5), the most naturally pristine of our project sites.

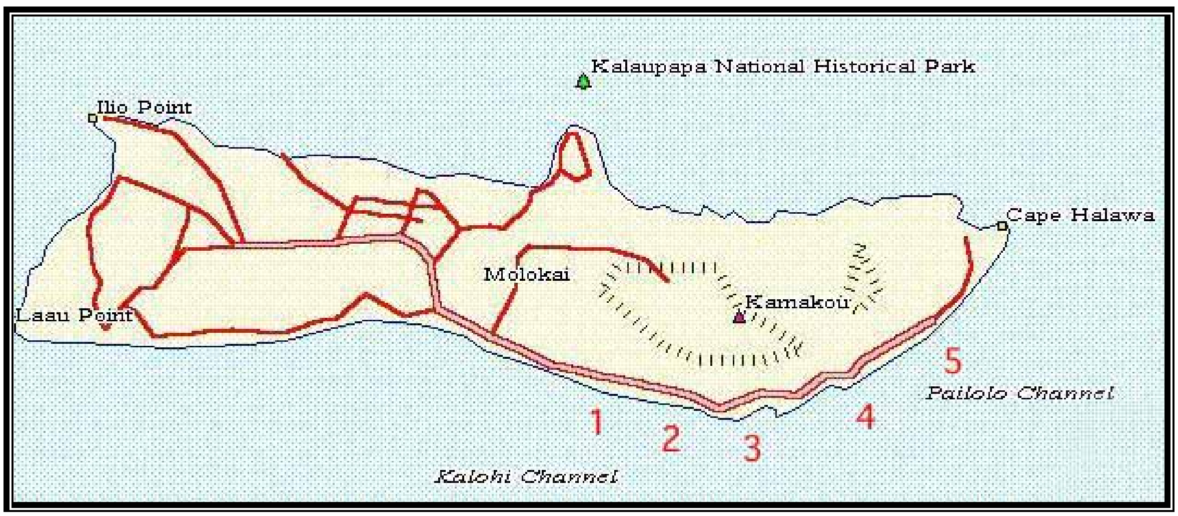


Figure 1. (1) Kapa'akea; (2) One-ali'i; (3) Ka-malō; (4) Mapulehu; (5) Moa-nui

Together with net mending supplies, each participant was assigned identical fishing gear consisting of two single-paneled 15 lb-test monofilament gill nets. Each net was 125' long and stood 7' high with standard floaters and bottom lead so as to be used in the typical demersal gill net fishing commonly employed on Molokai. All project nets had a stretch mesh size of 2-3/4", which was the minimal size allowable for gillnets under then prevailing State of Hawaii fisheries regulations.[6] Additionally, each net was duly registered and properly branded with identification tags obtained from the Dept. of Land & Natural Resources in accordance to Hawaii Administrative Rules section 13-75-12.5. To promote project uniformity, participants were

[5] Field, M. E., Cochran, S. A., Logan, J. B., and Storiazzi, C. D. *The Coral Reef of South Molokai, Hawaii--Portrait of a Sediment Threatened Fringing Reef: U. S. Geological Survey Scientific Investigation Report 200: 5101* (2008). Menlo Park, California.

[6] ___________________, *Hawaii Fishing Regulations, 2008-2009.* Division of Aquatic Resources. Honolulu, Hawaii.

limited to fish using a traditional practice known as *ho'omoemoe* in which nets were deployed at dusk and retrieved at dawn in chest deep waters.[7] The restriction to *ho'omoemoe* fishing avoided the idiosyncratic effort and catch results as described above, and had the added benefit of mimicking the gill net fishing technique most commonly practiced on Molokai. In order to verify total catch, participants were mandated to amass everything caught in project nets for formal documentation. All such garnered samples, whether conforming to DAR prevailing fisheries standards or not, were identified, weighed, and then measured for either fork lengths, tail widths, or carapace lengths. Additionally, a ventral incision was made on each fish to expose the abdominal cavity. When available, viable gonads were removed and placed in numbered bags. These bagged samples were placed on ice and returned to the office for further examination. Furthermore, when appropriate, entire stomachs were also detached and their contents scrutinized. Whenever encountering marine invertebrates governed by minimum length standards, straight carapace lengths and straight tail widths were determined with the use of calipers. Following the conclusion of the each netting episode, all nets were visually inspected to identify damaged areas to be repaired prior to the next deployment to ensure gear consistency throughout the project.

To eliminate adverse interactions with federally protected species, participants were required to physically examine their nets every two hours so as to be able to intervene at the occurrence of any incidental entanglement of either monk seals or sea turtles. As an added safety measure, participants were also ordered not to deploy their nets should they become aware of the presence of either seals or turtles on their planned fishing day. Aside from these restrictions, coupled with the requirement to fish only in their respective pre-defined areas, fishers were otherwise permitted to deploy their nets at their own discretions.

RESULTS

General Discussion

Between May 2008 and June 2009, fifty-four (54) lay gill-net fishery operations were performed, resulting in a total soak time of 1,285 net-hours. As it pertains to this project, "net" is defined as a single-paneled 7' high net fashioned from 15 lb-test nylon monofilament material together with a stretched mesh of 2-3/4". Typically, before deployment, both nets were laced together while still onshore to form essentially a single gill-net 250' long. These joined nets were then carefully set in a floating platform, most often a tire inner tube with a plywood inner bottom, then towed offshore and laid at preferred locations on sandy bottoms so as to avoid potential hindrance from and disturbance to rocks, coral, and the like. Buoys were attached to the ends of the float line, both to identify the nets and to act as a visual aid to other boaters and fishers. Similarly, a weight of some sort was also attached to both ends of the lead line so as to help ensure net stability. Ideally, the laying of nets coincided with moderate tidal movement, avoiding extreme high and low flooding. The successes of these netting operations hinged on numerous factors and resulted in catch landings ranging from a low of 2 to a high of 103 samples being obtained during a single trip. Superior results were found to coincide with bright nights coupled with a declining tide and a waxing moon. Notable factors that were found to negatively influence net efficiency were

[7] Kahaulelio, D. *Ka Oihana Lawaia, Hawaiian Fishing Traditions.* (2006). Honolulu, Hawaii.

heavy seas and excessive algal entanglement, both conditions altering the preferred net hanging ratio to a point at times rendering the nets totally ineffective.

At no time did any entanglement, much less the demise of either monk seals or sea turtles occur during the course of this project. However, several operations were compromised because of interactions with these federally protected species. On one occasion, a seal appeared near the net during a routine bi-hourly check. To not jeopardize entanglement, the nets were immediately retrieved thus curtailing further sampling. On another occasion, severed fish heads were observed laying on the substrate next to the nets revealing perhaps the selective feeding of a monk seal on fish that were caught in the net. A further time, a well recognized tagged juvenile monk seal (KP2) appeared during a routine morning net retrieval causing some anxiety to participants. This interaction proved to be benign as the seal simply swam away on its own accord after following the participants most of the way back to shore. In regards to sea turtles, four operations were cancelled and rescheduled upon detecting their nearby presence on the day of the planned expeditions.

The total number of organisms including vertebrates and invertebrates collected during the project period was 1,585. The mandate to retain all entangled items for formal documentation resulted in seeing several uncommon samples — otherwise undesirable and normally released or discarded — returned to shore and figured into the total catch. A complete listing of the marine species encountered during this project is depicted in Table 1, coupled with their numbers caught and their extant vernacular names as currently used on Molokai.

VERTEBRATES

Numbers

The total number of fish collected this project period was 1,448 and involved 31 species. Three non-native species,[8] introduced into Hawaii during the 1950s and now permanent fixtures in our near shore environment, figured significantly in the total landings accounting for 12.4% of all the fish caught. Of these introduced species, Lutjanus fulvus (*toau)* was the most frequently captured by a factor of 4.4 to 1 when compared to the combined totals of other non-native species. Native fish herbivores encountered during the course of this project consisted of only four species with their numbers totaling 4.6% of the entire project's catch.

Mulloidichthys flavolineatus *(weke-a'a)*, a common and widespread native Indo-Pacific species, proved to be the most ubiquitous species encountered in terms of both numbers (30.7%) (Figure 2) and biomass (27.3%). Together with Mulloidichthys vanicolensis *(weke-'ula),* Parupeneus porphyreus *(kūmū),* and Upeneus arge *(weke-pueo)* goatfish species constituted 58.4% of the caught fish (Figure 3). An introduced goatfish species, Upeneus vittatus, known to be caught from time to time when gill net fishing on Molokai, was not encountered during this project period. Representatives of large and common near shore Hawaiian fish families such as Chaedtondontidae (butterfly fish), Labridae (wrasses), Muraenidae (moray eels), Balistidae (triggerfish), and Pomacentridae (damselfish) were also absent in project catches. Also not entangled anytime during the project were any species of sharks or rays.

[8] Randall, J. E., and Katayama, R. K. *Marine Organisms—Introductions of Serranid and Lutjanid Fishes From French Polynesia to the Hawaiian Islands.* (1973) Nature Conservation in the Pacific, Australian National University. pp. 197-200

Table 1. List of Species Caught

Family Name	Species Name	Common Name	Vernacular Name	Number Caught
Acanthuridae				
	Acanthurus triostegus	convict tang	manini	18
	A. xanthopterus	yellowfin	pualu	2
	Naso unicornis	unicorn fish	kala	14
Albulidae				
	Albula glossodonta	bonefish	‘ō‘io	129
Belonidae				
	Tylosurus crocodilus	needlefish	‘aha‘aha	7
Cirrhitidae				
	Cirrhitus pinnulatus	hawk fish	po‘o-pa‘a	1
Carangidae				
	Caranx ignobilis	giant trevally	aukea	25
	C. melampygus	bluefin trevally	‘ōmilu	37
	C. sexfasciatus	bigeye trevally		1
	Carangoides orthogrammus	island jack		1
	Gnathanodon speciosus	golden trevally	pa‘opa‘o	6
	Scomberoides lysan	leatherback	lai	9
Dactylopteridae				
	Dactyloptena orientalis	gurnard		1
Elopidae				
	Elops hawaiensis	ladyfish	kalamoho	4
Holocentridae				
	Myripristis berndti	solder fish	‘ū‘ū	13
	Neoniphon sammara	squirrelfish	‘ala‘ihi	7
Kuhliidae				
	Kuhlia sandvicensis	flagtail	āhole	10
Kyphosidae				
	Kyphosus bigibbus	rudderfish	enenue	33
Lutjanidae				
	Lutjanus fulvus	blacktail snapper	toau	146
	L. kasmira	bluestripe snapper	taape	31
Mugilidae				
	Mugil cephalus	striped mullet	‘ama‘ama	39
Mullidae				
	Mulloidichthys flavolineatus	white goatfish	weke-a‘a	445
	M. vanicolensis	red goatfish	weke-‘ula	143
	Parupeneus porphyreus	whitesaddle goatfish	kūmū	13
	Upeneus arge	bandtail goatfish	weke-pueo	244
Polynemidae				
	Polydactylus sexfilis	threadfin	moi	58
Priacanthidae				
	Heteropriacanthus cruentatus	glasseye	‘āweoweo	1
Scaridae				
	Scarus psittacus	parrotfish	uliuli	1
Serranidae				
	Cephalopholis argus	peacock grouper	roi	2
Sphyraenidae				
	Sphyraena barracuda	barracuda	kākū	6
	S. helleri	Heller‘s barracuda	kawele‘ā	1
Invertebrates				
Carpiliidae				
	Carpilius maculatus	spotted pebble crab	‘alakuma	1
	C. convexus	convex crab		1
Palinuridae				
	Panulirus marginatus	spiny lobster	ula	1
Portunidae				
	Portunus sanguinolentus	white crab	kūhonu	3
	Scylla serrata	Samoan crab		1
	Thalamita crenata	blue-pincher crab	āla‘eke	1
Scyllaridae				
	Parribacus antarcticus	slipper lobster	ula-pāpa	129

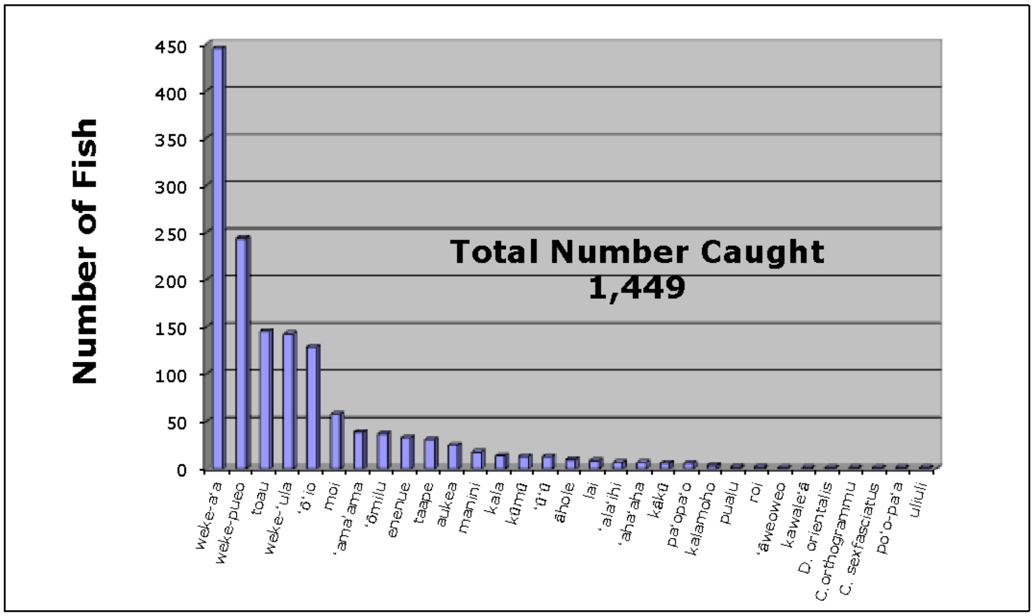


Figure 2. Numbers of Fish Caught

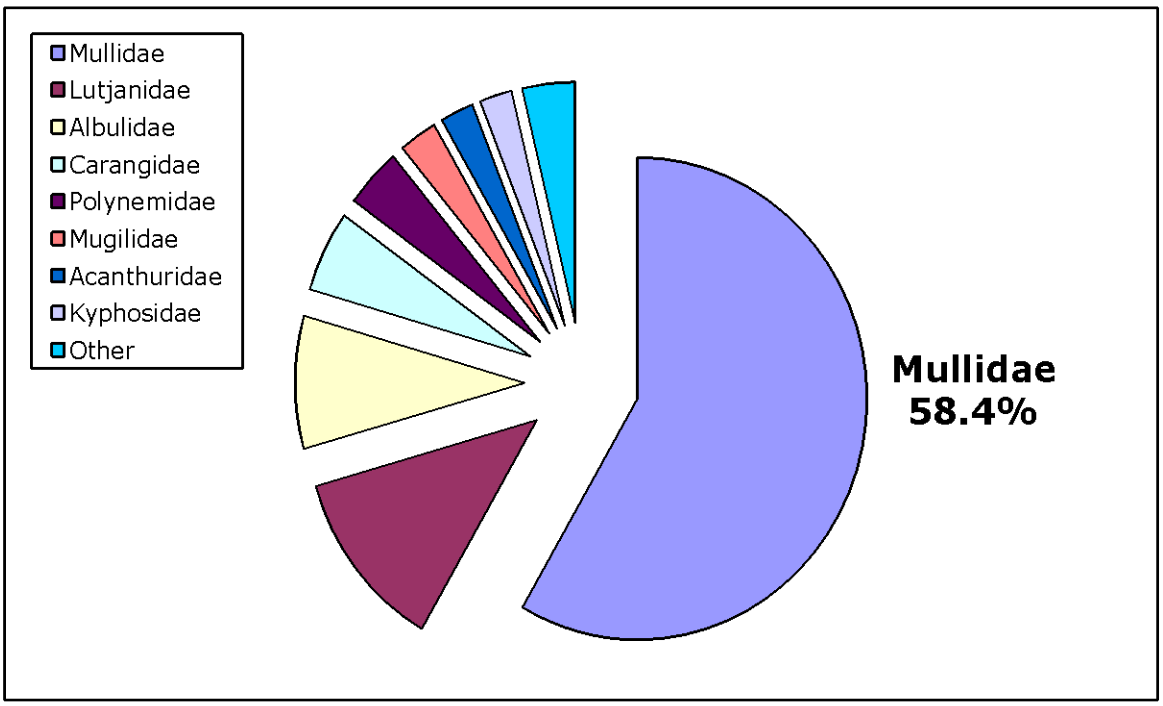


Figure 3. Fish Families Caught

Biomass

Species of the family Mullidae again dominated in terms of total biomass, if for no other reason but their sheer numbers. Four goatfish species made up 47.8% of the entire biomass collected. These surmullets in order of abundance were Mulloidichthys flavolineatus *(weke-a'a),* Upeneus arge *(weke-pueo)*, Mulloidichthys vanicolensis (*weke-ula)*, and Parupeneus porphyreus *(kūmū)* (Figure 4). While fewer in actual numbers, Albula glossodonta *(ʻōʻio)* ranked second in total biomass due to their size propensity. Other times caught with larger mesh sized nets within our project areas, the bonefish is known to reach at least 10 kg in weight and 1.2 meters in length. Not so coincidentally one of the largest fish netted during this entire project was an *ʻōʻio*, but then only half that size due to our nets' nominal mesh size.

Herbivores encountered were limited to four species and were found in this order of abundance: Kyphosus bigibbus *(enenue*), Acanthurus triostegus *(manini)*, Naso unicornis *(kala)*, and Acanthurus xanthopterus *(pualu)*. Although only 4.6% of the total number of fish caught, the collective weight of these herbivores made up 12.4% of the total biomass. Several of these herbivorous species are capable of reaching significantly larger sizes, which contributed to the relative overall gain in biomass by these algal feeders. The heaviest fish netted during this operation was a sizable *enenue*, weighing in at 4.8 kg and measuring 60.0 cm in fork length.

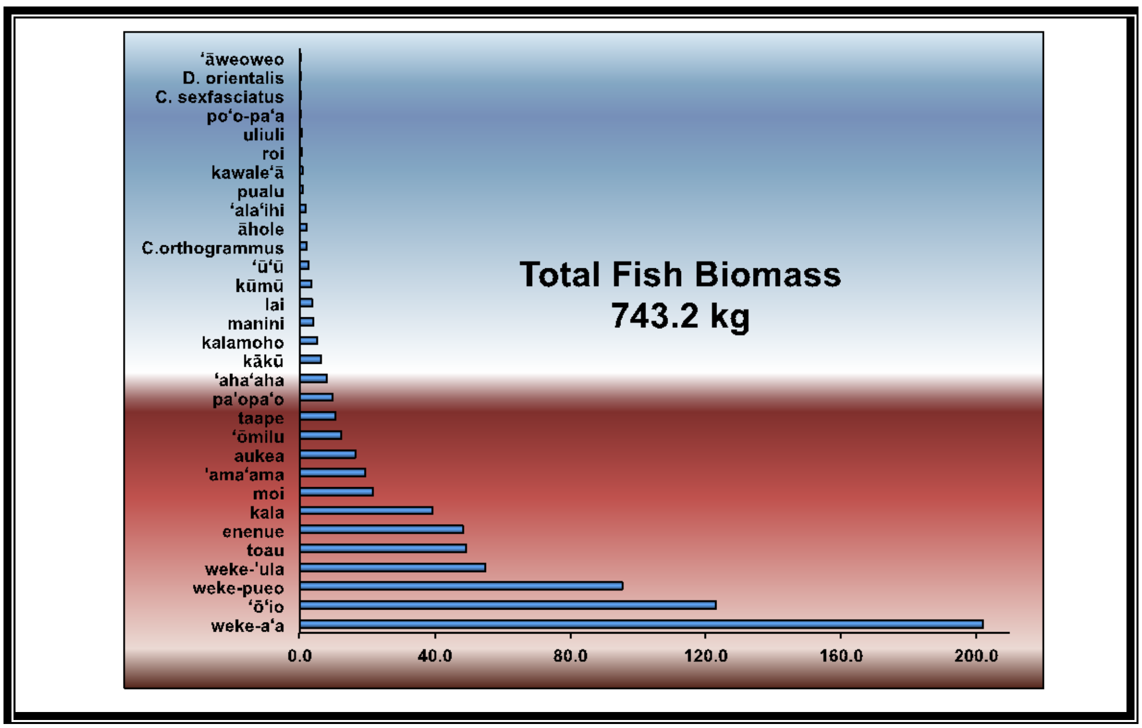


Figure 4. Total Fish *Biomass*

Fork Lengths

Each fish encountered in project nets was measured for its fork length. Using fish measuring boards, the straight length measurement from the tip of the snout to the caudal fork along the anteroposterior axis was recorded. Because gill lay net landings are predicated upon fish being entangled upon trying to squeeze through the net openings, our project nets with 2-3/4" mesh size were found to be very selective in regards to the species and size classes being caught. Smaller, slender individuals were allowed unabated passage though the netting while larger, deeply compressed/depressed types simply bounced off the nets and swam away. This is not to say that large fish were not caught with project nets, but that these landings were more the result of chance rather than entanglement. More often than not, the occasional landings of oversized fish were the serendipitous result of fisher and fish meeting at the net at the same time. Under these circumstances, these large fish were seized one way or another before sliding off the nets and escaping. The smallest fish entangled during this project was an immature convict tang at 12.0 cm, and the longest was a 100.0 cm needlefish. The size ranges of each species caught more than once during this project are depicted in Table 2 as follows.

Table 2. Size Ranges of Fish Caught

(# of fish caught)	Minimum Fork length (cm)	Maximum Fork Length (cm)	Mean Fork Length (cm)	Maximum fork length with no gonads
ʻalaʻihi (7)	16.0	30.0	22.1	
ʻahaʻaha (7)	71.0	100.0	83.1	
āhole (10)	20.5	24.0	21.7	
ʻamaʻama (39)	27.0	45.0	33.1	
aukea (25)	17.0	42.0	30.0	42.0
enenue (33)	17.0	60.0	39.0	35.0
kākū (6)	46.0	65.0	54.5	
kala (14)	35.5	60.0	52.2	
kalamoho (4)	39.5	70.0	49.5	48.5
kūmū (13)	17.0	29.0	22.3	24.0
lai (9)	26.0	46.5	36.8	40.0
manini (18)	12.0	28.5	19.4	19.0
moi (58)	15.0	36.0	22.0	
ʻōʻio (129)	28.0	70.0	42.0	51.0
ʻōmilu (37)	16.5	44.0	24.3	44.0
paʻo-paʻo (6)	17.5	45.0	39.3	45.0
pualu (2)	21.0	29.0	25.0	
roi (2)	22.5	29.5	26.0	
taape (31)	22.5	30.0	25.7	
toau (146)	19.5	32.0	25.5	24.0
ʻūʻū (13)	18.0	21.5	20.0	
weke-aʻa (445)	18.0	36.0	29.8	
weke-pueo (244)	20.5	35.5	28.1	
weke-ʻula (143)	18.0	34.5	28.4	

Red numbers indicate lengths at which gonads were not observed

Seven species or .5% of the entire project's landing were caught but once. These seven individuals along with their measured fork lengths are depicted in Table 3 below.

Table 3. Fork Lengths of Samples Caught Only Once

	Fork Length (cm)
'āweoweo	15.0
Dactylopterus orientalis	22.0
kawale'ā	69.0
Carangoides orthogrammus	47.0
Caranx sexfasciatus	24.0
po'o-pa'a	22.5
uliuli	30.0

Red numbers indicate lengths at which gonads were not observed

INVERTEBRATES

Results

Historically, lay-net fishing on Molokai is centered on the catching of fish. However, it is not uncommon for marine invertebrates to also be incidentally entangled in the nets. The common practice is to release these invertebrates unharmed, particularly if they are unfamiliar or undersized. During this fisheries operation, seven invertebrate species, all crustaceans, were caught (Table 4). The shallow water Hawaiian slipper lobster Parribacus antarcticus or *ula-pāpa* proved to be the most ubiquitous constituting 94.2% of all invertebrates caught within the project's time frame. This nocturnal shallow water species was found to be considerably less robust than other scyllarid species in Hawaiian waters. These specimens, when measured between the first and second tail segments, had a mean tail width of only 52.9 mm and an average weight of 149.8 grams. None of the many female *ula-pāpa* examined throughout the project were found bearing eggs. The only other invertebrate species besides *ula-pāpa* that appeared more than once in project nets was Portunus sanguinolentus *(kuhonū)*.

Table 4. Invertebrates Caught

	# caught	♀	Total weight (kg)	Carapace width (cm)	Carapace length (cm)
Parribacus antarcticus	129	49	19.32		
Portunus sanguinolentus	3	0	0.23	9.0-14.0	
Scylla serrata	1	0	1.7	20.0	
Carpilius maculatus	1	1	0.8	15.5	
Panulirus marginatus	1	0	0.2		8.5
Carpilius convexus	1	0	0.0875	7.5	
Thalamita crenata	1	0	0.075	7.5	

FISHERIES STANDARDS

Minimum Size

Because collaborators were required to submit all items encountered during the course of this project, fisheries operations resulted in the submittal of samples not in compliance with fishery standards as defined by DAR for the years 2008 and 2009. Under normal conditions, undersized landings would have been either discarded or released so as to avoid possession and thus potential violations of State laws and rules pertaining to fishing in Hawaii. However, to secure an accurate picture of the impact of lay net fishing, project participants were required to submit all items caught in project nets for formal documentation. Of the entire landing of 1,585 samples, 5.9% was found not to comply with acceptable minimum size standards at the time of this project. These sub-standard size samples consisted entirely of fish species. All invertebrate landings were discovered to have complied with their respective minimum size requirements. Four carangid species combined to form the bulk of the undersized samples, followed closely by *moi* and *ʻōʻio* (Figure 5).

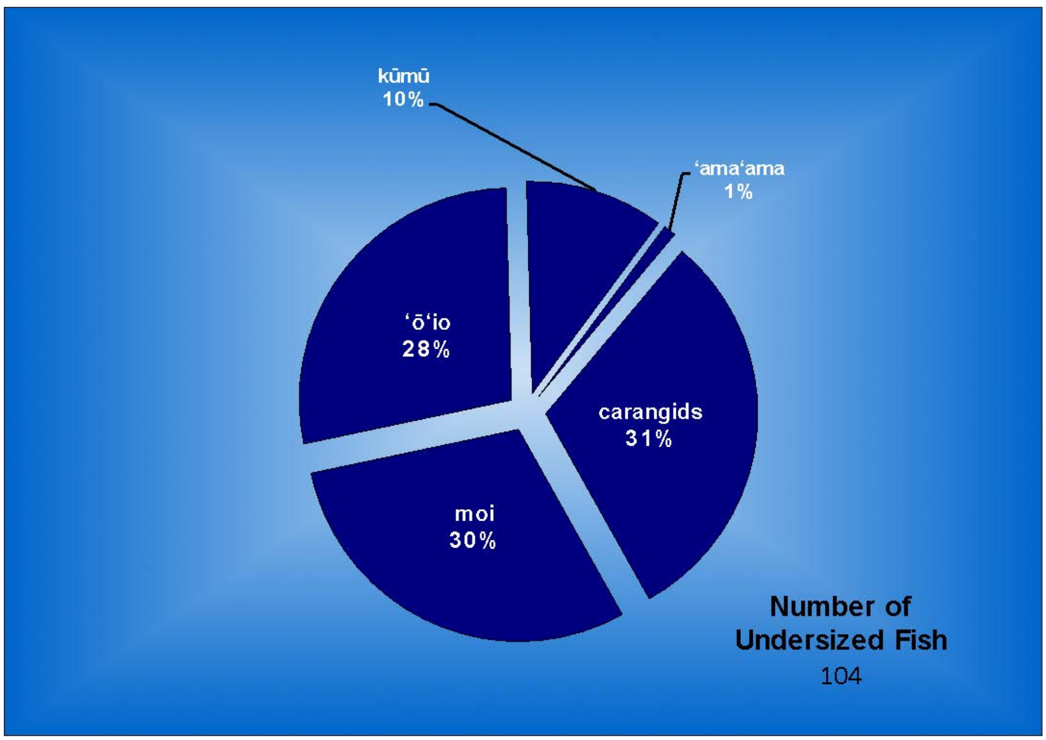


Figure 5. Undersized Landings

Closed Seasons

In the State of Hawaii, five marine species are managed by employing seasonal prohibitions. Two such species were encountered during this project period, their numbers amounting to less than 1% of the total landing (see Table 5). Of these two species, Polydactylus sexfilis *(moi)* was the only species that did not comply with both the prevailing minimum size and closed season standards of 2008-2009.

Table 5. Seasonal Prohibition

	Number undersized	Numbers out of season	Numbers both out of season & undersized
ʻōʻio	29	—	—
moi	31	18	9
ʻōmilu	20	—	—
aukea	8	—	—
paʻo-paʻo	1	—	—
C. fasciatus	1	—	—
kūmū	11	—	—
ʻamaʻama	1	12	0

Gonads Morphology

Gonad morphology has long been studied by fisheries biologists to identify annual reproductive cycles, length of breeding season, onset of reproductive maturity, spawning rhythms, fecundity, and various other aspects of reproductive biology that can be applied to fisheries questions and concerns.[9] Typical of many fishes found in the tropics most Hawaiian species are not sexually dimorphic, thus making internal inspections necessary for sexual identification. Each fish netted during this project was dissected and when present their gonads removed and placed in corresponding numbered Ziploc bags, which were then weighed, and examined (Figure 6). Distinguishing between sexually matured males and females in this manner proved relatively simple and straightforward. A notable exception involved a single hermaphroditic Polydactylus sexfilis bearing bisexual gonads (see Table 6). The relatively large size of this fish coupled with the presence of ovotestes indicated a transitional gender phase common to *moi* and other Polynemid species.[10]

Figure 6. Removing Gonads

[9] Parenti, L. R., Grier, H. J., *Evolution and Phylogeny of Gonad Morphology In Bony Fishes, vol. 33, no. 5.* (2004) New York, N. Y.

[10] Kanayama, R. K. *Life History Aspects of the Moi Polydactylus sexfilis in Hawaii.* (1973) Honolulu, Hawaii

Most, if not all, male fish testes were found to be smooth paired gland-like tissues. They were further differentiated from ovaries by their propensity to "smear" when pressed and squashed in their holding bags. This helpful dignostic feature extended to all fish species examined (Figure 7).

Figure 7. Smearing of Testes

In most cases, ovaries appeared as bilaterally paired sac-like organs into which extended numerous ovigerous folds ensconced by copious blood vessels. (Figure 8) Additionally, in matured females with well-developed ovaries, fish eggs were easily discernable upon viewing with a hand held magnifier.

Figure 8. Paired Ovaries

Table 6. Gender Identification

	♂	♀	?
ʻāweoweo	—	—	1
ʻalaʻihi	—	7	—
ʻahaʻaha	1	6	—
āhole	2	6	2
ʻamaʻama	12	18	9
aukea	—	—	25
C. orthogrammus	—	1	—
C. sexfasciatus	—	—	1
D. orientalis	—	1	—
enenue	9	10	14
kākū	1	3	2
kala	1	6	7
kalamoho	—	1	3
kawaleʻā	—	1	—
kūmū	1	2	10
lai	—	3	6
manini	2	9	7
moi	30(1*)	5(1*)	22
ʻōʻio	23	17	89
ʻōmilu	—	—	37
paʻopaʻo	1	3	2
poʻo-paʻa	—	—	1
pualu	—	—	2
roi	1	1	—
taape	10	18	3
toau	76	41	29
uliuli	1	—	—
ʻūʻū	1	8	4
weke-aʻa	146	248	51
weke-pueo	180	62	2
weke-ʻula	27	104	12

** hermaphrodite bearing bisexual gonads*

Spawning Seasons

By comparing the gonad weight against the total weight of the fish it is possible to derive certain indices for individual fish species. If enough of these indices can be collected and plotted over time, it may be possible to identify seasonal spawning periods for various fish species. However, it should be noted that several factors inherent to this project profoundly influence any predictions (or for that matter, any other estimated conclusions) that may be generated. Perhaps the most telling is the mesh size of the nets used during this project, which effectively dictated the size ranges of fish being caught. Depending on the species of the fish and regardless of sexual development, smaller individuals tended to pass through the netting unhindered while larger animals simply bounced off unfettered. As a result, our calculated gonad/weight ratios do not necessarily represent a complete profile of sexual maturity as related to fork lengths of several species. A case in point involved the very common and widespread blue fin trevally or *'ōmilu.* In spite of being netted numerously over the course of the project, none were sizeable enough to bear any sexual gonads. The relatively small mesh size of project nets selectively discriminated against the capture of any large sexually matured *'ōmilu* known to frequent project areas, these larger sizes being regularly caught by other means such as trolling, spearing, whipping, dunking, and trapping. However, if enough sexually matured individuals of other suitable species are encountered and an adequate amount of gonad weight/total weight ratios determined, it is possible to establish plausible spawning seasons for these species. This is exemplified in Figure 9 involving the three most often encountered goatfish species during our project, which together totaled 57.4% of the entire project's landings.

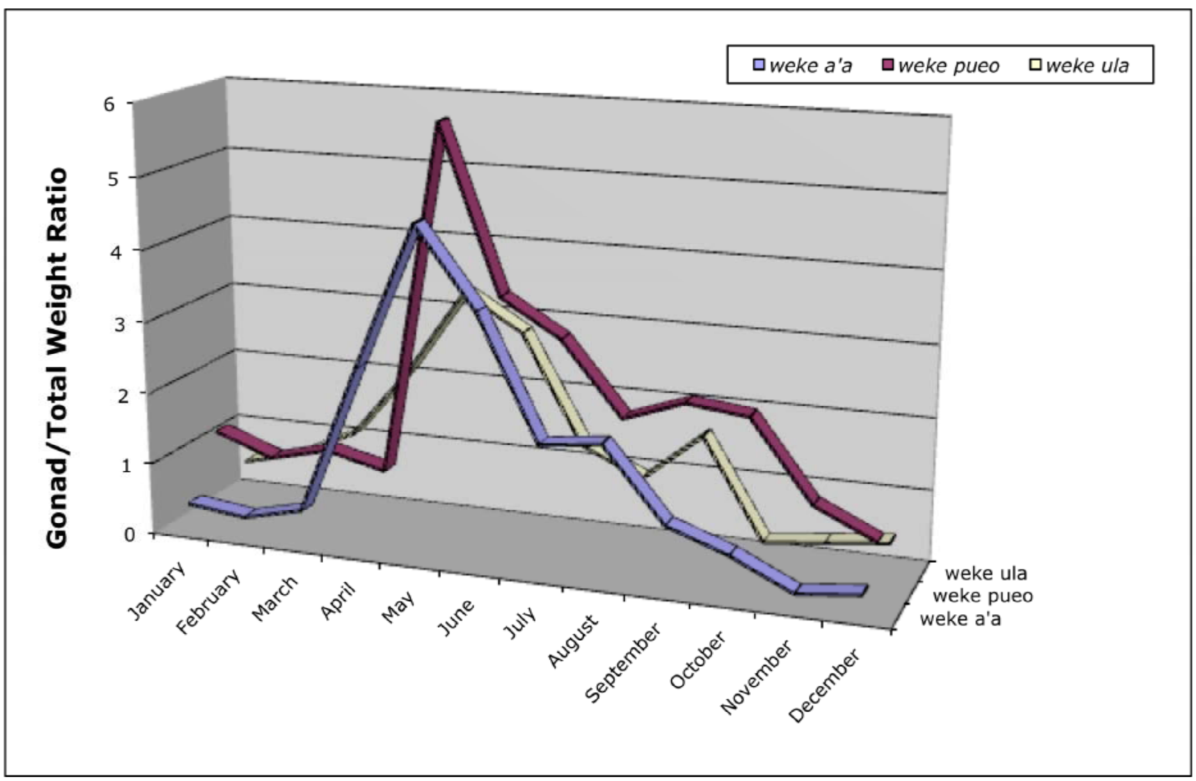


Figure 9. Spawning Months for Three Indigenous Goatfish Species

STOMACH CONTENTS

Carnivores

At times, fish dissections also provided the opportunity to single out ingested food items. Whenever firm and extended stomachs were encountered, incisions were made to expose their contents and were kept for further examination (see Figures 10 and 11). In those instances when digestion was well underway, only the gross identification of prey items was possible. In these cases, only generic descriptions of the stomach contents were notated. No effort was made to quantify stomach contents, or to assess the state of digestion. Occasionally, samples were intercepted early enough in the digestive process so as to allow positive identification of prey items. One case in particular confirmed local suspicions that Herklotsichthys quadrimaculatus, the yellow spotted sardine introduced into Hawaii in the 1970s and now widely distributed and permanently established in Hawaiian waters, was being foraged upon by native species.[11]

Figure 10. ʻOʻio Stomach Contents

Crustaceans were determined to constitute the principal diet component of netted carnivores and were detected in 88.1% of the examinable stomachs of such fish caught during this fisheries operation. Precise identification of some ingested items was hampered by the author's unfamiliarity with marine invertebrates. Nevertheless, generic identifications of prey items were reasonably accurate and have been listed in Table7. Each check mark indicates the observed presence of prey items upon a single incision, (i.e. not the number of consumed items per species).

Figure 11. Aukea Stomach Contents

[11] Baldwin, W. J., *A Note on the Occurrence of the Gold Spot Herring, Herklotsichthys quadrimaculatus (Riippell) in Hawaii.* (1984). Honolulu, Hawaii

Table 7. Stomach Contents of Carnivores

	unidentified caridean	unidentified eel	unidentified fish	unidentified goby	unidentified portunid	unidentified stomatodpod	unidentified xanthid	Euprymna scolopes	Herklotsichthys quadrimaculatus	Juxtaxanthias intonsus
ʻalaʻihi					√					
aukea	√	√			√	√√√√	√			
C. orthogrammus							√			
lai									√	
moi	√√		√	√	√	√√√				
ʻōʻio					√√√	√√√√	√			
pao'pao					√	√√√				
po'o-pa'a										√
taape					√		√√			
toau						√	√√	√√		
weke-pueo					√√√√√√	√√√√√√√√√√	√√√√√√			

Herbivores

In regards to the stomach contents of herbivores, the proper identification of the ingested algae was contingent upon the size of the fish together with their timely capture. Identifying the surf turf algae that smaller species such as Acanthurus sandvicensis *(manini)* feed upon required specialized equipment

Figure 12. Enenue Stomach Contents

and expertise, both conditions unavailable to this author. However, several timely gross examinations of the larger mouthed individuals such as Kyphosus bigbbus *(enenue)* and Naso unicornis *(kala)* revealed the observed presence of several easily identifiable algae (Figure 12), both native and non-native species.[12]

No effort was made to quantify stomach contents, nor was any attempt made to assess the state of digestion. While quantification proved problematic, the observed presence of ingested algae is notated in Table 8. In keeping with the checklist of ingested items by carnivores, each of the checkmarks in the following table represents the observed presence of consumed algae upon a single incision, (i.e. each check mark represents the observed presence of that algae upon any single incision).

Table 8. Stomach Contents of Herbivores

	Acanthophora spicifera	*Dictyopteris australis*	*Halimeda sp.*	*Hypnea sp*	*Padina sp.*	*Sargassum sp.*	*Turbinaria ornata*
enenue	√	—	√	√	—	√√	√√
kala	—	√	—	√	√	√√√	√

CATCH PER UNIT EFFORT

It was hoped that this project would establish a plausible catch per unit effort (CPUE) baseline for gill net fishing for future reference. While understanding that any assessment of fish stocks based on catch per unit data are notoriously problematic[13], it is nevertheless hopeful that an elemental understanding of the effects of *ho'omoemoe* fishing as practiced on the island of Molokai may be obtained from the results of this fishery operation. A concerted effort was made to design this project to be repeatable, thus providing future opportunities for DAR to easily judge the ongoing effects of this particular net fishing practice on island resources. Strict compliances to maintain fishing nets at optimal conditions were adhered to throughout the project to avoid gear bias. Additionally, fishers were required to retrieve all ensnared samples, sub-standard and otherwise, for formal documentation. This resulted in the recording of several unusual species that customarily would have been discarded and therefore anonymous in normal creel sampling, e.g. *Dactyloptena orientalis, Carpilius convexus*.

---

[12] Russell, D. J., Balazs, G. H., *Identification Manual For Dietary Vegetation of the Hawaiian Green Turtle, Chelonia mydas*. (2000). NOAA-TM-NMFS-SWFSC-294.

[13] Maundar, M. N., Sibert, J. R., Fonteneau, A., Hampton, J., Kleiber, P., and Harley, S. J. *Interpreting Catch Per Unit Effort Data to Assess the Status of Individual Stocks and Communities.* ICES Journal of Marine Science, 63: 1373-1385. (2006)

As it pertains to this report, the term "catch" embraces all items ensnared during a lay-net fishing episode to include undesireable species normally released upon netting, and still others not in total compliance with prevailing DLNR regulations. "Unit Effort" for this experiment is defined as "net-hour", with net being further defined as a single selvage 15 lb-test nylon monofilament net that is 125' in length and 7' in height, with a stretched eye mesh of 2-3/4". In perceived relative importance, the data collected suggested that the successful outcome of any lay-net fishing trip was strongly influenced by (1) the experience of the fisherman, and (2) the geographical areas where the fishing took place. As shown in Table 9, catch landings varied as much as 288% from one area to another, which in turn coincided with the age (and subsequent experiences) of the contributing fishers. It appeared more than coincidental that the more than 2 to 1 difference in CPUEs between Ka-malō and Mapulehu areas reflected the age and experience between the fishers of these two areas, this in light of the fact that the near shore habitats of these areas are very much similar. Moa-nui, the area with a lowest CPUE, was further handicapped by it affording the least amount of suitable *hoʻomoemoe* fishing areas when compared to the other four locations involved in this project.

Table 9: CPUE Expressed in Numbers Caught Per Net/Hour

	CPUE (fish only)	CPUE (fish & inverts)
Kapaʻakea	1.1	1.25
One-aliʻi	1.0	1.35
Ka-malō	0.72	0.73
Mapulehu	2.08	2.14
Moa-nui	0.71	0.72

SUMMARY

The merits of gill net fishing have been a contentious topic of discussion for many years in Hawaii. Consensus management of this fishery has long been stymied by inherent variables resulting in various points of view. Some of these opinions appear to be based on inadequate data and others on mere assumptions, conflating into confusion among researchers and practitioners. A fishery project was initiated on the island of Molokai to promote a better understanding of the effects of gill netting through the monitoring of the most commonly practiced gill-net fishing method known as *ho'omoemoe*. The primary goal of this artisanal fishing technique is to provide food for domestic consumption. Five experienced fishermen from different sections of the island were asked to collaborate in identifying and enumerating catch landings over a twelve-month period. In order to obtain a complete picture of resources being exploited, participants were required to retain all items ensnared during the project for formal documentation. When available, the gonads of mature specimens were extracted to determine sexual status and seasonal reproductive activities. When appropriate, stomach contents were scrutinized in an effort to determine preferred food items. Strict procedures were devised and adhered to throughout the project in order to minimize adverse interactions with federally protected species. Certain precautionary measures were followed to ensure gear consistency throughout the project.

The results of this project revealed catch landings consistent with historical anecdotal experiences, and furthermore confirmed testimonies expressed by experienced Molokai fishermen and *na kupuna* (elders) during the Governor's Advisory Panel public meetings held in 2006 and 2007, and during several Office Of Hawaiian Affairs gatherings convened to solicit public input regarding lay net fishing. This is by no means to suggest the use of gill nets is benign, nor that stock resources anywhere in Hawaii will continue to remain viable. However, such factors notwithstanding, on the island of Molokai at least it would not be unreasonable to expect catch and effort results between 1 to 2 fish per net/hour to persist during gill net usage in *ho'omoemoe* fishing.

BIBLIOGRAPHY

Baker, Michael E. 1987. "*Backyard Fishing On The South Coast Of Molokai." Master's Thesis, Department of Geography, University of Hawaii at Manoa.* Honolulu, Hawaii.

Baldwin, W. J. "*A Note on the Occurrence of the Gold Spot Herring, Herklotsichthys quadrimaculatus (Riippell) in Hawaii.*" Pacific Science. Volume 38 (2). (1984): pp. 123-126.

Brock, V. "*The Introduction of Aquatic Animals Into Hawaiian Waters*." Internationale Revue Gesamten Hydrobiologie. Volume 45, No. 4. (1960): pp. 463-480.

Buck, Peter H. 1957. *Arts & Crafts of Hawaii: Fishing.* Honolulu, Hawaii: Bishop Museum Press.

Division of Aquatic Resources. 2008. *Hawaii Fishing Regulations.* Honolulu, Hawaii.

Field, M. E., Cochran, S. A., Logan, J. B., and Storiazzi, C. D. 2008. *The Coral Reef of South Molokai, Hawaii—Portrait of a Sediment Threatened Fringing Reef: U. S. Geological Survey Scientific Investigation Report 2007-5101.* Menlo Park, California.

Gosline, William A., Brock, Vernon E. 1965. *Handbook of Hawaiian Fishes.* Honolulu, Hawaii: University of Hawaii Press.

Hobson, Edmund S., Chave, E. H. 1972. *Hawaiian Reef Animals.* Honolulu, Hawaii: University of Hawaii Press.

Hoover, John P. 1993. *Hawaii's Fishes.* Honolulu, Hawaii: Mutual Publishing.

Hoover, John P. 1999. *Hawaii's Sea Creatures.* Honolulu, Hawaii: Mutual Publishing.

Hoover, John P. 2010. *The Ultimate Guide to Hawaiian Reef Fishes*. Honolulu, Hawaii: Mutual Publishing.

Hui Malama O Moomomi. 1995. *Proposal to Designate Moomomi Community-Based Subsistence Fishing Area*. Honolulu, Hawaii.

Jordan, David S., Evermann, Barton W. 1973. *The Shore Fishes of Hawaii.* Tokyo, Japan: Tuttle Publishing.

Kahaulelio, D. 2006. *Ka Oihana Lawaia, Hawaiian Fishing Traditions.* Honolulu, Hawaii: Bishop Museum Press.

Kanayama, R. K. 1973. *Life History Aspects of the Moi Polydactylus sexfilis in Hawaii.* Honolulu, Hawaii.

Mahaney, Casey. 1999. *Hawaiian Reef Fish: The Identification Book.* Kailua, Hawaii: Planet Ocean Publishing.

Malo, David. 1987. *Hawaiian Antiquities.* Honolulu, Hawaii: Bishop Museum Press.

Manu, Moke. 1992. *Hawaiian Fishing Traditions.* Honolulu, Hawaii: Kalamaku Press.

Maundar, M. N., Sibert, J. R., Fonteneau, A., Hampton, J., Kleiber, P., and Harley, S. J. "*Interpreting Catch Per Unit Effort Data to Assess the Status of Individual Stocks and Communities."* ICES Journal of Marine Science. Volume 63. (2006): pp. 1373-1385.

Parenti, L. R., Grier, H. J. *"Evolution and Phylogeny of Gonad Morphology In Bony Fishes."* Integrative and Comparative Biology. Volume 44, Number 5 (November 2004): pp. 333-348.

Randall, John E. 1985. *Guide to Hawaiian Reef Fishes.* Honolulu, Hawaii: Harrowood Books.

Randall, John E. 1998. *Shore Fishes of Hawaii*. Honolulu, Hawaii: University of Hawaii Press.

Randall, J.E., Birkeland, C., Pyle, R. L., Kosaki, R. 2006. *The Case Against Lay Gill Nets.* Honolulu, Hawaii.

Randall, J. E., and Katayama, R. K. 1973. "*Marine Organisms—Introductions of Serranid and Lutjanid Fishes From French Polynesia to the Hawaiian Islands.*" Nature Conservation in the Pacific. pp. 197-200 .

Russell, D. J., Balazs, G. H. 2000. *Identification Manual For Dietary Vegetation of the Hawaiian Green Turtle, Chelonia mydas*. U.S. Department of Commerce, NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-294, 49 pages

Russo, Ron. 1993. *Hawaiian Reef: A Natural History Guide.* San Leandro, California: Wavecrest Publications.

Tinker, Spencer W. 1978. *Fishes of Hawaii*: A Handbook of the Marine Fishes of Hawaii and the Central Pacific Ocean. Honolulu, Hawaii: Hawaiian Service.

Tinker, Spencer W. 1965. *Pacific Crustacea*. Tokyo, Japan: Charles E. Tuttle Co., Inc.

Titcomb, Margaret. 1972. *Native Use of Fish in Hawaii.* Honolulu, Hawaii: University of Hawaii Press.

Titcomb, Margaret. "*Native Use of Marine Invertebrates in Old Hawaii."* Pacific Science. Volume 32, Number 4. (1979): pp. 325-386.