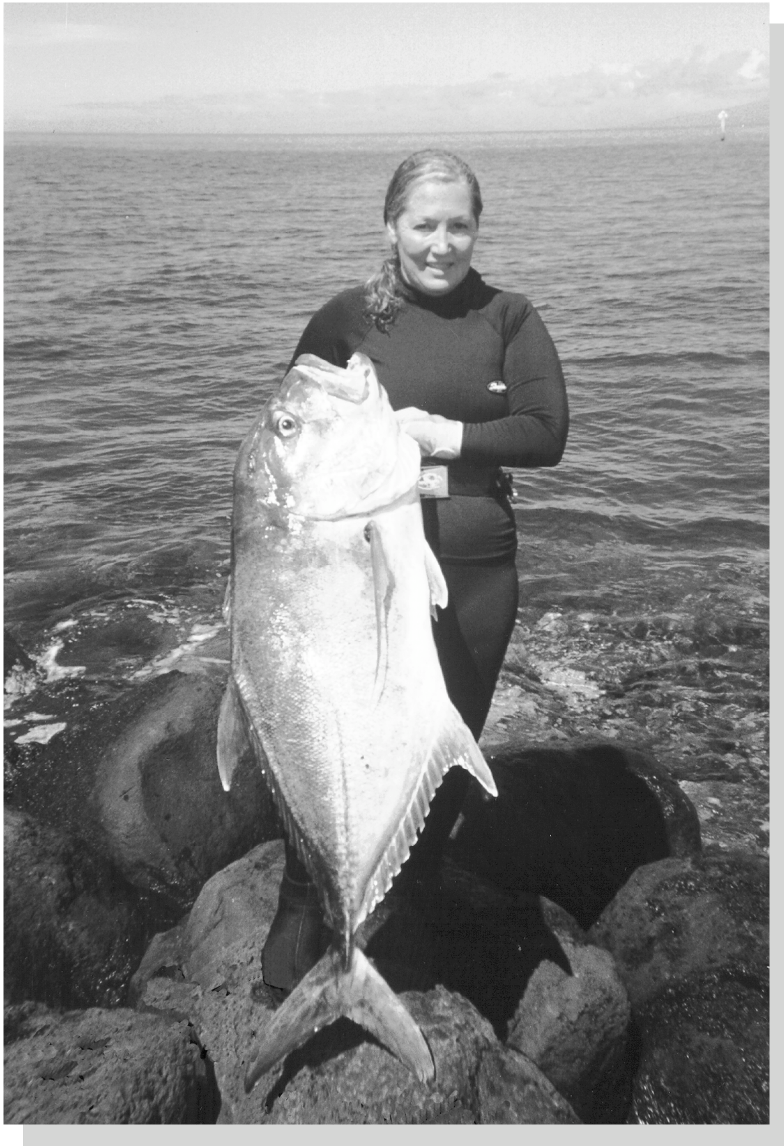

Department of Land and
Natural Resources

Division of
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Technical Report
20-02

Evaluation of the status of the recreational fishery for ulua in Hawai‘i, and recommendations for future management

October 2000

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DIVISION OF AQUATIC RESOURCES

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Kit Hinhumpetch

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DAR Technical Report 20-02

“Ka ulua kapapa o ke kai loa”
The ulua fish is a strong warrior.
Hawaiian proverb

“Kayden, once you get da taste fo’ ulua fishing’, you no can tink of anyting else!”
From *Ulua: The Musical*, by Lee Cataluna

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Introduction

Unique marine resources, like Hawai‘i’s ulua/papio, have cultural, scientific, ecological, aesthetic and functional values that are not generally expressed in commercial catch statistics and/or the market place. Where their populations have not been depleted, the various ulua popular in Hawai‘i’s fisheries are often quite abundant and are thought to play the role of a significant predator in the ecology of nearshore marine ecosystems.

However, Hawai‘i’s ulua have been considered an important food, market and game fish since at least the turn of the century. Stocks of these important predators in the Main Hawaiian Islands “are certainly considerably depressed,” and the reported landings of ulua in Hawai‘i have declined by over 84% since the turn of the century (Shomura 1987).

The decline of our coastal fisheries is a manifestation of the failure of our resource management strategies. Current fishery management strategies are based upon single species (i.e., population-based, yield, seasonal closures, size and bag limits). These strategies offer little hope for the recovery of over-fished or otherwise impacted fisheries. Our fisheries management strategies were not designed for complete ecosystem protection.

Natural resource decisions in Hawai‘i have traditionally emphasized achieving the management goals of a particular legislator, agency, organization or interest group and/or addressing specific needs (agriculture, water, development or commercial fisheries). In recent years, the limitations of this approach have become obvious as our fisheries have declined.

The need for greater public participation and cooperation among all affected parties - federal, state and local government, academic institutions, private industry, interest groups and stakeholders, in developing and implementing natural resource use and management goals, is fundamental to designing and achieving sustainability and protecting our marine ecosystems. However, the inability to obtain all the data required to make management decisions may be an opportunity to seek a new paradigm for fisheries management that is not based on intensive data gathering and analysis, but on self-reinforcing feedback at the local level. Community based management pays greater attention to information provided by the community, and to the ways in which traditional and community measures can maintain a fishery.

Despite their popularity as food and game fish throughout their range, and the wealth of evidence that stocks are not what they once were, comparatively little is known about the biology and ecology (life history parameters and age, growth, mortality, level of predation and recruitment details) of many species of jacks. That information is critical both to understand and to preserve their important role in our marine ecosystem and as a valued recreational fishery, and in order to develop rational management of carangid stocks.

An important caveat is that science-based management studies and policies will only be of use if they include the involvement of all players (decision makers, economists, sociologists, and user groups). Lack of information or uncertainty has been known to freeze political action in Hawaiʻi. Pure recreational catch data is essential to the management of any species with important recreational impact, like Hawaiʻi's ulua. Unfortunately, most of the data collected and/or available in Hawaiʻi today is commercial/market catch data, which has little relevance to managing what is primarily a recreational and subsistence fishing resource. Many different jack species are components of Hawaiʻi's subsistence, recreational and commercial fisheries, and because nearly all of the coastal carangids have been heavily exploited in Hawaiʻi for years, concerns are often raised publicly regarding conservation and management of the species.

Expenditures in the sportfishery for ulua amount to over $20 million annually and with a commonly accepted multiplier applied to that number it is reasonable to state that the recreational ulua fishery in Hawaiʻi has more than a $31 million per year impact on Hawaiʻi's economy.

We recommend a number of management measures including:
1) empowering community based management for an increasing number of contiguous, homogeneous coastlines across Hawaiʻi,
2) evaluation and establishment of harvest refugia,
3) implementation of biologically appropriate minimum lengths, reduced bag limits and banning the commercial sale of several species of ulua/papio,
4) hiring of new DAR staff specialists for ulua/papio and for recreational fishing,
5) expanded study of the biology and ecology of ulua/papio,
6) collection and archiving of recreational fishing data.

Background

The Ulua in Hawaiian Culture
(courtesy Donald Aweau, Hawaiʻi Fishing News)

Early Hawaiians recognized that many species of ulua are found in Hawaiian waters. The more common names they used for ulua were: *ulua ʻaukea* (white ulua), *ulua ʻeleʻele* (black ulua), *paʻopaʻo* (green and yellow with vertical green bands), *ulua nukumoni* (grey/green trevally with mottled spots), *ulua kihikihi* or *mahai* (kagami or silver ulua) and *ʻomilumilu* or *ʻomilu* (blue with black and yellow markings).

The Hawaiians also had names for the different growth stages of the ulua. The three categories include: *papiopio* or *papio* (young), *paʻuʻu* (intermediate), and *ulua* (adult). The names for each size varied since weight and length were not considered to be as important as they are today. The distinction between a papio and an ulua is often one of judgement and varies upon locality. For instance, people on O‘ahu may consider a 10 pound trevally to be an ulua, while folks in Ka‘u (South Point), Hawai‘i call the 15 pounders, *papio*.

The ulua played an important role in Hawaiian religious rites and was used as a substitute if a human sacrifice was not available. Possible reasons can be found in the meaning of the word ulua, broken down into components. The *"ulu"* in ulua means possessed or inspired by a god. The eye of an ulua was said to be like that of a human thus the sacrifice option. The strength of the ulua was also compared to warrior-like qualities.

Culturally and religiously, the ulua was seen as an *akua* (a god). In ancient times ulua were fished for sport by the *ali‘i* in much the same way the *mano* (shark) were. A certain mystique therefore surrounded the ulua, and they were not pursued by the commoners, who apparently caught them only by happenstance, while fishing for other species.

It is not safe to assume that konohiki protections or kapu restrictions were specifically placed on ulua in ancient times. Only certain species of fish were offered such protections, such as moi.

Several verses regarding ulua are found in Hawaiian songs and chants (e.g., *huki i ka ulua, pull in the ulua,* which could figuratively be taken to mean, get your man). In a popular Hawaiian song, *Moanalua*, a verse speaks of the strong and powerful actions of the ulua. *Holo lio la‘au me ka ulua*. Ride the merry-go-round with an ulua fish. (S. Elbert and N. Mahoe, "Na Mele o Hawai‘i Nei" [1970]).

Na ‘olelo noe‘au (Hawaiian sayings and proverbs) regarding ulua.

"Aia i ka huki ulua." Gone to haul-in ulua., or gone to get her man.
" ‘A‘ohe ia e loa‘a aku, he ulua kapapa no ka moana." He cannot be caught for he is an ulua fish of the deep ocean. Said in admiration of a hero or warrior who will not give up without a struggle.
"*Ka i‘a kaohi aho o na kai uli*." The fish of the deep that pulls the line taut.
"Ka ulua kapapa o ke kai loa." The ulua fish is a strong warrior or fighter. (Pukui 1983).

Legends concerning Hawaiian akua, with a connection to the ulua:

Pimoe: Maui fishes for the big ulua, Pimoe, with his hook called Manaiakalani. For two days they pull at it before it comes to the surface and is drawn close to the canoe. The brothers are warned not to look back. They do so. The fishing line breaks, and the fish vanishes. That is why the islands are not united as one. (Ka Nupepa Ku‘oko‘a, June 27, July 4, 1863, by Puaoalaoa). Another version is that Pimoe was a demigod with an ulua fish form that was hooked by Maui in his efforts to unite the islands. Maui warned his older brothers not to look back. But they did and saw a canoe bailer (*ka*) which they placed in the canoe. It changed into a beautiful woman, Hinaikeka. While they struggled to embrace her, the fish slipped away.

Kamohoali‘i: Brother of Pele and a shark god. Also the *akua* of ulua at Ka‘ena Pt., O‘ahu.

***Na Hua ‘Olelo* (ulua fishing vocabulary)**
aho - fishline
makau - fish hook
waihona makau - fish hook container
ko‘a - fishing grounds
makoi - fishing pole
maka ki‘i - lure
poho aho - fishline container
i‘a ku - fish run
ku‘ula - fishing shrine
ka makoi - to fish with a pole
hi - to cast or troll
kikomo - pole fishing in shallow seas
kupali - to pole fish from a rock or cliff
ka‘ili -t o cast for fish
pakali - to decoy fish by doling out bait little by little
kupalu - chumming water with bait
ipu holoholona - bait container
ku‘i palu - to make palu
maunu - bait
maunu pahe‘e - slide bait
pepenu - dunk
hawai‘i loa - name of a line for ulua fishing in 17 or more fathoms of water
ho‘ohe‘e - to slide; to put to flight
he‘e pulu - octopus slightly decomposed. Also *he‘e makole*.
hiana - depression or hole, as under water.
hiana ulua - hole frequented by ulua.
hilala - to reel, lean or tilt sideways
hupu - catch, as of fish
pakau ulua - ulua hook

Coastal Fishery History since 1900

The coastal fisheries of Hawai‘i have evolved from almost exclusively small-scale artisanal fisheries to an industry using modern gear, technology and equipment, designed to meet the demand of a growing population as the State economy developed and urbanization increased. Yields from coastal and reef fisheries have not been able to keep pace with the State’s population growth. “The available data, although not entirely reliable, suggest that the coastal fishery resources have declined drastically in the 20th century.” (Shomura 1987)

When Hawai‘i was annexed by the United States (1898) the population of the islands was about 150,000 residents, most of whom lived in small towns and villages spread across the six major islands of the Hawaiian chain. Fishing was primarily undertaken from shore and from canoes, and roughly 2000 commercial fishermen were “registered” with the territory at that time. They reported catches of over 6 million pounds. “In addition to this small but active commercial fishery, the lifestyle at the turn of the century must have included a substantial artisnal fishery whose catches were not recorded.” (Shomura 1987)

By the middle of the century Hawai‘i’s population had swelled to roughly half a million residents, Honolulu had become a major city, sugar and pineapple were agricultural giants, and tourism had begun to blossom into a major industry. The growth in population, industrialized agriculture, and geometric growth of tourism in the later half of the 20th century all had significant consequences on the coastal marine ecosystems of the Hawaiian islands. Reported commercial catch at mid-century was about 16 million pounds annually, and the catch peaked in 1953 with reported landings of 18.86 million pounds, after which they tailed off precipitously. In 1980 the reported catch was 10 million pounds, and in 1985 it was just 8 million pounds.

By the mid- to late-1980’s the population of the islands had reached a million residents and tourism was attracting 6 million visitors each year. There were over 2500 registered commercial fishermen and over 8000 commercial and recreational fishing vessels were reported (Skillman & Louie 1984). In the mid-1980’s the longline fleet based in Honolulu grew dramatically, increasing the overall annual reported catch back up toward 1953 levels. The bulk of the new catch figures were coming from waters farther offshore than had been traditionally fished from the Hawaiian islands.

The 1998 reported landings were 21,397,075 pounds, down from over 25 million pounds in 1995. Roughly 15 million pounds of the 1998 catch is represented by tuna and swordfish, most of it taken well offshore, leaving only about 6 million pounds of the catch coming from the near-coastal and coastal areas of the state, far below the 16 million pounds that was being caught by the largely near shore fleet at mid-century.

“Several major changes have occurred since 1900. There has been a dramatic decline in the catch of coastal species. The catch during the post World War II (1950, 1953) and recent years (1985,1986) ranged from 16 to 24% of the 1900 catch of coastal species; thus, an 80% reduction in the catch of coastal species apparently has occurred since 1900.” (Shomura 1987)

Ulua Landings
The reported landings of all ulua/papio declined from 652,000 pounds in 1900 to 102,300 pounds in 1986, which represents just 16% of the reported catch at the turn of the century - an 84% decline in reported landings.

In 1990 some of Hawai‘i’s largest fish dealers (including United Fishing Agency, the Honolulu auction block) stopped buying and selling ulua (except for butaguchi and NWHI fish) after concerns were raised regarding the dealer’s potential liability due to unknown ciguatera contamination of the species (Takenaka and Kawamoto, pers. comm.). By 1998 reported landings of all species of jacks (except butaguchi which was not included as part of the earlier catch statistics), was just over 29,000 pounds. From the most recently available landing information, 10,149 pounds was white ulua (*Caranx ignobilis*), 704 pounds was ‘omilu (*C. melampygus*) and the balance was made up of assorted other coastal species.

In a study conducted by Meyer Resources (1987) O‘ahu fishermen said they had observed a 12-pound decline in the weight of the ulua caught. Big Island and Kaua‘i ulua fishermen noted an 18-pound decline, and Maui fishermen a 40 pound decline. These same resident shore fishermen claimed anywhere from three (Kaua‘i) to twenty-four (O‘ahu) fewer ulua caught per fishing trip.

The Ulua Sportfishery in Hawai‘i

The ancient Hawaiians apparently considered ulua to be a sportfish worthy of pursuit by the *ali‘i*. Some of the earliest sportfishermen to visit Hawai‘i were introduced to the species as one of the most revered game fish found in island waters.

Archival newspaper accounts from Hilo indicate that modern sportfishing for ulua (with rod and reel) date back to at least 1914. The oldest known shoreline fishing club in the Hawaiian Islands is the Atlapac Fishing Club, founded circa 1926. There are accounts of a “Honolulu Japanese Casting Club” being founded in 1929 and the Hilo Casting Club, which like Atlapac is still in existence, was founded in 1933.

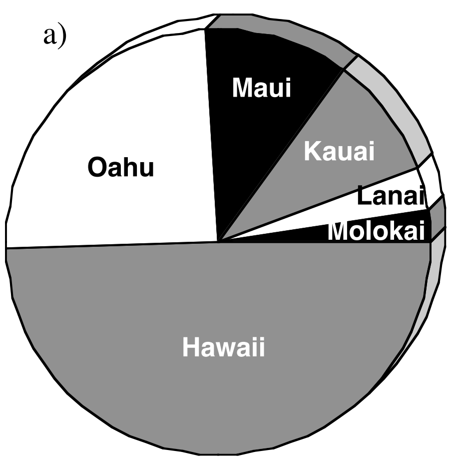
Several pre-World War II written accounts about sportfishing in Hawai‘i include details about the impressive size and tenacity of giant jacks found in Hawai‘i. The largest giant trevally (ulua) in the world may well be those found in Hawaiian waters. Ulua over 100 pounds are apparently uncommon anywhere else the species is found. Only three over 100 pounds have been reported to the International Game Fish Association from elsewhere (Samoa, Mozambique and Reunion Island in the Indian Ocean). Australians, who also revere the giant trevally as a game fish, rarely see them over 70 pounds, despite having one of the largest single trevally habitats in the world (the Great Barrier Reef).

The All-Tackle International Game Fish Association (IGFA) World Record for the species is a 145 pound ulua taken by Russell Mori off the beach at Makena in March of 1991. Several other IGFA world records for the species have been set in island waters since 1978, when the species was first added to the list of fish eligible for World Record consideration, (see Appendix Table 1, page 33).

The most recent data (USFWS 1996) on the fishery indicate that there are 32,000 recreational ulua fishermen in Hawai‘i, ranging from neophytes who struggle to store long rods in tiny apartments and dream of their first 50+ pound ulua, to old timers with garage racks full of a mix of old style rods and modern technology, who can claim more than a couple of fish over 100 pounds in the course of their ulua fishing career.

The capture of a 100+ pound ulua on shore fishing tackle is the ultimate goal of these fishermen. Over 200 ulua topping the century mark have been reported by Hawai‘i anglers, dating back to a 137 pound ulua reportedly caught by angler Jules Cravalho on the Big Island in 1940. In the years 1984, 1988 and 1991 more than a dozen ulua over 100 pounds were reported to Hawai‘i Fishing News for inclusion in the prestigious 100+ Club, which is exclusive to anglers who have landed ulua weighing over 100 pounds from Hawai‘i's shoreline. There have been 103 ulua over 100 pounds taken on the Big Island of Hawai‘i since Cravalho's fish in 1940; O‘ahu has the second largest number with 51 fish over 100 pounds (Figure 1). July has pro-

a)



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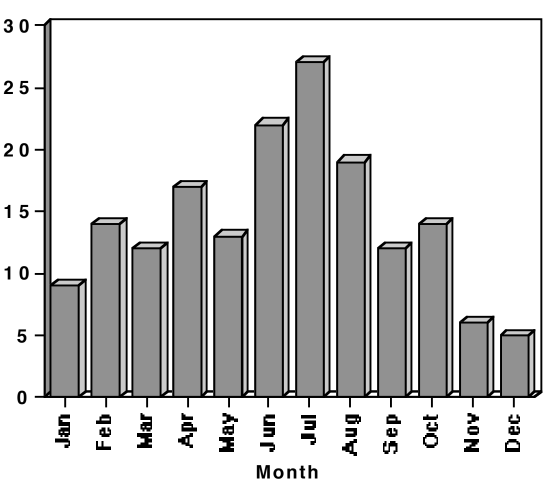

Figure 1. a) Proportion of 100+ pound ulua taken by island;
b) number of 100+ pound ulua taken by month

duced more 100 pound ulua than any other month (27), followed by June (22) and April and August (18). December produced the fewest ulua over 100 pounds with just five.

From the early days when Calcutta cane, hickory, and bamboo rods were fitted with Atlapac, Templar, Pflueger, and Vom Hofe reels, to the modern technology which features meticulously re-engineered star and lever drag reels, and graphite and composite rods specially made for Hawaiʻi's ulua fishery, the sport has come a long way. The technology used to catch ulua from Hawaiʻi's shoreline has improved significantly.

Shore fishing tournaments regularly draw large entry lists, with some groups staking out special fishing spots weeks (or more) in advance. Weekend shore-casters regularly invade remote, productive points of land across the State with forests of rods and extended campsites.

Recreational ulua fishing is such a important part of the Hawaiʻi lifestyle that it has contributed substantially to the content of a monthly newspaper (Hawaiʻi Fishing News) and provided grist and content for various writers and artists. It has even spawned Lee Cataluna's musical comedy, "Ulua: The Musical."

Ulua fishing is primarily a shorefishing endeavor in Hawaiʻi, although small boats are often used to pursue the species on broad coastal reefs and flats like those of Kaneʻohe Bay and south Molokaʻi. A couple of charterboat operators (from Maui and Kona) have focused at least part of their effort on ulua and other jacks, by whipping, plug-casting, jigging, fly fishing and bait fishing.

The popular sportfishery for giant trevally in Japan results in a high degree of interest in Hawaiʻi's ulua by a percentage of our Japanese visitors. However, to date few opportunities have been available for their pursuit of ulua, because shoreline guide services are almost non-existent here, success is uncertain, and very few charterboat operators are familiar with productive ulua fishing techniques and grounds.

Ulua have been actively pursued by spear-fishermen in Hawaiʻi for generations. Ulua over 100 pounds are considered to be one of the ultimate trophies for the growing cadre of free-diving spearfishermen across the State and for a select few visiting spearfishermen, as well.

Biology

Despite their widespread occurrence in the Indo-Pacific, and their importance in some fisheries, the species biology and ecology of most jacks has been inadequately studied and little information is currently available to guide reasoned decisions in fisheries management.

For the two most common jacks on Hawaiian reefs (*Caranx ignobilis* and *C. melampygus*) the level of predation on demersal fauna is thought to be significant. Therefore additional study of the biology and ecology of the ulua is important both for management of the fisheries and to better understand the ecosystems in which they occur.

White ulua (Ulua ʻaukea)

The giant trevally (*Caranx ignoblis*) is a highly-mobile, agile, primarily coastal predator that ranges through the Indian Ocean, eastward across the Pacific Ocean to the Marquesas Islands of French Polynesia and the islands of Hawaiʻi.

C. ignobilis is variously known as ulua, ulua aukea, ulua kea, (young are known as papio) and white ulua in Hawaiʻi. It is called turrum or G.T. (short for Giant Trevally) in Australia, and is also known as G.T. or kaiwari-zoku in Japan where it is revered as a game fish. It was previously known (and are occasionally found in some literature) by the misnomers "lowly" or "lesser" trevally. Mature males may be nearly black in color and are sometimes referred to as black ulua, which confuses the identification of this species with that of the true black trevally (*C. lugubris*) or ulua laʻuli.

Of the 24 Caranx species found in Hawaiian waters, *C. ignoblis* is the largest. It is highly rated as a game fish throughout their range and also highly esteemed as a food fish in many areas. It is a strong swimming, open water, carnivorous, near-apex predator that feeds mainly on fishes. Data suggest that an individual might consume 150.69 kg/year. Fish made up 73% of the diet, crustaceans 11%, and cephalopds 15.9% in a study at French Frigate Shoals (Sudekum et al. 1991)

The body and head of this species are very deep, with a blunt snout. There is a small oval patch of scales in the center of a larger scaleless patch on the breast, just forward of the pelvic fins. The lateral line is curved anteriorly with the straight portion covered by 25-33 scutes, the centers of which are blackish in color. The first dorsal fin contains 8 spines, the second dorsal contains 17-21 soft rays and the anal fin contains 3 spines and 15-17 soft rays. There is a total of 18-23 gill rakers in the front arch.

Sexual maturity occurs at about 600 mm (23.4") or 3.5 years of age. Peak spawning period is May - August, although gravid fish have been found from April through November. The sex ratio was slightly skewed toward females (1:1.39) in one study of 110 specimens (Sudekum, et al. 1991).

The Other Ulua

The various jacks found in Hawaiian waters vary greatly in shape from fusiform, such as the species of *Decapturus* (‘opelu), to deep-bodied, as seen in the genera *Alectis* (ulua kihikihi) and *Caranx* (ulua, ‘omilu, etc.). The caudal peduncle is slender and usually reinforced by a series of external overlapping bony plates called scutes; the caudal fin is strongly forked to lunate. The eyes are generally protected by a transparent so-called adipose eyelid. (Randall 1996).

All of the species of jacks in Hawaiian waters are commonly referred to as ulua, although some have distinct Hawaiian names. The young are generally referred to as papio or papiopio when small, and sometimes pa‘upa‘u or pau u‘u or pau‘u when medium sized. The criteria for differentiating between sizes varies island-to-island, and fisherman-to-fisherman. Some maintain a papio is any ulua weighing less than 10 pounds, some say it is any ulua without teeth, etc.

Other than *Caranx ignobilis*, ulua species encountered most commonly by island fishermen are: *Alectis ciliaris* (African Pompano, threadfin jack, kagami ulua or ulua kihikihi). This fish is bright silvery iridescent and the anterior 4th or 5th dorsal and anal rays are extremely elongate in the juveniles of the species. The fish is circumtropical and can attain weights of over 50 pounds (IGFA world record is 50.8 pounds, set in Florida). Hawai‘i State record is 48 pounds.

Caranx melampygus (bluefin trevally, blue-spotted jack, hoshi ulua, ‘omilu or ‘omilumilu).This coastal, reef-associated species is highly regarded as both a food and a game fish, and is also one of the most beautiful of the jacks. In the adult stage, the back and flanks are an iridescent turquoise, silvery or greenish blue, freckled liberally with blue or black spots. The tail and other fins tend to be an even more striking blue in color. Juveniles are often found in schools, and while less colorful with a silvery-yellow body, have distinctive bright yellow pectoral fins and deep blue second dorsal and anal fins. Adults are deep bodied and have strong scutes. Sloping forehead is distinctive. Males are slightly larger than females and sexual maturity occurs at two years and about a length of 13.5 inches (35 cm). Male:female sex ratio was slightly skewed toward females (1:1.48) in one study (Sudekum et al. 1991). Peak spawning season is May-August. ‘Omilu are the most common of the larger jacks in Hawai‘i and have been reported to top 40 pounds in weight (Peter Dunn-Rankin, pers. comm.), but the IGFA all tackle world record is a 26 pound 11 ounce fish caught off Clippertorn Island in Mexico. Hawai‘i state record is 22 pounds 6.5 ounces.

Caranx sexfasciatus (bigeye trevally, pake ulua, mempachi ulua). This relatively large-eyed species of jack is more elongate in shape than other common Hawaiian species and often forms dense schools. The breast is completely scaled, the head is curved to a slightly pointed snout. The body ranges in color from silver-gray to dusky or dark along the black, with a small black spot at the upper corner of the operculum and white tips on the second dorsal and anal fins. Courting males are nearly black in color. Juveniles are golden yellow with 4-7 dark vertical bars across the body. Lateral line is strongly curved anteriorly with the straight portion consisting of 28-37 scutes. Adults feed most actively at night with a diet including eels, crustaceans, blennies (paoʻo), damselfish (mamo) and other fishes. All tackle IGFA World Record for the species is a 31.5 pound fish taken in the Seychelles. Hawaiʻi state record is 15 pounds 8.8 ounces.

Gnathanodon speciosus (golden trevally, yellow ulua, ulua paʻopaʻo or paʻapaʻa ulua or ulua kaniʻo). Juveniles of this species are dramatically golden yellow in color with narrow black zebra striping and are occasionally found in company of larger fishes, riding their bow wave, perhaps feeding on scraps, but are generally found feeding on bottom-dwelling invertebrates, over sandy bottoms. Adults can attain weights of over 30 pounds, and a length of four feet (all tackle IGFA World Record is a 31 pounds 3 ounce fish from Australia) and are iridescent silver with a few randomly scattered black spots, occasionally with faint black bars still visible. Lips are very fleshy and adults have no teeth. Hawaiʻi state record is 16 pounds 3 ounces.

Pseudocaranx dentex (thicklipped jack, butaguchi, buta ulua). One of the more common jacks in the Northwest Hawaiian Islands, the butaguchi is generally found only in deep water in the Main Hawaiian Islands. The fish has thick fleshy lips (butaguchi means pig-mouth in Japanese), is silvery iridescent in color with a narrow brassy-yellow stripe and a black spot on the operculum, level with the eye. The stripe is less visible on adults, which also sport some black spots. The fish reach up to 36 inches (94cm) in length, the 11 pound 3 ounce all-tackle IGFA World Record for the species was caught at Midway Atoll.

Carangoides ferdau (barred jack, papio or ulua). This relatively uncommon jack attains 21 inches in length and can be distinguished by the seven vertical gray bars on the upper two-thirds of the body that are nearly as wide as the pale silver spaces between them. Colors are silvery blue-green dorsally, to fully silver ventrally. Often seen in small schools.

Carangoides orthogrammus (island jack, paʻapaʻa ulua, papio or ulua). Like *C. ferdau*, this jack feeds primairly on benthic fauna and small fishes, mainly on sand bottoms. The fish is silvery blue-green on the upper body, fading to silvery below. Attains a length of at least 27.5 inches. Hawaiʻi state record is 16 pounds 12.8 ounces.

Caranx lugubris (black jack, ulua ʻeleʻele or ulua laʻuli). These fish have a very distinctive head slope above the snout that is either straight or slightly concave, They have a dark, dusky coloring that ranges to nearly black dorsally and shades to silver-blue gray ventrally, with 27-34 black scutes and darker fin shading. Adults reach a length of 32 inches, generally found in deeper water, although they frequent shallow areas in the Northwest Hawaiian Islands.

Caranx helvolus (dobe ulua, black ulua, ulua la‘uli) This market fish is distinctive because its mouth opens nearly at the level of the eye and the cleft is at a sharp downward angle giving it a pugnacious look. The dead-white color of the tongue and the roof of the mouth and the distinct blue-black of the inner mouth surface gill openings and pharynx are other unmistakable identifiers.

NOTE: Biological details above were generally taken from Randall (1996) with input from other commonly used sources (Tinker 1968, Gosline & Brock 1976, etc.).

Movements and Dispersal patterns of Bluefin trevally and Implications for Management
Short and long-term movement patterns of ‘omilu (bluefin trevally, *Caranx melampygus*) were monitored and reported by Holland et al (1996).

A total of 410 fish were tagged and released on the patch reef surrounding the Hawai‘i Institute of Marine Biology at Coconut Island in Kane‘ohe Bay. Results of both sonic tag tracking and 85 recaptures indicated that most fish did not move far from their release points. Time at liberty ranged from 4 to 454 days. All sonic tracking was done on sexually mature adults. Sexually mature adults showed the same site fidelity as sub-adults.

“Both tracking and recapture data indicate strong site fidelity in this species and low occurrence of long distance emigration. These behavioral traits suggest that successful husbandry of this species may be accomplished through the use of management practices such as establishing no fishing zones.”

The results of this work suggest harvest refugia would provide significant protection for ‘omilu in Hawaiian waters, both because of their limited range and because their slow dispersal rates would keep most fish within the limits of a refuge, until after sexual maturity.

“This would indicate that even quite small fisheries conservation zones (e.g. 5 km of reef face) could be an effective management option for increasing spawning biomass of this species. The limited range of movement of the sexually mature adults indicates that refugia of this modest size would give significant protection to *C. melampygus* broodstock.”

Economics

By 1958, the lack of data on the impact of recreational fishing in Hawai‘i prompted the Hawai‘i State Division of Fish and Game to begin to survey anglers, which eventually led to the first analysis of the economic impact of sportfishing in Hawai‘i. However, it was not until 1971 that a viable measure of the value of sportfishing to Hawai‘i was completed for the first time.

That effort led to the conclusion there were 122,400 recreational fishermen in Hawai‘i 12 years old or older, and 68.1 percent of Hawai‘i’s recreational fishermen were shoreline fishermen. The survey also concluded that over 4.3 millions days of fishing effort were undertaken by Hawai‘i’s anglers annually.

Estimated expenditures by all recreational fishermen in Hawai‘i totaled about $16.1 million or roughly $137.50 per angler, in 1970 dollars.

Hilo Casting Club shore fishing expenditures were pegged at $90.23/trip and Kona Casting Club per trip expenditures were said to be $59.72. Those expenditures totaled $1985/person per year for the Hilo club members and $1382/year for the Kona club members.

The most recent survey of recreational fishing in Hawai‘i (US Fish & Wildlife Service and US Department of Commerce, 1996) indicates that 130,000 state resident anglers and 130,000 visiting anglers (16 years old or older) fish a total of 3.1 million days in Hawai‘i (average of 12 days/angler), annually. Eighty-five percent (2.6 million angler days) of that fishing time was undertaken by resident anglers.

Those 260,000 anglers who fished in Hawai‘i in 1996 spent $130,039,000 in total expenditures, $88,419,000 of which was by Hawai‘i resident anglers. Total trip related expenditures for recreational anglers in Hawai‘i totaled $96,086,000 and total equipment and other expenditures by local anglers totaled $33,953,000 in 1996.

Hawai‘i anglers were reported to have spent $22 million on fishing equipment (rods, reels , lines, etc.). Auxiliary equipment purchased primarily for fishing (tents, camping gear, fishing clothes, etc.) amounted to $11 million dollars in additional expenditures. Other items such as magazine subscriptions, membership dues, etc. amounted to an additional $949,000.

The survey states that 32,000 anglers reportedly fished for ulua in Hawai‘i in 1996, and they are said to have spent 554,000 days pursuing the popular game fish. The average trip expenditure per day was reported to be $31, which means $17,174,000 was spent on ulua fishing trip expenses in Hawai‘i in 1996. Other expenses include tackle and other fishing related equipment and expenditures which amounted to over $4,061,538 for ulua fishing alone, bringing the value of the ulua fishery in actual dollars spent to $21,235,538. With a commonly accepted multiplier (50%, Pooley, 1999 pers. comm.) included in the equation, the ulua fishery appears to have an annual impact on Hawai‘i’s economy of over $31 million dollars.

As early as 1967, members of the Governor’s Marine Resources Advisory Panel apparently believed “that the recreational sector provides greater benefits to Hawai‘i than the commercial fishing sector.” (Hoffman & Yamauchi 1973).

Market value of the white ulua (*Caranx ignobilis*) which was sold and reported, ranged from a low of $1.03/pound (1985) to a high of $1.76/pound (1990) over the last 20 years. The total value of white ulua reported as sold in the last year for which statistics were available (DAR 1998), was $11,569.86 (10,149 pounds @ $1.14/pound). (See also Appendix Table 2, page 33.)

After 1990, white ulua from the main Hawaiian islands were no longer accepted by United Fishing Agency for sale on the auction block due to concerns over liability from ciguaterra poisoning. Apparently a small direct market for the fish continues.

Comparing the value of the commercial catch of white ulua and the value of the recreational sportfishery for that species, one could reasonably conclude that the recreational sector for that species provides far greater economic benefits to Hawai‘i than the commercial sector does.

Management Options

Overview

Fishing is one of the most pervasive and popular human activities in our marine environment. In modern times, commercial, recreational and subsistence fishing have been subjected to a complicated and often controversial array of management strategies, many of which have failed to sustain productive, healthy fish populations and their supporting marine habitats.

Natural events such as upwelling and ocean current patterns, and episodic events such as hurricanes, tsunamis, El Nino/La Nina can radically alter the ecological structure of any marine area. Human induced changes including diversion of freshwater inflow, dredging, point- and non-point-source pollution. Commercial and recreational fishing can have significant and long-term consequences for the health of marine ecosystems.

Encroachment on coastal areas is increasing across the state, as is an associated increasing demand on the natural resources of these areas. Habitats are being lost irretrievably. Still other marine habitats are being significantly altered and damaged on a routine basis through exploitation of natural resources (e.g., commercial and recreational fishing, recreational diving, boating, etc.). Destruction of coastal and marine habitats, if unchecked, will lead to deterioration of the quality and productivity of our marine environment.

Enormous resources have been spent in the effort to understand and regulate human impact on the ocean and its resources. To date, however, these efforts have not led to development and implementation of management strategies that have assured sustainable fisheries and the protection of marine ecosystems.

Science-based management studies and policies will only be of use if they include the involvement of all stake-holders, as well as decision makers, economists, sociologists, and user groups. Lack of information or uncertainty has a history of freezing political action.

The collapse of various coastal, estuarine and marine fisheries is another manifestation of past natural resource management strategies. Current fishery management regimes are generally based upon single species (i.e., population-based, maximum sustainable yields, seasonal closures, size limits, limited entry). These strategies offer little hope for the unaided recovery of over-fished or otherwise impacted fisheries. Fisheries management strategies are seldom designed for complete ecosystem protection.

Natural resource decisions have traditionally emphasized achieving the management goals of a particular legislator, agency, organization or interest group in addressing particular human needs (such as the need for agriculture, water, fisheries or recreation) in a particular management unit (such as water management districts). In recent years, the limitations of this approach have become obvious as competition for available resources has increased.

The need for greater public participation and cooperation among all affected parties - federal, state, and local government, academic institutions, private industry, interest groups and stakeholders, in developing and implementing natural resource use and management goals is fundamental to designing and achieving sustainability and protecting marine ecosystems.

Harvest Refugia

NOTE: the following section on harvest refugia was obtained from an extensive discussion of the subject during the Marine Harvest Refugia for West Coast Rockfish workshop sponsored by NOAA, NMFS, Southwest Fisheries Science Center. The workshop was held 17-19 Sept. 1997 in Pacific Grove, CA, and is summarized at the following web site:
http://www.pfeg.noaa.gov/events/workshops/refugia/refugia_index.html

It is believed that the principles and details of the discussion are pertinent to Hawai‘i as well. As there has been little public discussion of harvest refugia in Hawai‘i, extensive detail on this relatively new management approach has been included in this report to allow more complete evaluation of this option.

Fisheries managers are always looking for alternative ways of achieving sustainable harvests. One method is to use marine protected areas, also known as marine harvest refugia. A well-designed system of these sorts of marine protected areas, in conjunction with managed levels of fishing effort, has the potential to sustain catches.

The need for better management of natural and human made landscapes is inescapable. Marine habitats and resources have been assumed to be almost unlimited, and that if one habitat became degraded or a particular fisheries depleted, there always would be another to replace it. Ludwig et al. (1993) have observed that "there is remarkable consistency in the history of resource exploitation: resources are inevitably over-exploited, often to the point of collapse or extinction." A number of reasons were given for this consistency, including wealth or prospect of wealth generating power, the difficulty in reaching a consensus on scientific understanding, and the enormous complexity and natural variability of natural systems.

One of the key recommendations that was put forth by Ludwig et al. (1993) for future natural resource management principals is to include human motivation and responses as part of the system to be studied and managed. Although these aspects are critically important, the scientific approach must be coupled with the development of improved management strategies in order to fully sustain vital marine ecological systems.

An important caveat, however, is that science-based management studies and policies will only be of use if they include the involvement of all players, such as decision makers, economists, sociologists, and user groups. Lack of information or uncertainty freezes political action (Wurman, 1990)

Some Benefits of Marine Harvest Refugia

Bohnsack (1993) suggests that zoning coastal, estuarine and marine areas into reserves with surrounding fishery harvest zones could enhance fished populations, sustain fishery yields, and preserve whole ecosystems by:

1) protecting critical breeding stock,
2) maintaining biotic and genetic diversity,
3) preserving population age structures of target species,
4) stabilizing community structure, and
5) enhancing community/ecosystem resiliency

Roberts and Polunin (1991) suggested that marine harvest refuges would have many benefits to fishermen including:

1) protection of spawning stock biomass,
2) supplementation of surrounding areas through recruitment,
3) supplementation of fished areas through emigration,

4) maintenance of natural population age and size structure,
5) protection of habitat,
6) preservation of genetic diversity,
7) insurance against management failures in fished areas,
8) reduction of data collection needs, and
9) simplification of enforcement.

Dugan and Davis (1993) also suggested that reserves would function as experimental areas, and enhance species diversity and hence community stability. Alcala (1988) added that refuges can maintain undisturbed breeding areas.

The following characteristics of fish species that might be managed effectively with harvest refuges have already been identified in the literature:

1) sedentary (Polacheck 1990),
2) long distance larval dispersal (Carr and Reed 1993),
3) strong site association as in coral reef fish (Roberts and Polunin 1991),
4) changing spatial distribution with age (Armstrong et al. 1993), and,
5) presence of sink areas in which the death rate exceeds the birth rate (Pulliam and Danielson 1991).

Social characteristics of fisheries in which traditional management is outperformed by management with marine refuges may include the following:

1) difficulty in reducing fishing effort,
2) highly priced large fish,
3) fishing costs that vary significantly by target area,
4) lack of money to conduct surveys,
5) difficulty enforcing regulations, and
6) well known spatial characteristics of the target species.

Management Considerations for the Establishment of Harvest Refugia for Ulua

The biological benefits of refugia include:

1) maintenance of longevity and genetic diversity by reducing the effects of fishery selection
2) complete protection for a portion of the population
3) increased habitat and biological diversity
4) *de facto* protection of other species
5) a control area for monitoring demographic and ecological trends
6) decreased uncertainty in stock assessments, and
7) insurance or a hedge against uncertainty in management

Costs and Risks in the Establishment of Harvest Refugia
There are a number of costs and risks involved in establishing harvest refugia or no-take areas, and there are few opportunities to learn from other's experience as this is a new management technique. Refugia may confound fishery stock assessments, given the current assessment techniques. For example, "leakage" of older fish from the protected area into the non-protected areas may distort catch-age composition, causing errors in standard age-based fisheries analyses.

Refugia may actually lead to an increased fishing effort in open areas, which could negatively affect other open-area fisheries. Fishermen may expect a reduction in traditional regulations in trade for no-take areas. While refugia could actually reduce maximum yields under some scenarios, this outcome could be compensated to an even greater extent by reduction in the risk of overfishing.

There is always the risk of making hollow promises when offering harvest refugia as a management tool. A realistic payoff scenario should be established, including how soon to expect benefits and at what level of benefit. Evaluating the success and benefits of the refugia will be difficult. Optimal locations may change over time. Appropriate sizes of refugia need to be determined. A schedule to evaluate the effectiveness of the refuge should be established.

Identifying specific sites for ulua refugia focuses attention on locations of prime habitat. This could result in increased harvest in these locations if the refugia are not implemented. A related concern is that the no-take areas, once established, will attract illegal fishing. This type of risk possibly can be reduced by assignment of community or konohiki management processes, which would encourage fishermen to take a personal interest in the protection of the refuge.

Evaluating the effectiveness of refugia may require expensive monitoring programs.
Enforcement of no-take areas will be difficult and will require additional costs; a feasible plan of enforcement should be developed early in the process. Establishing and monitoring refugia for management purposes requires large upfront and ongoing costs, potentially with little measure of pay off.

Recommendations
Marine harvest refugia are one of the few constructive ways to address protection and conservation of essential fish habitat and the implementation of ecosystem principles in fisheries management. A marine harvest refugia is a permanent no-take area.

Expected benefits of marine refugia for ulua include:
1) protection insurance (demographic, ecological and habitat, and genetic)
2) establishment of control areas that will provide information on effects of fishing and base-

line data for stock assessment
3) reduction of catch variability and increased possibility of sustainability

The expected level of success and benefits of the refugia need to be identified and defined; how success or effectiveness will be evaluated should be established prior to refugia implementation.

Marine reserves provide one of the few management tools including the protection of essential fish habitats, the incorporation of ecosystem principles in fisheries management, and taking a precautionary approach to management.

Socio-economic Considerations for the Establishment of Harvest Refugia for Ulua

Adequately identifying and effectively measuring all relevant consumptive and non-consumptive values of the many varied stakeholders in Hawai‘i's ulua fishery is a complex matter, but it should be undertaken. In evaluating the concept of harvest refugia for ulua, the following social and economic topics and questions should be carefully considered:

1. Do we currently have sufficient understanding of the social and economic considerations associated with implementing harvest refugia for the management of ulua?
2. Who are the stakeholders involved in managing these resources?
   a) What do they require?
   b) What are their motivations?
   c) What are their expectations?
3. Can we establish valuation of our ulua resources from the ecological as well as economic perspective?
4. What are the risks involved in establishing harvest refugia?
5. What would be the most effective approach to implementing refugia?

The establishment of harvest refugia for ulua necessitates two broad sets of policy decisions: 1) those concerning whether or not to establish them, and 2) those addressing the management of refugia once established, i.e. policy issues related to the establishment and management of marine reserves.

These decisions are not only about resource management *per se*. They also are about the management of people, and therefore require consideration of the social, cultural, economic and political environment in which these decisions are made. In particular, it is important to understand the range of individuals and groups who value these resources, the nature and extent of those values, in what way the establishment of harvest refugia likely will affect these people, and how they might respond.

Differences in values, perceptions, and beliefs among groups are likely to lead to fundamentally different responses to the establishment of harvest refugia. By understanding these differences, proponents of refugia can: 1) capitalize on the support and initiative of a group; 2) provide appropriate and more effective communication about the concept of no-take areas; and 3) predict and mitigate opposition to refugia.

The direct involvement of these diverse stakeholders throughout the process can bode even better for the outcome of a refugia effort because this provides for ongoing feedback that can contribute to appropriate design and implementation, and invests these groups in the process and the outcome.

Among the questions that should be asked when exploring the social and economic aspects of marine refugia are:

1) What individuals and groups have interest in, or would be affected by harvest refugia for ulua;
2) What are the social and economic characteristics of these groups;
3) What are their values, perceptions, beliefs and attitudes regarding ulua, marine resources, and refugia;
4) What is the nature and extent of their 'use' of the resources;
5) What are the costs and benefits of harvest refugia, in psychological, social and economic terms, to these individuals and groups, as well as to society as a whole; and,
6) How do these costs and benefits change, given different harvest refugia alternatives versus the status quo?

Answers to these questions can, and should, inform and direct decision-making at all stages - from conceptualization through evaluation - in the establishment of ulua harvest refugia. The process should begin by asking a general question: is enough known about ulua life history and the status of and vulnerability to their fisheries to establish harvest refugia? If the conclusion is "yes," we have sufficient understanding to proceed, refugia exemplify a precautionary approach to resource management. It is important ecologically to enhance population health (such as genetic, habitat, and species diversity).

It should be understood that if harvest refugia are to be used, the problems they are meant to address (e.g., growing fishing pressure, declining ulua populations, diminishing productivity) must be recognized, and the objectives of the proposed refuge(s) clearly defined.

There are a diversity of stakeholders, variously identified as consumptive and non-consumptive users, non-users (i.e., those who value the resource for its existence - like visiting divers), and more specifically as commercial and recreational fishermen, scientists, resource managers, and individuals and groups from among public. Each of these groups has particular values, perceptions and beliefs about the existence and nature of the problem, its importance, whether and how it can be solved, and what might be expected of specific protective measures.

Some of the socio-economic considerations that are likely to influence their views on both the problem of conserving ulua populations and harvest refugia as a solution include ethnic and cultural views of natural resources in general and fishes in particular, socio-economic status, physical proximity to the resource, and economic dependence on it. It is important to understand the diversity and complexity of stakeholders because their support for (or opposition to) harvest refugia will be a function of these characteristics.

Stakeholders clearly need to be involved in identifying the reasons for establishing harvest refugia, and in conceptualizing, designing, implementing and evaluating them. Among the implementation options and arenas are federal legislation and/or decisions of the Western Pacific Fishery Management Council (WESPAC), state legislation and/or BLNR/DAR action, and citizen (grassroots) action initiatives.

The risks associated with establishing protected areas for ulua include overselling the refugia concept, thereby creating inappropriate and unreasonable expectations that could lead to erosion of the credibility of the refugia concept and of its proponents. The results of the implementation of refugia might not be reasonably evaluated for several years following establishment, yet the public is likely to expect clear results in the short term.

This discrepancy between ecological and socio-economic time horizons could lead to withdrawal of public support and increased opposition to these protective areas. However, this concern could be addressed (partially if not completely) through concerted efforts to understand and work with the perspectives and expectations of the diverse stakeholders.

It is also possible that the evaluation of refugia could render inconclusive results. Such an outcome could be due to the actual inefficacy of refugia, or to mitigating circumstances (e.g., unforeseen design flaws, illegal fishing within the closed area, and disturbances from either natural or anthropogenic impacts within the refuges).

The socio-economic considerations related to location, distribution and size of the refuges, are important. In terms of spatial distribution, ulua harvest refugia should be established in multiple areas along the coast. Broad distribution would more likely cover a range of ulua habitats, and would more equitably distribute the costs and benefits among coastal communities. This could help make refugia more appealing to, and supportable by, diverse stakeholders.

The process of establishing a network of harvest refugia, including conceptualization, design, implementation and evaluation, should begin by using a plan that can be phased in and expanded over several years. As part of this process, it is critical that the refugia, individually and as a network, be evaluated periodically to determine their effectiveness relative to the objectives articulated clearly from the start.

With regard to compliance with and enforcement of harvest refugia, it is presumed that a portion of the stakeholders would comply with rules associated with the protected areas, and would exert social pressure on others to do the same. Public education about harvest refugia should reinforce compliance and help lessen the need for enforcement. Nonetheless, enforcement will still be necessary and should be considered in the design and implementation process. Planning should carefully consider the range of needs and concerns, resources available, and opportunities for cooperation among local, state, and federal entities in promoting compliance and carrying out enforcement.

In connection with this, it was noted that enforcement also pertains to the active involvement of relevant agencies; agency inaction can jeopardize the effectiveness of harvest refugia. Thus, in addition to ensuring compliance and facilitating enforcement *vis a vis* citizens (the public), a harvest refugia strategy must include mechanisms for ensuring agency involvement.

Finally, there should be a network established among all those involved in the ulua refugia process that considers protection through traditional resource management (e.g., gear restrictions, catch limits) as well as refugia. A primary concern is the need to coordinate the development of ulua harvest refugia efforts among all interested groups to avert conflict with other initiatives (and thus potential loss of resources or support for refuges) and, more positively, to leverage resources to more effectively pursue and achieve the goals related to the establishment of harvest refugia for ulua.

Scientific Considerations for the Establishment of Harvest Refugia for Ulua

<u>Scenario I: Harvest Refugia as a Strategy For Sustainable Fishery Management</u>

In this scenario, the goal is for the designated marine harvest refugia to collectively comprise an area that is sufficient to sustain fisheries in adjacent fished areas. Refugia at this level of protection are designed from an ecosystem approach, whereby specific requirements for targeted species are considered along with more general objectives.

Objectives

1) Protect and maintain spawning biomass
2) Select for larval dispersal over adult spillover
3) Establish and maintain natural size and age structure of population
4) Preserve essential fish habitats and increase habitat diversity
5) Enhance and protect biological diversity (i.e., species, community and genetic diversity)

6) Provide control communities, that is “pristine” communities that can be used as benchmarks for comparison with unprotected areas to estimate the effects of exploitation

Design Considerations

Size. Refugia are established on the largest scale, protecting over 20% of 1) the total area of habitat for multi-species, or 2) the spawning potential for targeted species. Size of individual refugia are based on the extent of ulua movements and pristine size structure of protection.

Number. The number of refugia will be based on the size of individual refugia and on the collective or total area of protection.

Shape. The shape of each refuge is region-specific, encompassing an onshore-offshore swath for increased protection of the whole ecosystem. Additionally, a contiguous swath of protected area, rather than patches, offers logistical advantages in terms of effective enforcement.

Location. Refugia would be established with consideration for the following criteria:

1) Sites should be located with consideration to ocean current regimes;
2) Sites should include both heavily and less exploited populations. Heavily exploited populations are more likely to exhibit a greater, although lagged, response to protection. Areas of heavy exploitation most likely indicate sites of historically large populations. Less exploited populations may provide immediate response to protection by maintaining existing spawning biomass.
3) Sites should meet habitat diversity and depth requirements for multi-species assemblages.
4) Sites should have sufficient resources to support spawning biomass.
5) Sites should be distributed in a network that guarantees replenishment of one another and increases the likelihood of sustainability.

Restrictions. These refugia would prohibit directed fisheries that harvest ulua. They also would prohibit those gear types that adversely affect these species and that adversely disturb or destroy essential habitats, i.e. netting.

Primary Information Needs For Effective Design

1) Current regimes
2) Spatial structure of populations
3) Demographics of exploited and unexploited populations, especially size and age structure
4) Regional-scale habitat maps
5) Habitat associations, depths, movements
6) Stock assessments for targeted species
7) Distribution of fishing effort

Research Goals

1) Explore methods to quantitatively or qualitatively describe larval dispersal
2) Describe mechanisms that influence larval dispersal and recruitment
3) Conduct adaptive management, using the information gleaned from established refugia (e.g., the effects of various design criteria) to improve the design and management of existing and future refugia

<u>Scenario II: Harvest Refugia as a Buffer or Insurance Against Overfishing</u>

In this scenario, marine harvest refugia supplement fishery management practices, thereby providing a buffer against fishery collapse caused by environmental change, failed fishery management plans, or unexpected natural or anthropogenic events. Refugia created under this scenario also serve as a benchmark for management trials or experiments.

Objectives

1) Provide a buffer against uncertainty associated with environmental change and deficiencies in fishery management strategies
2) Preserve essential fish habitats and increase habitat diversity
3) Enhance and protect biological diversity (i.e., species, community and genetic diversity)
4) Provide control communities, that is "pristine" communities that can be used as benchmarks for comparison with unprotected areas to estimate the effects of exploitation

Design Considerations

Size. Refugia are established on an intermediate scale, protecting from 5 to 20% of a species' essential habitat. The smallest possible size (e. g., 5%) should encompass the typical movements of individuals of a targeted species.

Number. The number of refugia will be based on the size of individual refugia and on the collective or total area of protection.

Shape. The shape of each refuge is region-specific, encompassing an onshore-offshore wedge for increased protection of the whole ecosystem. Additionally, a contiguous swath of protected area, rather than patches, offers logistical advantages in terms of effective enforcement.

Location. The refugia need to encompass the essential fish habitat. The criteria listed for large scale refugia need even more emphasis and consideration here.

1) Sites should be located with consideration to ocean current regimes;
2) Sites should include both heavily and less exploited populations. Heavily exploited populations are more likely to exhibit a greater, although lagged, response to protection. Areas of heavy exploitation most likely indicate sites of historically large populations. Less exploited populations may provide immediate response to protection by maintaining existing spawn-

ing biomass.
3) Sites should meet habitat diversity and depth requirements.
4) Sites should have sufficient resources to support spawning biomass.
5) Sites should be distributed in a network that guarantees replenishment of one another and increases the likelihood of sustainability.

Restrictions. These refugia would prohibit directed fisheries for ulua. They also would prohibit those gear types that adversely affect these species and that adversely disturb or destroy essential habitats, such as netting.

Primary Information Needs For Effective Design
1) Demographics of exploited and unexploited populations, especially age structure
2) Regional-scale habitat maps
3) Habitat associations, depths, movements
4) Stock assessments for targeted species
5) Distribution of fishing effort
6) Current regimes

Note: Although comprehensive information for the above listed items generally is unavailable, effective refugia implementation can occur using existing data.

Research Goals
1) Evaluate response of populations to protection
2) Explore response of stock in terms of a) spawning potential, b) change in size and age distribution, c) yield and catch per unit effort at different spatial scales
3) Experiment with management strategies on exploited population
4) Monitor the response of the fishery to harvest refugia
5) Improve the design and management of existing and future refugia using the information gleaned from established refugia

Ongoing Research on Refugia in Hawai'i

EVALUATION OF HARVEST REFUGIA: EFFECTS OF FISHING PRESSURE ON FISH ASSEMBLAGE STRUCTURE AND MOVEMENTS

Dr. Kim Holland, UH, Hawai'i Institute of Marine Biology

GOALS & OBJECTIVES
1) To describe and quantify the impacts of annually alternating fishing and no-fishing regimes on reef fish assemblages in a fisheries management area (FMA).
2) To evaluate the nature and time-course of the response of fish assemblages to the imposition and removal of protection and compare these assemblages with those in an adjacent, permanently closed marine life conservation district (MLCD).

3) To take advantage of the unique circumstances of this study site whereby the fish populations in one zone (FMA) can be directly compared with those in the adjacent control area.
4) To determine if the density of fish resident on the reef impacts the subsequent recruitment of additional individuals.
5) To continue the empirical evaluation of the biological effectiveness of fisheries conservation zones as potential fisheries management tools.

RESEARCH METHODS/APPROACH

The primary methodology is a carefully planned visual census protocol augmented by a continuation of the tag-and-recapture program that is currently in place. Paired transects (one each from the FMA and MLCD) were established for six habitat types and three depths found in both zones. The composition of the reef assemblages in both areas was monitored as the FMA went through the two year fishing and no-fishing cycle. The type and intensity of fishing effort in the FMA was monitored. Quantifying the movements of fish from the MLCD into the FMA was expedited by the tag-and-release of fish in the two zones, and tagging helped quantify the long-term dispersal of fish into the adjacent fisheries.

RATIONALE

Fisheries conservation zones (harvest refugia) are receiving tremendous amounts of attention as the last, best hope for the management of reef fisheries. Although there are many potential and practical benefits to the establishment of these areas, it is widely recognized that there are very few empirical data with which to evaluate their effectiveness or to support the establishment of these refuges on a wide scale. This program has been addressing this lack of information and this proposal is a continuation of that work.

PROGRESS:

This project has been funded since August 1997 but significant progress has been made toward the goal of documenting the impact of fishing pressure on the species diversity and biomass density of fish populations within the Waikiki management zones. Three different reef habitat types were identified and replicate 50-meter transects established in each of the zones. Monthly fish densities and species composition measurement were made for both the MLCD and the FMA in anticipation of the FMA being opened to fishing on January 1, 1998. Statistical analyses were made on the early census data to predict the intensity of sampling necessary as the project continued. Fish branding experiments were initiated with captive fish to improve identification of individuals in the field.

Evaluation of Harvest Refugia: Final Phase

The study of split management of fisheries as a fishery management area, where harvesting is allowed, and a conservation district, where harvesting is not allowed, ends in 1999-2000 after four years of continuous Division of Aquatic Resources and Sea Grant funding. A significant finding is that there is only limited migration of fish from one area to the other, even though the areas are adjoining. The implications of this behavior for regulations and management will be analyzed during the final year of funding.

Counterpoint:
Harvest Refugia: Fact and Fantasy
(from California Seafood Council 1997)

The concept of "harvest refugia," closing areas as a quick fix to protect marine resources, is gaining popularity worldwide. There is a perception that marine reserves (harvest refugia) will provide effective protection to all resident species with little need for detailed knowledge of the species and without direct management of populations within the reserve. This is ... wishful thinking.

What is known about harvest refugia and - equally important - what isn't? Here's food for thought from independent scientists on the potential for marine reserves in fishery management.

For heavily fished resident species (as opposed to wide ranging species), marine reserves tend to support denser populations of larger individuals than are found outside reserves. But dense populations within reserves do not necessarily lead to increased catches in surrounding waters.

To have a strong effect on local fishing, there must be net spillover of fishes across reserve boundaries. Many species are habitat specific, reluctant to disperse across foreign habitats. While it is reasonable to expect some amount of spillover, accurate prediction of the amount is, at present, impossible. And spillover from a reserve will probably not demonstrably increase catches other than very near the reserve boundaries.

Export of larvae from reserves has the potential to increase the sustainability of heavily impacted fisheries. But the significance of this effect depends on the species involved, the fishing pressure received, the size of the reserve, and local and regional current patterns.

The export of larvae from reserves to augment regional fisheries has theoretical potential but is almost entirely unproven. Its only great benefit will be to fisheries that are limited by the number of larvae that settle, and its success will depend on many difficult-to-predict factors.

To design effective marine reserves, studies are needed of the movement patterns and habitat requirements of all life stages (larval, settlement, juvenile, adult, feeding and breeding) of targeted species.
The lack of detailed and scientifically defensible knowledge regarding the effects of reserves

makes the establishment of new reserves very difficult. Existing reserves have been established without baseline studies.

Because improperly designed refuges may endanger a fishery by providing a false sense of protection (or by placing unwarranted limits and restrictions on harvesting of resources), determining the effectiveness of a refuge is of utmost importance.

Management may need to include a variety of options - including allowing selective fishing.

Essential Fish Habitat: the Federal Approach

The Essential Fish Habitat (EFH) mandates in the 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act represented a new (and long overdue) effort to integrate fisheries management and habitat management by stressing the ecological relationships between fishery resources and the environments upon which they depend.

Essential fish habitat (EFH) is defined in the Magnuson-Stevens Act as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” As required by the Act, NMFS promulgated regulations to provide guidance for EFH designation.

The regulations further clarify EFH by defining “waters” to include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; “substrate” to include sediment, hard bottom, structures underlying the waters, and associated biological communities; “necessary” to mean the habitat required to support a sustainable fishery and the managed species‘ contribution to a healthy ecosystem; and “spawning, breeding, feeding, or growth to maturity” to cover a species‘ full life cycle.

EFH will be a subset of all areas occupied by a species. Acknowledging that the amount of information available for EFH determinations will vary for each species, the regulations direct the federal Fishery Management Councils to use the best information available, and to be increasingly specific and narrow in their delineations as more refined information is available.

The regulations also direct the Councils to consider a second, more limited habitat designation for each species in addition to Essential Fish Habitat. Habitat Areas of Particular Concern (HAPCs) are described in the regulations as subsets of EFH which are rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area.

Designating the boundaries of EFH has taken careful consideration by the Councils, which were required to identify and delineate EFH in their fishery management plans by the statutory deadline of October 11, 1998. These EFH designations were to go into effect by means of fishery management plan amendments under the Magnuson-Stevens Act, in mid-1999.

Community-Based Management

The inability to obtain all the data required to make sound management decisions is actually "an opportunity to seek a new paradigm for fisheries management," argues Johannes (1994), "one that is not based on the conventional approach of intensive data gathering and analysis, but based on self-reinforcing feedback systems at the local level." He emphasizes that "dataless management is not information-less management, but rather a mechanism that pays greater attention to the information provided by fishermen on their assessment of a stock, and of the ways in which traditional and community measures were brought into play to maintain stocks."

Johannes also suggests that conventional fisheries research requires data collection over long periods of time before they generate significant answers, whereas management decisions are usually required immediately, and that a trial and error approach, where the errors are part of the learning process, may be more suitable in situations like those we find ourselves in today.

The community based management process is not new to Hawai‘i. It has been tried on a small-scale at Mo‘omomi on Moloka‘i and has been undertaken in a much larger scale by the legislatively empowered West Hawai‘i Fishery Council, on the West coast of the Big Island of Hawai‘i. Both are functional examples of this process which have been successful to varying degrees.

Community based management decentralizes the process of managing natural resources. It may also be able to hasten the process of establishing regulations (although that has not been the case with the two local examples, to date) and it puts the process more directly into the hands of the stakeholders.

Successful community based management requires complete stakeholder involvement, community support for the management entity and regulatory process and strong agency support at the local level. Decentralization of agency staffing - employing qualified biologists and education specialists in each community - is essential, as is the requirement of dependable enforcement, once new regulations have been put in place.

Recommendations

The various jacks, collectively known as ulua and papio in Hawai‘i, have cultural, scientific, ecological, aesthetic and functional values that are not necessarily expressed in commercial catch statistics and/or in the market place. We have also shown that Hawai‘i’s recreational fishery for ulua and papio has a substantial annual impact on the State’s economy, and that the species are important apex predators in our nearshore marine ecosystem.

Study after study, and observations of natural populations of ulua and papio in areas not subject to substantial, long-term harvest pressures (NWHI, Kiribati, Micronesia, Australia, Maldives, etc.) clearly indicate that the populations of these species are significantly depressed in the Main Hawaiian Islands.

Restoring natural populations of these predators should contribute to the quality of the recreational fishing experience and the economy of Hawai‘i, as well as to the overall health of the ecosystem and may even act to counter the impact of some imported species.

The following recommendations are therefore oriented toward restoring a healthy population of ulua and papio in the Main Hawaiian Islands.

1. The various species of jack in island waters are both important enough to Hawai‘i’s marine ecosystem, and have enough value to the State’s economy, to warrant the creation of new positions on the DAR staff for both a full time ulua specialist, and a full time recreational fishery specialist.

2. Additional study of the biology and ecology of the ulua is important both for management of their fishery and to better understand and manage the ecosystems in which they occur, and in which the species apparently plays a significant role as a near-apex predator. Particular attention should be paid to dispersal, survival rate of released fish, and the study of predation of various introduced species by ulua/papio.

3. Recreational fishing data should be an important component of management decision making, and little such data exists. Recommendations for the gathering valuable recreational catch data on ulua and papio:

   a) Devise a tournament catch record and require that organizations or individuals holding any fishing tournament in island waters submit a complete tournament catch record, containing specified catch and effort data, upon completion of the event. Said data to be entered into and maintained in a data base at DAR;

   b) Enable a process whereby all the ulua data chronicled in Hawai‘i Fishing News over the last 25 years is entered into a data base, and follow up by collecting monthly data from this source;

c) Enable a process whereby all ulua data which may have been collected by various fishing clubs/tournaments in Hawai‘i is entered into a data base;
d) Enable a process under which select individual ulua fishermen on each island be asked to voluntarily maintain a catch and effort log book, through the course of their fishing year.

4. Fishing tournaments have been shown (Holland and Meyer 1996, HIBT, etc.) to be a valuable tool for fisheries research, and when the tournaments are specifically designed around scientific objectives they can provide a variety of high quality data that would otherwise be difficult or impossible to obtain. Fishing tournaments also provide an opportunity for resource users to participate in data collection and interact with the scientific community. For these reasons it would be useful to expand the use of angling tournaments as methods for improving recreational fisheries research and fisheries resource management.

5. Establish new community based management (CBM) programs (based partially on lessons learned from CBM at Mo‘omomi, Moloka‘i and in West Hawai‘i), in various homogeneous coastal areas across the State. Empower the new community managers to establish harvest refugia (marine protected areas).

In establishing these community based management programs, DAR should seek to forge new relationships based on a collaborative approach which provides a means for all stakeholders to work for healthy fisheries in the long run, and not merely focus on their own short-term interests, by:

1) changing structures, processes and styles of working with stakeholders to ensure their input is heard, valued and included in the new frameworks;
2) placing the focus on people by enhancing technical knowledge with facilitation skills. This means ensuring that the Division can provide stakeholders with knowledge they can use;
3) providing user friendly information to stakeholders on the fishery ecosystem in order to enable them to effectively participate in dialogue and in decision-making;
4) support new ways for stakeholders to take responsibility for managing the access/allocation of rights and the obligations that go with them.

6. Current marine protected areas in Hawai‘i - Marine Life Conservation Districts, Fishery Management Areas, Fishery Replenishment Areas, Natural Area Reserves and the like - should each be revisited and reconsidered in light of current resource conservation needs and community interests, by these CBMs. The various conservation areas may need to be adjusted to reflect current needs/impacts, and to contribute to improving the overall efficiency of a statewide system of refuges (refugia).

7. Reserve the catch of white ulua (*Caranx ignobilis*) and bluefin trevally (*C. melampygus*) for subsistence and recreational fishermen only, by banning the commercial sale of those two species.

8. Establish new minimum lengths for *Caranx ignobilis* and *C. melampygus* that are more reflective of their length at sexual maturity, and decrease the bag limit for all species. Encourage the release of all undersize fish.

Appendix

Table 1. International Game Fish Association Ulua World Records from Hawai'i

Mens-37 kg (80 lb)	110 lb 0 oz	Waikiki, O'ahu, Hawai'i, 10/13/1980	Kinney K.K. Louie
Mens-37 kg (80 lb)	114 lb 8 oz	Kaua'i, Hawai'i, 7/4/1981	David H. Nakamura
Womens-37 kg (80 lb)	58 lb 8 oz	Hilo Bay, Hilo, Hawai'i, 4/11/1982	Pauline F. Sugimoto
Womens-37 kg (80 lb)	75 lb 0 oz	Manuka, Kau, Hawai'i, 5/23/1982	Pauline F. Sugimoto
Womens-37 kg (80 lb)	84 lb 0 oz	Kings Landing, Hilo, Hawai'i, 7/22/1982	Pauline F. Sugimoto
Mens-24 kg (50 lb)	118 lb 0 oz	Wailua Bch, Kapaa, Kaua'i, 7/10/1983	Yasuo Moribe
Mens-37 kg (80 lb)	137 lb 9 oz	Mackenzie State Park, 7/13/1983	Roy K. Gushiken
Mens-37 kg (80 lb)	145 lb 8 oz	Makena, Maui, Hawai'i, 3/28/1991	Russell Mori

Table 2. Hawai'i 1998 Reported Landings

Species	Caught	Sold	Value ($)	$/lb
Jacks (misc.)	14,128	11,505	23,907	2.08
Amberjack	15,885	2,402	2,046	0.85
Blue crevally	704	427	783	1.83
Pig-lipped ulua	40,520	37,941	51,752	1.36
Dobe ulua	1,816	1,816	2,995	1.65
Paapaa ulua	1,814	1,496	2,260	1.51
White ulua	10,149	9,455	10,810	1.14
Black ulua	778	748	1,057	1.41
Reef jacks	15	15	53	3.55
TOTAL (All Fish):	21,397,075	20,986,213	45,652,782	2.18

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