An Ecological Perspective on Inshore Fisheries in the Main Hawaiian Islands

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Introduction

Regional Geography and Fishing Pressure

The volcanic peaks and platforms that make up the Hawaiian Islands rise from the ocean floor between roughly lat. 19–28° N and long. 155–178° W, giving the archipelago a length of close to 1,500 miles. However, almost all of Hawaii's population and land mass (above sea level) is concentrated on eight islands, located within 300 miles of the southeastern tip of the island chain (Fig. 1). These are the main Hawaiian Islands (MHI), which include Hawaii, Maui, Lanai, Kaho'olawe, Molokai, Oahu, Kauai and Ni'ihau. They are distinguished geologically and for management purposes from the submerged islands and atolls northwest of Kauai (beginning with Nihoa), known as the Northwestern Hawaiian Islands (NWHI).

Accessibility and rates of exploitation of Hawaiian inshore fisheries are determined largely by regional geography. Emergent portions of the NWHI are minimal, are exposed to treacherous northerly storms, and offer only limited freshwater and vegetation. These are some of the reasons the NWHI are largely uninhabited by humans. Travel from populated islands can take from days to weeks, depending on the size and condition of the vessel. Because of the distances involved, commercial fishermen with large vessels are essentially the only participants in NWHI fisheries.

The NWHI are an important breeding and resting ground for monk seals, green sea turtles, and various migratory seabirds whose natural habitat has been disturbed because of human activity in the MHI (Balazs, 1980; Gilmartin et al., 1980; Harrison and Hida, 1980). Most of the inshore area is part of the Hawaiian Islands National Wildlife Refuge (designated in 1909 by President Theodore Roosevelt as a bird refuge), managed by the U.S. Fish and Wildlife Service (USFWS). To maintain a less disturbed environment for threatened and endangered species, recreational and commercial activities (including fishing) are not allowed within the 10–20 fathom isobath of most islands northwest of Kauai (varying with location). Because of this, inshore fisheries in the NWHI are largely unexploited.

Inshore fish and invertebrate resources in the NWHI include many popular MHI species, such as a'ama crab, *Grapsus grapsus*; ahólehóle, *Kuhlia sandvicensis*; striped mullet, *Mugil cephalus*; and moi, *Polydactylus*

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ABSTRACT—A description of fisheries within a depth of 100 fathoms is provided for the eight southeastern-most islands of the Hawaiian Archipelago, known as the main Hawaiian Islands (MHI). These are the inhabited islands of the State of Hawaii and are those most subject to inshore fishing pressure, because of their accessibility. Between 1980 and 1990, an average of 1,300 short tons of fishes and invertebrates were reported annually within 100 fm by commercial fishermen. Total landings may be significantly greater, since fishing is a popular pastime of residents and noncommercial landings are not reported. Although limited data are available on noncommercial fisheries, the majority of this review is based on reported commercial landings.

The principal ecological factors influencing fisheries in the MHI include coastal currents, the breadth and steepness of the coastal platform, and differences in windward and leeward climate. Expansive coastal development, increased erosion, and sedimentation are among negative human impacts on inshore reef ecosystems on most islands. Commercial fisheries for large pelagics (tunas and billfishes) are important in inshore areas around Ni'ihau, Ka'ula Rock, Kauai, and the Island of Hawaii (the Big Island), as are bottom "handline" fisheries for snappers and groupers around Kauai and Molokai. However, many more inshore fishermen target reef and estuarine species.

Two pelagic carangids, "akule," Selar crumenopthalmus, *and "opelu,"* Decapterus macarellus, *support the largest inshore fisheries in the MHI. During 1980-90, reported commercial landings within three miles of shore averaged 203 and 125 t for akule and opelu, respectively. Akule landings are distributed fairly evenly throughout the MHI, while more than 72% of the state's inshore opelu landings take place on the Big Island. Besides akule and opelu, other important commercial fisheries on all the MHI include those for surgeon, soldier, parrot, and goatfishes; snappers; octopus, and various trevallies. Trends in reported landings, trips, and catch per unit effort over the last decade are outlined for these fisheries. In heavily populated areas, fishing pressure appears to exceed the capacity of inshore resources to renew themselves. Management measures are beginning to focus on methods of limiting inshore fishing effort, while trying to maintain residents' access to fishing.*

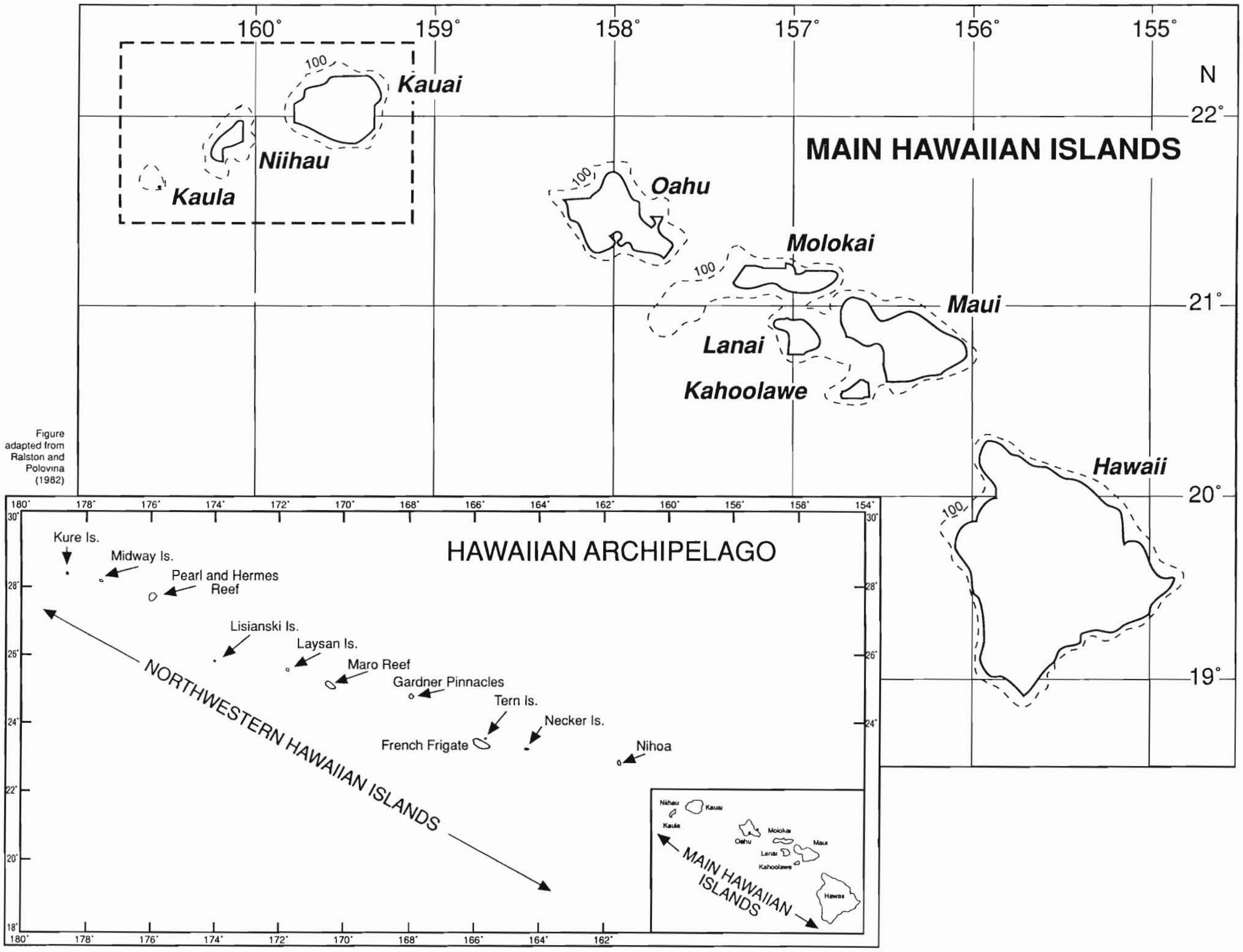

Figure 1.—Hawaiian Archipelago showing main Hawaiian islands.

sexfilis (Okamoto and Kanenaka, 1984). Spiny lobster, *Panulirus marginatus*, various eteline and lutjanid snappers, jacks, groupers, and large pelagic fishes are found slightly farther from shore (Uchida and Uchiyama, 1986), just as is seen in the MHI. These and other inshore fisheries in the MHI, where they are harvested, are the subject of this review.

Climate, Coastal Topography, and Inshore Fishery Habitats

Inshore fisheries will be defined for this review as those within the 100–fm contour. This arbitrary boundary is found within three miles of shore throughout most of the MHI. Its correspondence with the offshore limit of state waters is convenient, although many inshore species migrate freely across the three-mile boundary. Normally the continental shelf is used as a guideline for the limit of inshore fisheries; however, these volcanic islands have no continental shelf. Gosline and Brock (1976) also selected the 100–fm isobath as an outer boundary, justifying this in part because it was the maximum depth fished by traps and handlines at that time. Modern hydraulic gurdies have extended the depth limit for fishing somewhat, but 100 fm is still a reasonable limit for small boat inshore fisheries (Squire and Smith, 1977).

Depth profiles, climate, and terrestrial influences are important determinants of the distribution of inshore fisheries in the MHI. The importance of coastal topography and hydrography may be accentuated by Hawaii's relative isolation in the northern tropical Pacific. The attraction of some pelagic species toward land formations (Murphy and Shomura, 1972) may also enhance inshore fishing opportunities.

The climatic pattern, which affects the distribution of terrestrial and aquatic communities throughout the MHI and most of the northern tropical Pacific is determined by prevailing trade winds. Wind-born weather fronts lose some of their moisture in passing over the mountainous portions of islands in this region. Thus, windward (northeastern) slopes have higher rainfall than leeward (southwest-facing) slopes. Because of this, windward embayments tend to support more estuarine fisheries than leeward areas.

Although high rainfall, erosion, and sedimentation are antagonistic to the survival of healthy corals, the coastal shelf also sustains fringing and patch reefs in windward regions. These habitats support rock- and crevice-dwelling organisms, such as octopus, crabs, and lobsters. The balance between the degree of protection from wind and waves, the amount of rainfall and sedimentation, and the availability of shallow shelf influences the extent of reef development in windward and leeward areas.

There are few stream-fed estuaries in Hawaii. The most important freshwater input to inshore areas may well be through groundwater (Carlquist, 1980). Wherever sources of freshwater meet the ocean (particularly in embayments), fish such as the Hawaiian anchovy or "nehu," *Encrasicholina purpurea*; round herring, *Etrumeus micropus*; and gold spot herring, *Herklotsichthys quadrimaculatus*; return seasonally to spawn (Williams and Clarke, 1983; Clarke, 1989). More commonly, Hawaiian fishes use estuaries as feeding and nursery areas, and may spawn offshore (Clarke, 1991). Fishes which feed in Hawaiian estuaries include mullet, *Mugil cephalus*; Hawaiian flagtail, *Kuhlia sandvicensis*; bigeye scad, *Selar crumenopthalmus*; and various species of snappers and trevally. Schools of adults and juveniles are targeted by fishermen as they enter and leave embayments.

Substrate, current, shelter, and food preferences of Hawaiian fishes are among other factors that separate species guilds and fisheries in relation to habitat (Gosline and Brock, 1976; Squire and Smith, 1977). Despite its narrow shelf, a wide variety of submerged habitats can be found around the MHI. The lagoons, bays, and beaches that surround these islands vary in composition from sand and mud to rock and coral. Sandy corridors, rocky slopes, and outcroppings are inhabited by large carangids, snappers, and groupers which are harvested with bottom "handlines" (Ralston and Polovina, 1982). Kona crabs, *Ranina ranina*, are also caught in these areas (Onizuka[1]). Schools of goatfishes, small carangids, and the introduced blueline snapper or ta'ape, *Lutjanus kasmira*, are common closer to shore in open and embayed habitats.

Hawaiian reefs support diverse and colorful communities of tropical fishes, invertebrates, and marine algae, which vary as a function of the depth, exposure, and three dimensional relief of their habitat (Fielding and Robinson, 1987; Oishi[2]). Reef fishes and invertebrates include lobsters, crabs, octopus, surgeonfishes, parrotfishes, and cryptic nocturnal species such as glasseyes (*Heteropriacanthus cruentatus* and other priacanthids), soldierfishes, *Myripristis* spp., and squirrelfishes, *Sargocentron* spp. Many of these are targeted by pole-and-line fishing, trapping, or spearing; nets are also employed along the reef flats and edges, yielding much larger catches per gear-unit.

The Main Hawaiian Islands

The MHI, or "high islands" (islands above sea level), represent the younger portion of the Hawaiian Archipelago. Because they have emerged in relatively recent geologic time, these islands have less well-developed fringing reefs and have not subsided as far below sea level as the NWHI. The MHI form natural geographic groups, unified by shared channels and portions of interisland shelf (Fig. 1), which include: 1) Ni'ihau, Ka'ula Rock, and Kauai (the Kauai Complex), 2) Oahu, 3) Molokai, Maui, Lanai, and Kaho'olawe, (the Maui Complex), and 4) Hawaii (the Big Island). These island platform groups are meaningful for the discussion of inshore fisheries because of the dispersal characteristics of Hawaiian fishes (Jordan and Evermann, 1905; Gosline and Brock, 1976). Fishing activity, navigable sea conditions, and movements of fishermen are closely tied to shallow coastal waters and thus are based within shared portions of coastal shelf (Squire and Smith, 1977; PAC[3]). County designations throughout the state also reflect these associations. Kauai and Ni'ihau are in Kauai County; Oahu is in Honolulu County; Lanai, Molokai, Maui, and Kaho'olawe are in Maui County; and the Island of Hawaii makes up its own county.

The Kauai Complex

Kauai, Ni'ihau, and Ka'ula Rock (a small peak southwest of Ni'ihau) are located at the northwestern corner of the MHI, separated from the other islands by the 72–mile-wide Kauai Channel between Kauai and Oahu. Kauai is dominated by a single mountainous mass, cut by steep slopes and ridges, which occupies most of its central and western sectors. Most of Kauai's coastline has lush vegetation, high rainfall (600–700 inches annually on some parts of the island), strong currents, and precipitous drop-offs to oceanic depths. The windward coasts are shaped by seasonal flooding and stream input, providing avenues along which endemic gobies enter and leave their oceanic larval phase (Radtke et al., 1988; Kinzie, 1990). Intensive spawning and migration events stimulate inshore fisheries. During the breeding season, Kauai's northeastern to southern shores are a popular area for recreational fishermen targeting the gobiid *Awaous stamineus* (known as 'o'opu nakea). Although reef fishes are seen all around the island, the southwestern coast shows a stronger oceanic influence and supports more reef and coastal pelagic fisheries, including those for bigeye and mackerel scads, goatfishes, surgeons, and squirrelfishes. Thrownetting and spearfishing are also prevalent on Kauai's leeward coast.

Ka'ula Rock and Ni'ihau, with steep nearshore slopes are drier than Kauai. All three islands provide habitat for snappers and groupers, captured by bottom hook-and-line fishing (referred to as "handlining," although hydraulic gurdies are used). Ni'ihau also supports a significant fishery for Kona crab

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[1]E. W. Onizuka. 1972. Management and development investigations of the Kona crab, *Ranina ranina* (Linnaeus). Final Report to Div. Aquatic Resources, Dep. Land and Natl. Resources, State of Hawaii, 28 p.

[2]F. Oishi. 1992. Hawaii's marine life conservation districts. Div. Aquatic Res., Dep. Land and Natl. Resources, State of Hawaii, 18 p.

[3]Pacific Analysis Corporation. 1984. Status of commerical fishing in the State of Hawaii. U.S. Army Eng. Div., Pac. Ocean Corps, Ft. Shafter. Prepared by PAC, 68 p.

(Onizuka[1]). Depths of 100 fm are reached within two miles of the shore of all three islands that make up the Kauai Complex, broadening to within 3–5 miles on the north shore of Kauai.

Oahu

Seventy-two miles southeast of Kauai and twenty-six miles north of Molokai (across the Kaiwi Channel), Oahu is home to about 75% of the state's 1.3 million inhabitants (DBEDT, 1990). Having sustained the largest population for more than a century, it has experienced the highest levels of fishing pressure and other human impacts of all the Hawaiian Islands. The impacts of human development on fish populations along Oahu's heavily populated coast have been noted since the turn of the century (Jordan and Evermann, 1905). Artificial islands and airstrips have been built over reefs, bays, and sandbars on Oahu's leeward side; commercial and private piers, loading docks, high-rise hotels, and heavily populated beaches have overrun the natural shoreline. Dynamite was used to carve shipping channels into the reefs of Kaneohe Bay, on the windward coast, and the resulting coral rubble was placed into various landfills along its shoreline (Devaney et al., 1982). Coastal sites invaded by urban development include many ancient Hawaiian fishponds. In spite of congestion, residents can be found fishing from shore at all times of the day and night, especially along the less developed windward coast. Fishermen using light tackle line the windward shore during summer runs of oama and hahalalu (juvenile goatfish and bigeye scad).

The coastal shelf around Oahu is broader than that of the Kauai Complex, particularly at its prominent points. However, the 100–fm contour is still within three miles of shore in most areas. Bottom handlining, spearing, and trapping are among fisheries which depend on Oahu's relatively wide coastal shelf. Surround net and gill net fishing also take place on this shelf in embayments and along the edges of reefs.

Parallel mountain ranges, running northwest to southeast, determine Oahu's pattern of leeward and windward climate. Its northern and northeastern shores are strongly influenced by stream, surface, and groundwater input, seasonal storms, flooding, and high waves. Windward fisheries include several for estuarine species, such as mullet, crabs, carangids, octopus, sardines, and anchovies. The climate is generally drier on the southwestern side of the island, supporting more typically marine fisheries. However, Pearl Harbor in the middle of Oahu's leeward shore is the state's largest estuary.

Together, Pearl Harbor and Kaneohe Bay represent over 80% of true estuarine habitat in Hawaii. Kaneohe is a windward embayment containing a sandbar and many patch and fringing reefs. A unique mixture of corals and sediments, it has received decreasing amounts of fresh water and increased sediments over the years, owing to deforestation, erosion, and diversion of streams and groundwater to the leeward (more populated) side of the island. Despite decreased freshwater input, Kaneohe Bay is affected by seasonal floods which damage its coral reefs. Freshwater and sediment loading during floods has been intensified by channelization of streams and steeply graded urban development (Devaney et al., 1982; Gordon and Helfrich, 1970; OSP[4]). Freshwater input to Pearl Harbor has also decreased over the years. Together with marine pollution, this may have diminished its populations of estuarine fishes, such as mullet and certain carangids (Smith et al., 1973; Kimmerer and Durbin, 1975). Regardless of human impacts, both Pearl Harbor and Kaneohe Bay still support two of Oahu's largest and most diverse fisheries.

The Maui Complex

On the southeast side of the Kaiwi Channel, Maui, Molokai, Lanai and Kaho'olawe form parts of a unified platform with a maximum depth of <100 fm. The Maui Complex has the widest coastal shelf of all the island platform groups. In some places (notably Penguin Bank), the 100–fm isobath is found over 30 miles from shore. The shallow, protected channels and beaches between islands provide a nesting and feeding ground for marine turtles, and a breeding and nursery ground for humpback whales. The channels and broad shelf are also a favorite fishing ground for full-time and experienced part-time fishermen, the latter known locally as the "weekend warriors."

Maui's dominant geological features are two volcanic peaks, Pu'u Ula'ula (Red Hill, on eastern Maui) and Pu'u Kukui (Candlenut Hill or the West Maui Mountains), united by a narrow land bridge. The double-mountain formation creates two natural embayments, windward Kahului and leeward Ma'alaea Bay. Maui's windward side is a lush, green agricultural area. Its leeward slopes are dry (but fertile) volcanic soil. Coastal soils have been heavily eroded by farming and development, as is common throughout the MHI. Spearfishing, surround and gill netting are the principal inshore methods used on the windward coast; while throw netting and handlining are popular on Maui's leeward shore. Due west of Ma'alaea Bay is Molokini Shoal, a unique and abundant area which is protected as a (State) Marine Life Conservation District (MLCD).

Molokai, the northernmost member of the Maui group, is also a double island. Its peaks, (western) Pu'u Nana and (eastern) Kamakou, are less than half the height of the mountains on Maui, giving the island a relatively dry climate and providing a less heterogeneous coastal habitat. Penguin Bank, on the western end of Molokai, is the most extensive shallow shelf area in the Hawaiian Islands. This bank supports a productive bottom "handline" fishery for snappers and groupers (Ralston and Polovina, 1982) and extensive net harvests of Kona crab (Onizuka[1]). Molokai is known for its numerous Hawaiian fishponds, many of which are now either partially or fully submerged. With fewer inhabitants and a closer adherence to traditional fishing methods than is seen on

[4]Office of State Planning. 1992. Kaneohe Bay master plan. Rep. of Kaneohe Bay Master Planning Task Force. OSP/Coastal Ocean, Reef and Island Advisors, Ltd., 171 p.

more populated islands, Molokai has fewer problems from overfishing of inshore habitats.

Kaho'olawe, now uninhabited, was taken over by the U.S. Navy in 1941 and used as a training area for more than 50 years (Clark, 1985). In 1968, the Navy began to reopen nearshore areas to fishermen and boaters. The island is gradually being reclaimed and debris (including monofilament line, plastic garbage, and unexploded ordnance), which accumulated during the military occupation, is being removed to eliminate the hazard to humans and marine life in the area.

Lanai, a small island west of Maui, is dedicated to agriculture. With the exception of the state harbor at Manele Bay, its entire coastline above the vegetation zone is private property. Access is mainly limited to resident workers and their guests. A few partially submerged Hawaiian fishponds are found on Lanai's eastern coast, where the fringing reef is farthest from shore. Quiet beaches on the western side of the island provide a nesting ground for green sea turtles. The southwestern shore supports another type of marine life refuge, the Manele-Hulopo'e MLCD.

Hawaii, the "Big Island"

The Island of Hawaii, at the southeastern end of the Hawaiian Archipelago (across the Alenuihaha Channel), is known to residents as the "Big Island." Still volcanically active, the Big Island is dominated by two large dome volcanoes (Mauna Loa and Mauna Kea), and a few smaller ranges and craters. New beaches can be created in days or weeks on the southeastern coast, as a consequence of volcanic activity. The 100–fm isobath is found well within a mile of shore, from Kealakekua Bay on the western side and around the southern tip of the island to Cape Kumukahi. The coastal shelf widens to within 2–5 miles along the northern coast, from Cape Kumukahi to Kealakekua.

Wind and weather are particularly important along Hawaii's northeast shore, which receives year-round high rainfall, and periodic storm and seismic waves (or "tsunamis"). Windward Hilo Harbor supports extensive recreational and commercial fisheries for sardines, 'ama'ama (mullet), ahólehóle (Hawaiian flagtail), hahalalu (young bigeye scad), kuahonu crab, *Portunus sanguinolentus*; and Samoan crab, *Scylla serrata*[5]. Reef fishes are also caught on the open coast in this region.

The repercussions of land-based human activities in the Big Island's windward fisheries have been noted since the effluents of the sugar industry made streams and inshore areas uninhabitable to some fishes (Welsh[6]). These impacts have been mitigated to a certain extent over the years (Grigg, 1972, 1985), but have by no means been eliminated. Erosion and freshwater input via streams and groundwater influence nearshore ecology dramatically. The brown halo seen along the windward coast during rainy periods is an index of the magnitude of coastal erosion. Natural erosion has been intensified by the loss of forested areas to cattle ranching and agriculture. Additional environmental concerns for the Big Island's windward coast include those from toxics (DOH, 1981; Hallacher et al., 1985), sewage (Ambrose and Johnson, 1987), privately owned septic systems (Dudley et al., 1991), and petroleum derivatives from small and large vessels.

In contrast to the lush green valleys and raging rivers of the windward side, the Big Island's leeward (Kona) coast is flatter and drier and has more developed coral reefs. The inshore dropoff is particularly steep on the Kona Coast. Deep inshore waters and currents favorable to large pelagic fishes make it a preferred site for trollers and deep pelagic handline fishermen, who catch tunas, mahimahi, *Coryphaena hippurus*; and billfishes in this region. However, the most prominent inshore fisheries are those for smaller coastal pelagics, such as mackerel scad, *Decapterus macarellus*; and bigeye scad, *Selar crumenopthalmus*. Reef fish harvests of surgeon and soldierfishes are also significant in this area.

Available Data

Commercial Fisheries

Although anecdotal information is available, the only consistent long-term source of data on Hawaii's fisheries is the commercial landings database maintained by the State Division of Aquatic Resources (DAR, formerly the Division of Fish and Game). Anyone who catches and sells even one fish is considered a commercial fisherman and is required to report his or her landings and fishing effort on a monthly basis. The location of fishing activity is referenced to numbered geographic areas from the Commercial Fisheries Statistical Charts (DAR[7]), which are given to fishermen with catch report forms.

Despite legal reporting requirements, in practice there is considerable nonreporting. In the past, actual commercial landings may have been as much as double the amount reported for some species. Improved follow-up measures to track down licensed fishermen who fail to report have significantly increased the proportion of licensed commercial landings registered since 1989; however, other commercial fishermen remain unlicensed and commercial landings are still underestimated. Methods of improving the accuracy and completeness of commercial landings data are constantly under review (DAR[8]; Kasaoka[9]). Regional, seasonal, and short-term annual trends in these data are considered reliable and provide a plausible index of differences in commercial landings and

[5]J. Kahiapo and M. K. Smith. In review. Recreational fishing survey of Hilo Bay: 1985–1990. Div. Aquatic Resources, 75 Aupuni St., Rm. 220, Hilo, Hawaii 96720, 41 p.

[6]J. P. Welsh. 1949. A preliminary report to the Division of Fish and Game Bait Program. Section 1. Summary of field work with special reference to Hilo Harbor nehu scarcity. Fish. Progr. Rep., Div. Fish Game, Bd. Comm. Agr. Forest, Hawaii 1(1), 25 p.

[7]Div. Aquatic Resources, State of Hawaii. 1990. Commercial fisheries statistical charts. Div. Aquatic Resources, Dep. Land and Natl. Resources, Charts A-H.

[8]Div. Aquatic Resources, State of Hawaii. 1984. Hawaii fisheries statistics design study. Div. Aquatic Res., Dep. Land and Natl. Resources, 187 p.

[9]L. D. Kasaoka. 1991. Revising the State of Hawaii's commercial fish catch reporting system. Final Report to Div. Aquatic Resources, Dep. Land and Natl. Resources, 466 p.

fishing activity. However, recorded data would not represent total landings even if 100% reporting could be achieved, because there is no law to require recreational catches to be reported.

Noncommercial (Recreational and Subsistence) Fishing

Hawaii is a state of fishermen and both recreational and "subsistence" landings are an important consideration. Actual "subsistence" fishing is rare. Most noncommercial fishermen fish either for enjoyment or to put food on the table, but do not rely on fishing as a source of food. Many are either retired or have a full-time job. Hawaii is one of the few U.S. coastal states which does not require a saltwater recreational fishing license. Because there are no recreational permitting or reporting requirements, it is difficult to estimate the number of recreational fishermen in Hawaii or their landings. Surveys indicate that 19–35% of residents fish (Hoffman and Yamauchi, 1972; USFWS, 1988). Estimates of recreational anglers alone were above 187,000 in the early 1980's (DAR[10]), as opposed to about 4,000 licensed commercial fishermen. Lal and Clark (1991) cited the State Department of Transportation and the U.S. Army Corps of Engineers as a source for an estimated 12,690 "personal boats," of which approximately 74% were engaged in fishing as their primary activity.

Recreational fishermen may outnumber commercial fishermen significantly, but per-trip landings are considerably lower. The difficulty in interpreting trends in total landings is compounded by differences in fishing gears and species targeted recreationally vs. commercially (SMS Research[11]; Samples and Schug[12]; Meyer Resources, Inc.[13]). Shoreline fishing with pole and line, trolling, spearfishing, throw netting, and crab netting are all popular activities of noncommercial fishermen. Surveys at Hilo, on the Big Island, show that 40–70% of shoreline fishing is conducted either with rod and reel or handpole (a bamboo pole without a reel) (Kahiapo and Smith, unpubl. data). This can be contrasted with an estimated 0.5% of commercial fishermen using light tackle in this area. Skillful fishermen, averaging 40–60 years of age, spend hours fishing patiently for 'ama'ama, hahalalu, crabs, and ahólehóle at Hilo and other areas throughout the state (Table 1 provides local and common fish names).

Differences in fishing areas, access methods, and target species of recreational fishermen mean their contribution to the total weight and species composition of landings must also be different. These differences make it impossible at present to interpret overall trends in landings and catch rates for species taken jointly by the recreational and commercial sectors. An independent estimate of recreational landings is needed. Only fragmentary information is presently available, but an effort is in progress to improve the data.

In the last 5–8 years, the DAR and the National Marine Fisheries Service (NMFS) have begun developing methods of estimating total landings through port and shoreline fishing (or "creel") surveys. Creel surveys involve field observation and interviews of recreational and commercial fishermen. Results of a pilot port-of-landing survey for greater Oahu show that some gears and species which are insignificant in commercial landings become important when total landings are considered (Hamm and Lum[14]). Inshore methods which are widely dispersed along the shoreline, such as spearing (for octopus and reef fishes), trapping (for small fishes), and handpicking (for marine algae) are particularly difficult to sample and may not show up at all in either commercial catch reports or port-of-landing surveys (Everson[15]). Shoreline creel surveys are now being conducted in several locations, including Kaneohe Bay (Everson[15]) and Waikiki (Yamamoto[16]; DLNR, 1992), Oahu; Hilo Bay, Hawaii (Kahiapo and Smith, unpublished data); and Hanalei and Nawiliwili Bays, Kauai. Fishery scientists may rely increasingly on information obtained through creel surveys to assist in interpreting reported data for estimates of overall landings for the state. Where data are available, recreational fisheries are included in the present discussion. However, it is important to keep in mind that the following summaries are based primarily on reported commercial landings.

Sport Fishing

Besides residents, Hawaii supports an extensive gamefish charter boat industry catering to visitors. Samples et al.[17] estimated that 73,780 passenger-trips per year were completed during 1982, capturing about 2.2 million pounds of fish and $8.1 million in total revenue. It is common for the sport catch to become the property of the vessel and be sold by the captain. Charter boat operators are considered to be commercial fishermen (Hawaii Revised Statutes §189–2) and thus are required by law to submit catch reports

[10]Div. Aquatic Resources, State of Hawaii. 1981. Management of Hawaii's coastal zone: Living marine resources. Div. Aquatic Resources, Dep. Land and Natl. Resources, 95 p.

[11]SMS Research. 1983. Experimental valuation of recreational fishing in Hawaii: Final Report. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Sci. Cent., Honolulu Lab., Southwest Fish. Sci. Cent. Admin. Rep. H-83-11C, 43 p.

[12]K. C. Samples and D. M. Schug. 1985. Charter fishing patrons in Hawaii: A study of their demographics, motivations, expenditures and fishing values. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Sci. Cent. Admin. Rep. H-85–8C, 95 p.

[13]Meyer Resources, Inc. 1987. A report on resident fishing in the Hawaiian Islands. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Sci. Cent., Honolulu Lab., Southwest Fish. Sci. Cent. Admin. Rep. H-87–8C, 74 p.

[14]D. C. Hamm and H. K. Lum. 1992. Preliminary results of the Hawaii small-boat fisheries survey. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Sci. Cent., Honolulu Lab., Southwest Fish. Sci. Cent. Admin. Rep. H-92–08, 35 p.

[15]A. Everson. 1991. Fishery data collection system for fishery utilization study of Kaneohe Bay: One year summary report. Hawaii Inst. Mar. Biol. NMFS job report to Div. Aquatic Res., Dep. Land and Natl. Res., 14 p.

[16]M. Yamamoto. 1990. Annual job progress report. Federal aid in sportfish restoration activities. Statewide Marine Research and Surveys Project F-16–R-15. Monitoring of Waikiki-Diamondhead FMA.

[17]K. C. Samples, J. N. Kusakabe, and J. T. Sproul. 1984. A description and economic appraisal of charter boat fishing in Hawaii. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Sci. Cent., Honolulu Lab., Southwest Fish. Sci. Cent. Admin. Rep. H-84–6C, 130 p.

Table 1.—Inshore commercial species by habitat, gear, and fishing method.

Habitat	Fishing gear or method	Scientific name	Local name	Common name	Percent weight[1]
Shelf, slope and channel:	Bottom handline	*Etelis coruscans*	Onaga	Red snapper	0.79
Rocky to sandy bottoms		*Etelis carbunculus*	Ehu	Red snapper	0.23
		Pristipomoides filamentosus	Opakapaka	Pink snapper	1.54
		Pristipomoides sieboldii	Kalekale	von Siebold's snapper	0.14
		Aprion virescens	Uku[2]	Grey snapper	1.33
		Seriola rivoliana	Kahala[2]	Amberjack	0.53
		Epinephelus quernus	Hapu'upu'u	Seale's grouper	0.13
		Lutjanus kasmira	Ta'ape[2]	Blue-line snapper	2.80
		Heterocarpus laevigatus	Ono Shrimp	Deepwater shrimp	1.39
Coastal pelagic:	Surround net	*Selar crumenopthalmus*	Akule/Hahalalu[3]	Bigeye scad	28.92
Interisland channels and	Purse seine	*Decapterus macarellus*	Opelu	Mackerel scad	17.82
inshore areas right outside	Pelagic handline	*Makaira mazara*	A'u	Blue marlin	0.94
the reef	Trolling	*Tetrapturus audax*	A'u	Striped marlin	0.17
	Pole and line	*Xiphias gladius*	Shutome	Broadbill swordfish	0.18
	Palu'ahi (using fish chum)	*Thunnus albacares*	'Ahi	Yellowfin tuna	9.37
	Ikashibi (using squid as bait)	*Thunnus alalunga*	Tombo	Albacore	0.11
		Katsuwonus pelamis	Aku	Skipjack tuna	1.65
		Acanthocybium solandri	Ono	Wahoo	2.29
		Coryphaena hippurus	Mahimahi	Dolphinfish	1.05
		Euthynnus affinis	Kawakawa	Bonito	0.22
		Sphyraena barracuda	Kaku	Barracuda	0.10
		Sphyraena helleri	Kawelea	Heller's barracuda	0.27
		Elagatis bipinnulatus	Kamanu	Rainbow runner	0.12
Reef[6] and rocky:	Handline	*Mulloides flavolineatus*	White/Green Weke	Yellowstripe goatfish	2.39
Open coast predominantly	Spear	*Mulloides pflugeri*	Weke-ula	Pfluger's goatfish	0.71
marine areas	Traps	*Parupeneus porphyreus*	Kumu	Whitesaddle goatfish	0.57
Juveniles in embayments	Various nets	*Parupeneus multifasciatus*	Moano	Manybar goatfish	0.39
		Pseudupeneus cyclostomus	Moano Kea	Blue goatfish	0.15
		Acanthurus dussumieri	Palani	Eyestripe surgeonfish	1.15
		Acanthurus triostegus	Manini	Convict tang	0.60
		Acanthurus xanthopterus	Pualu	Yellowfinned surgeon	0.30
		Naso unicornis	Kala	Unicornfish	0.69
				Other surgeonfishes	0.39
		Myripristis berndti & others	U'u (Menpachi)	Soldierfishes	2.07
		Scarus spp.[4]	Uhu	Parrotfishes	1.96
		Atule mate	Omaka	Yellow-tailed scad	2.97
		Caranx ignobilis	White (Ulua/papio)	White trevally[5]	
		Caranx melampygus	Omilu (Ulua/papio)	Bluefin trevally[5]	
		Caranx sexfasciatus	Ulua Menpachi	Bigeye trevally[5]	
		Carangoides orthogrammus	Papa (Ulua/papio)	Yellowspot trevally[5]	
		Gnathodon speciosus	Pa'opa'o	Striped trevally[5]	
		Priacanthus meeki and	Aweoweo	Red bigeye	0.40
		Heteropriacanthus cruentatus			
		Bodianus bilunulatus	A'awa	Blackspot wrasse	0.17
		Octopus cyanea	He'e (Tako)	Octopus	1.46
Embayments[6] and estuaries:	Gill net	*Mugil cephalus*	'Ama'ama	Striped mullet	0.42
Including sand, mud, and	Surround net	*Polydactylus sexfilis*	Moi	Threadfin	0.16
patch reef habitats	Paipai net	*Chanos chanos*	Awa	Milkfish	0.09
	Spearing	*Elops hawaiensis*	Awaawa	Ladyfish/Ten pounder	0.05
	Handpicked	*Kuhlia sandvicensis*	Ahólehóle	Hawaiian flagtail	0.33
	Handline	*Albula vulpes*	'O'io	Bonefish	0.58
	Pole and line	*Ranina ranina*	Kona Crab	Spanner crab	0.56
	Casting and spinning	*Portunus sanguinolentus*	Kuahonu Crab	White crab	0.29

[1] Percent weight = mean annual percent (by weight) of commercial landings reported between 1980–90 to the DAR in required Commercial Fish Catch Reports.
[2] Uku, kahala, and ta'ape come in quite close to shore as juveniles and adults.
[3] Adult and juvenile bigeye scad are referred to as "akule" and "hahalalu", respectively. Residents think of the two as distinct and report catches of each separately, as if they were different species.
[4] Parrotfishes captured are mainly *Scarus perspicillatus* and *Scarus sordidus*.
[5] The five species of trevallies listed make up more than 90% of "ulua/papio" landings. Omaka landings were also grouped as uluas since their juveniles may not always be distinguished in catch reports. Adult trevally and other jacks are referred to generally as "ulua"; juveniles as "papio". Kahala landings may also be placed into this group as juveniles because of their similar appearance, but they are separated in this table because of differences in adult habitat. It should be noted that the size at which fish become designated "ulua", rather than "papio" varies from island to island.
[6] There is some overlap in distribution between species listed under "reef" and "estuarine/embayment" habitats. Reefs and their fauna may also be found within embayments and estuaries in Hawaii.

(HRS §189–3). Thus, charter boat landings should be included in reported commercial data.

Inshore Species

Table 1 summarizes local and common names of the principal inshore fishes as a function of depth and habitat. These 47 species represent 91% (by weight) of the state's inshore commercial landings. Individual reef species weigh a fraction of the average for coastal pelagics. Therefore, the weight of landings increases significantly in areas where large pelagic species are caught close to shore (such as on the Kona Coast). Landings in other areas represent a much larger number of organisms and many more hours of fishing effort. Unfortunately, available data do not allow an in-depth evaluation of mean size or numeric abundance, since fishermen often report only the number of pounds caught (most species are sold by weight).

Reef species make up a relatively small fraction of the total weight of landings, but market preferences increase the economic value of the reef catch. Goatfishes, such as kumu, *Parupeneus porphyreus*, and moano kali (or moano kea, *Parupeneus cyclostomus*), are targeted with traps and spears by inshore fishermen and sell for 2–6 times the price of other goatfishes, depending on the season. Prices for moano kali are the highest because these fish inhabit deeper water, making them more difficult to target.

Reported inshore landings by island platform groups (Table 2) illustrate the most important regional trends in weight and relative abundance of the top ten species in each area. Many species that are major constituents of inshore landings are also captured in significant numbers farther from shore. Because of their high mobility, the assessment and management of these stocks rely on collaboration between State and Federal agencies. Areas in the mid-MHI (Oahu and the Maui Complex), with more developed inshore shelf, fringing and patch reefs, sustain a larger proportion of landings of reef, shelf, and crevice-dwelling species, such as kumu, weke, u'u, ta'ape, palani, uhu, and he'e. The steep coastal slopes and swift currents of the Kauai Complex and the Big Island are a more suitable habitat for inshore pelagic species.

Akule, *Selar crumenopthalmus*; and opelu, *Decapterus macarellus*, landings rank within the top ten fisheries on all islands. From 1980 to 1990, reported commercial landings within three miles of shore averaged 203 and 125 tons for akule and opelu, respectively. Akule (bigeye scad) are the most productive inshore fishery throughout the MHI, except on the Big Island where more opelu (mackerel scad) are caught. Akule are captured with surround nets, made of either nylon or monofilament line (DLNR, 1992). Hoop nets are effective for catching opelu, which dive deeper when startled. Both species are also captured with hook and line. Night jigging with flies for akule and opelu on dark nights or during the new moon, using a small light to attract the fish (Kawamoto[18]), is extremely popular on all islands and among residents of all ages. Either a rod and reel or a simple bamboo "handpole" can be used.

Figures 2 and 3 show regional trends in landings of opelu and akule, respectively, from 1980 to 1990. More than 72% of the state's inshore opelu landings takes place on the Kailua-Kona Coast of the Big Island (Fig. 2). Therefore, trends in opelu landings are dominated by the success of the Big Island fishery. Akule landings (Fig. 3) are distributed fairly evenly throughout the MHI but are greatest on the Kailua-Kona Coast, at Ma'alaea Bay (on Maui) and Waianae (Oahu). Both fisheries have shown cyclical changes in abundance over the past 11 years, with peaks in 1983 and 1989. Changes in catch rates (CPUE, pounds/trip) are primarily responsible for the observed annual differences in catch, presumably because of actual changes in abundance of these highly mobile species in inshore areas. This trend is much stronger for the akule fishery. Regional trends in landings also vary somewhat from year to year (Fig. 2, 3). This is partly due to differences in seasonal migration patterns of the fishes around each island platform group and partly because of movements of a few large purse seiners.

Table 2.—Mean annual landings (short tons) reported for 1980–90 by geographic region for Hawaii's principal inshore commercial species.

Island platform group	Principal Species[1] (descending order by weight of inshore landings) Local name	Scientific name	Mean annual tons[2]	Spp. freq.[3] (%)
Kauai complex	Akule/hahalalu	*Selar crumenopthalmus*	48.98	13.8
	'Ahi (yellowfin)	*Thunnus albacares*	15.71	7.4
	Opelu	*Decapterus macarellus*	10.89	2.8
	Ono shrimp	*Heterocarpus laevigatus*	7.45	0.1
	Ta'ape	*Lutjanus kasmira*	5.69	3.5
	White/green weke	*Mulloides flavolineatus*	3.99	3.2
	U'u	*Myripristis* spp.	3.58	5.2
	Ulua/papio	Primarily *Caranx* spp.	3.55	7.8
	Ono	*Acanthocybium solandri*	3.18	4.2
	Uku	*Aprion virescens*	2.36	3.3
Oahu	Akule/hahalalu	*Selar crumenopthalmus*	67.40	11.9
	Opelu	*Decapterus macarellus*	18.97	6.8
	White/green weke	*Mulloides flavolineatus*	7.98	3.8
	Ta'ape	*Lutjanus kasmira*	6.77	4.0
	He'e/tako	*Octopus cyanea*	6.39	4.6
	'Ahi (yellowfin)	*Thunnus albacares*	5.95	1.1
	Palani	*Acanthurus dussumieri*	5.29	3.3
	Ulua/papio	*Caranx* spp.	5.17	7.0
	Aku	*Katsuwonus pelamis*	4.78	0.5
	Uhu	*Scarus* spp.	3.85	2.4
Maui complex	Akule/hahalalu	*Selar crumenopthalmus*	52.36	4.2
	Ulua/papio	*Caranx* spp.	5.72	10.4
	Shutome	*Xiphias gladius*	5.01	<0.1
	Uhu	*Scarus* spp.	4.74	3.5
	Opakapaka	*Pristipomoides filamentosus*	4.43	2.8
	White/green weke	*Mulloides flavolineatus*	4.07	3.7
	Uku	*Aprion virescens*	4.02	3.5
	Opelu	*Decapterus macarellus*	3.95	2.1
	He'e	*Octopus cyanea*	3.03	4.9
	'Ahi (yellowfin)	*Thunnus albacares*	2.82	1.1
Hawaii	Opelu	*Decapterus macarellus*	91.18	14.4
	'Ahi (yellowfin)	*Thunnus albacares*	41.42	5.7
	Akule/hahalalu	*Selar crumenopthalmus*	34.07	8.8
	Ono shrimp	*Heterocarpus laevigatus*	10.71	0.1
	Ono (wahoo)	*Acanthocybium solandri*	9.44	4.1
	U'u	*Myripristis* spp.	6.82	5.1
	Ta'ape	*Lutjanus kasmira*	5.61	5.0
	Ulua/papio	*Caranx* spp.	5.04	5.2
	Opakapaka	*Pristipomoides filamentosus*	4.29	3.9
	Uhu	*Scarus* spp.	4.07	2.0

[1] There are three multispecies categories (u'u, trevallies, and uhu). The species making up each of these categories are defined in Table 1

[2] Mean annual tons = average annual weight of reported landings from 1980–90.

[3] Spp. freq. (%) = mean annual percentage of trips for 1980–90 which reported catching the species.

[18] P. Y. Kawamoto. 1973. Management investigation of the akule, or bigeye scad, *Trachurops crumenopthalmus* (Bloch). Completion rep. for NMFS under Comm. Fish. Res. Devel. Act. P.L. 88–309. Proj. H-4-R, Div. Fish and Game, Dep. Land and Natl. Res., Hawaii, 28 p.

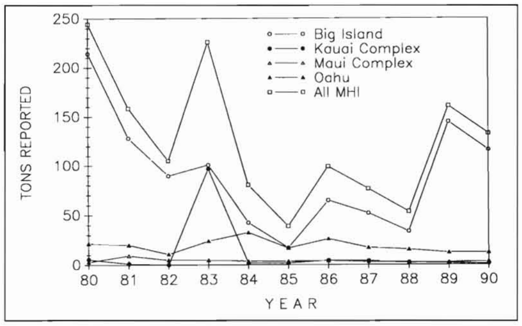

Figure 2.—Regional commercial landings of opelu in the main Hawaiian islands by island platform group.

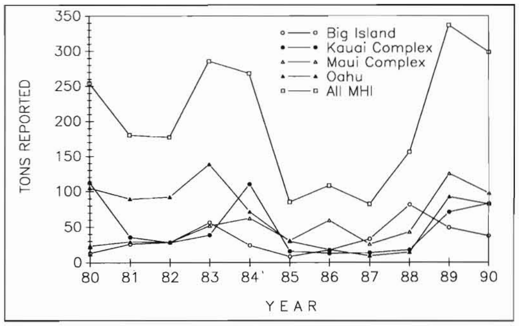

Figure 3.—Regional commercial landings of akule in the main Hawaiian islands by island platform group.

Fishing Gears and Methods

Fishing gears employed in Hawaii include various pole-and-line methods (spin casting, handlining, or trolling) from shore, pier or platform, using motorized or unmotorized boats, canoes, kayaks, or surfboards. He'e (octopus), limu (algae), and cryptic fishes such as aweoweo (glasseyes) and u'u (soldierfishes) are speared or hand-collected by diving or swimming (with or without scuba). Trolling from windsurfers, canoes, and kayaks is used to capture ulua and papio near the reef drop-offs. Huge uluas, over 40 lb, are taken in this manner. Mahimahi, ono, and billfishes can be caught by moving slightly offshore, changing to lures or live bait, and by trolling with a high speed engine. The most extensive description of Hawaii's nearshore angling methods has been compiled by Rizzuto (1983, 1987, 1990). This information is complemented by Hosaka's (1973) publication and by popular televised programs that celebrate the art of Hawaiian fishing.

Table 3 summarizes the most common inshore commercial fishing gears by island platform group. Each group has unique fisheries characteristics, but there are more similarities than differences. The most important gear around all islands is the bottom handline. Trolling (for large pelagics) is the second most important fishing method on the Kauai Complex and the Big Island; diving, spearing, and other reef methods are second in importance around Oahu and Maui. Gill netting and related methods ranked third everywhere, except on the Big Island, where surround netting (for opelu) is more important. Throw netting is more prevalent around the Maui Complex than in other areas. There is not necessarily a direct relationship between gear frequencies and the proportion of landings by gear type. In fact, the least abundant gears often show the highest catch rates. Table 4 illustrates this, showing mean catch per unit effort (CPUE) and number of trips by gear type.

The relatively low proportion of trolling trips and high proportion of trapping around Oahu are both unique to this area. Oahu is also the only is-

Table 3.—Mean proportion of inshore commercial fishing trips by gear type and geographic region.

	Relative gear abundance (% of annual trips[1])			
Fishing gear/method	Kauai complex	Oahu	Maui complex	Hawaii
Aku boat (pole and line)		0.2	<0.2	<0.1
Longline/flagline		<0.1	0.2	0.1
Drifting pelagic handline	2.5	0.7	0.5	2.8
Bottom handline	42.4	46.2	33.3	56.1
Kaka line/set line, ikashibi, palu'ahi	0.7	0.3	<0.1	1.3
Trolling	19.4	4.5	14.4	14.3
Rod and reel (light tackle)	0.1	0.2	0.2	0.5
Trap	1.9	10.7	3.0	0.8
Diving (knife, spear, hand-picked)	11.8	15.3	22.1	8.8
Seine/gillnet/hukilau net	12.5	12.1	14.9	2.7
Akule/opelu/surround/purse nets	2.1	2.7	3.5	8.8
Throw net	1.7	0.9	4.1	1.5
Lobster/crab nets	1.9	1.8	2.0	0.4
Bait net		<0.1		
Other and unspecified	3.1	4.1	1.9	1.9

[1] Tabled values are the mean annual number of trips reporting each gear type from 1980 to 1990, expressed as a percentage of the total mean annual number of trips.

Table 4.—CPUE by gear type for principal fishing gears.

	Annual mean (1980–90)		
Geartype	Trips	Landings (lb.)	CPUE (lb/trip)
Aku boat (pole and line)	36.3	10,245.6	282.2
Longline/flagline	30.3	8,648.2	285.4
Drifting pelagic handline	641.8	33,581.3	52.3
Bottom handline	8,976.8	426,581.4	47.5
Kaka line/set line, ikashibi, palu'ahi	87.2	15,992.3	183.4
Trolling	4,450.8	108,711.0	24.4
Rod and reel (light tackle)	114.5	1,141.4	10.0
Trap	371.1	57,078.4	153.8
Diving (knife, spear, handpicked)	1,154.4	91,660.6	79.4
Seine/gillnet/hukilau net	1,157.8	227,443.4	196.4
Akule/opelu/surround/purse nets	641.0	347,869.4	542.7
Throw net	681.5	7,843.4	11.5
Bait net	2.0	11.4	5.7
Lobster/crab nets	171.4	9,327.4	54.4

land supporting a major bait fishery at this time. Baitfishes (primarily nehu, or Hawaiian anchovy) were formerly harvested from Ma'alaea Bay, Maui (Nakamura, 1967) and other locations. These fisheries declined for marketing reasons during the mid-1980's (Kushima et al., 1992). Baitfishes harvested in Pearl Harbor and Kaneohe Bay are used to catch aku slightly offshore (Comitini, 1977), making Oahu the most important island for aku fishing. All aku boats presently have their home ports on Oahu.

Advances in the technology for fishing and locating fish are constantly increasing the efficiency of Hawaii's fishermen. Differences in the construction of fishing gears over the years have resulted in higher catch rates which, together with the rapidly increasing population, contribute to the potential for overfishing. For example, cotton or "linen" nets used by early Hawaiians have been replaced by monofilament nets which require less maintenance, bring in larger catches, and are less easily perceived by fish in clear water. Monofilament nets are employed along the reef faces, on the open coast and in embayments, both fixed (as a gill net) and to surround and bag fish schools (as a purse net) (DLNR, 1992). Paipai is another popular method of net fishing, whereby certain species (particularly weke) are herded into nets, either by divers or from a boat. The advent of monofilament line makes this method extremely effective, since the nets are essentially invisible in the water.

There are no trawl fisheries in Hawaii, since sharply sloping, coralline, or rocky coasts do not provide suitable substrate for trawl operations. Attempts at bottom and midwater trawling in the 1970's and 1980's were therefore abandoned. Bullpen nets are set in areas that are open and flat, facilitating the capture of large and highly mobile fishes. Sea turtles captured in bullpen nets, are easily released alive. Fish caught by surround methods can also be kept alive for long periods of time and released or harvested selectively. While many fish or turtles caught accidentally are released by conscientious fishermen, some die because people leave nets unattended or hold fish for long periods of time. This practice is particularly wasteful in Hawaii where the standard of quality for local fish consumption is high and where injured fish may not be marketable.

Other variations in fishing methods that influence catch composition include daytime vs. night fishing (and diving); diving with scuba; fishing with or without the moon; and carefully selecting seasons, tidal phases, and locations (Titcomb, 1952; Hosaka, 1973). All these tools are at the command of experienced fishermen in Hawaii, who pass on their special fishing secrets from one generation to another. Cultural heritage and family traditions, including preferences for certain species, are among the underlying factors that determine the composition of fisheries landings in Hawaii.

Geographic Trends in Catch Rates and Fisheries Exploitation

Table 5 summarizes total reported landings and provides an index of commercial harvest rates within each island platform. The index, mean annual pounds per square nautical mile of shelf, was obtained by dividing reported landings by an estimated area for each coastal shelf, based on the difference between the area of land above sea level (DBEDT, 1990) and that of a circle enclosed by the 100–fm isobath. The length of the isobath for each platform group was taken from Ralston and Polovina (1982). Landings within three miles of shore were used for the Kauai Complex, Oahu, and Hawaii. For the Maui Complex, landings and estimated shelf area within 20 miles of shore were used owing to the extensive shallows of Penguin Bank.

The index indicates a higher rate of exploitation around Oahu, as would be expected because of its large population. Oahu's landings are accomplished

Table 5.—Annual reported inshore and nearshore commercial landings and coastal harvest rates by geographic region.

Island platform group	Inshore landings[1, 2] (<3 n.mi.)	Nearshore landings[3] (3–20 n.mi.)	Total (0–20 n.mi.)	Length of 100 fm isobath[4] (n.mi.)	Estimated shelf area[5] (n.mi.^{2}) within 100 fm	Mean annual lb./n.mi.^{2} of shelf[6]
Kauai complex	260,313 lb. 18.56 %	769,557 lb. 10.81 %	1,029,870 lb. 12.08 %	195	2,484	104.8
Oahu	372,042 lb. 26.53 %	2,737,943 lb. 38.45 %	3,109,985 lb. 36.49 %	150	1,274	292.0
Maui complex	258,738 lb. 18.45 %	1,197,168 lb. 16.81 %	1,455,906 lb. 17.08 %	390	11,080	131.4
Hawaii	511,506 lb. 36.47 %	2,416,141 lb. 33.93 %	2,927,647 lb. 34.35%	290	3,187	160.5
Total all island groups	1,402,599	7,120,809	8,523,408	1,205	18,205	144.2[7]

[1] Lb = mean annual pounds reported between 1980 and 1990 (all species).
[2] Inshore % = percent of total MHI landings reported within three nautical miles of shore.
[3] Nearshore % = percent of total MHI landings reported from 3–20 miles of shore.
[4] Length of 100-fm isobath = approximate nautical miles (from Ralston and Polvina, 1982).
[5] Estimated shelf area (ESA) = estimated square nautical miles of coastal shelf shallower than 100 fm.
[6] Mean annual lb./n.mi.^{2} shelf = lb./ESA (landings within 20 n.mi. of the Maui complex included; only landings within 3 n.mi. for other areas).
[7] The all-islands total for "Mean annual lb/n.mi.^{2}" is based on a total of 2,599,767 lb. Landings greater than three miles from shore (nearshore) are not included for the Kaui complex, Oahu, and the Big Island.

by a large number of fishermen and catch rates per fishermen for comparable fishing effort are lower than on other islands. To compensate for this, Oahu's fishermen tend to use more fishing gear (considerably longer nets, more hooks, traps, etc.) and to fish for longer periods of time. Neighboring island residents are often astonished at the amount of effort invested by fishermen on Oahu. Reduced CPUE on Oahu may be an indication of adverse environmental impacts as well as overfishing. The Kauai and Maui groups show nearly equivalent annual landings within three miles of shore, but Maui's shallow depths extend to 3–20 miles from shore (and beyond). Once scaled to the total shallow shelf area, estimated annual catch rates (mean lb/n.mi.^{2}) around Maui are similar to those estimated for the Kauai Complex.

To evaluate catch rates around the islands, landings and CPUE (lb/trip) were summarized for the five most populated islands. Inshore catches and CPUE within 90° quadrants around each island are presented in Table 6. Trends for Kauai, Oahu, Maui, Molokai, and the Big Island indicate higher total landings and CPUE on the leeward (southwesterly) sides of all islands, in part because of increased landings of large pelagic species in this quadrant. However, there were also more trips recorded in most leeward areas. Increased pelagic productivity in leeward areas may be a function of localized upwelling and larval entrainment, driven by persistent (northeasterly) trade winds (McGary, 1955). Increased fishing activity in these areas probably results from improved sea conditions in the wind shadow of the islands, making leeward regions generally an easier place for small boats to troll and set nets. Other factors include accessibility from the shoreline and availability of launch ramps (PAC[3]). Because of their relative protection from winter storms, leeward areas are a more likely location for small boat harbors with associated launch facilities. The southwestern sector of most islands, which is also a somewhat sheltered quadrant, had the second highest number of trips.

Trends in inshore landings and CPUE from 1980 to 1990 were summarized for seven other important inshore species or groups (in addition to akule and opelu), which ranked in the top 10–20 consistently for three or more island platform groups. The groups selected were the white or green weke *Mulloides flavolineatus*; palani, *Acanthurus dussumieri*[19]; uhu, *Scarus* spp.; u'u, *Myripristis* spp.; he'e, *Octopus cyanea*; ta'ape, *Lutjanus kasmira*; and ulua/papio (jacks and trevallies, see Table 1). Statewide summaries only are provided here (Fig. 4 and 5), to show general trends in these fisheries. Regional mean CPUE by species groups are shown in Table 7. Catch rates were generally higher on Kauai and in the Maui Complex for all species.

Reef fishes are most important on the islands of the Maui Complex and on Oahu. The highest volume of uhu were seen on all sides of Oahu, as well as at Kahului, Maui; and Kailua-Kona, Hawaii. Weke, palani, u'u, and uhu are abundant in both leeward and windward landings because of the presence of well-developed reef habitats in both types of areas. Most weke were caught on Oahu's northeastern and southeastern sides, on Kauai's eastern coast, and on western Maui. Landings of green weke (Fig. 4A) have shown a gradual decline since about 1983. This is primarily attributable to decreasing CPUE, because the number of trips has remained fairly stable. The number of trips has also remained constant for uhu (Fig. 4B), whereas reported landings have varied as a function of variation in CPUE. Palani landings (Fig. 4C) have shown a decline since 1986, but this has been due to decreased fishing effort (fewer trips), while CPUE has increased or remained the same.

[19]It should be noted that two other surgeonfishes, known locally as "pualu" (*Acanthurus xanthopterus* and *A. mata*) are difficult to distinguish from the palani. Although separate records are kept when these species are reported separately, some pualu may be included in palani landings if they are not distinguished by fishermen.

Table 7.—Trends in catch per unit effort (lb./trip) from 1980 to 1990 for selected species by island-platform group.

Species	Big Island	Kauai complex	Maui complex	Oahu	Mean All MHI
U'u	36.39	52.5	27.87	13.07	29.95
Ta'ape	24.41	139.41	24.18	37.45	37.22
Weke	15.70	97.75	59.19	48.88	52.14
Uhu	42.04	32.90	63.66	27.34	40.03
He'e	13.71	26.95	28.42	26.94	26.74
Palani	20.38	39.05	20.53	35.15	29.37
Ulua	29.74	38.28	31.62	21.02	28.18
Mean[1]	26.05	61.04	36.50	29.98	38.39

[1] All species.

Table 6.—Catch per unit effort (lb/trip) within 90° quadrants.

Island Group Quadrant	Mean annual lb. landed	Mean annual trips	Average CPUE (lb./trip)
Kaui			
I (Northeast quadrant)	22,156	269	82.3
II (Northwest quadrant)	30,312	231	131.3
III (Southwest quadrant)	77,149	571	135.1
IV (Southeast quadrant)	33,854	336	100.8
Oahu			
I (Northeast quadrant)	59,568	539	110.5
II (Northwest quadrant)	51,866	500	103.6
III (Southwest quadrant)	107,933	1,442	74,8
IV (Southeast quadrant)	77,263	1,073	72.0
Maui			
I (Northeast quadrant)	17,167	219	78.2
II (Northwest quadrant)	64,223	491	130.3
III (Southwest quadrant)	106,188	399	266.3
IV (Southeast quadrant)	35,020	190	184.1
Molokai			
I (Northeast quadrant)	6,297	49	127.5
II (Northwest quadrant)	4,754	55	87.1
III (Southwest quadrant)	42,912	244	175.7
IV (Southeast quadrant)	8,256	125	66.1
Hawaii (Big Island)			
I (Northeast quadrant)	33,132	573	57.8
II (Northwest quadrant)	71,775	814	88.2
III (Southwest quadrant)	284,449	2,025	140.5
IV (Southeast quadrant)	77,878	965	80.7

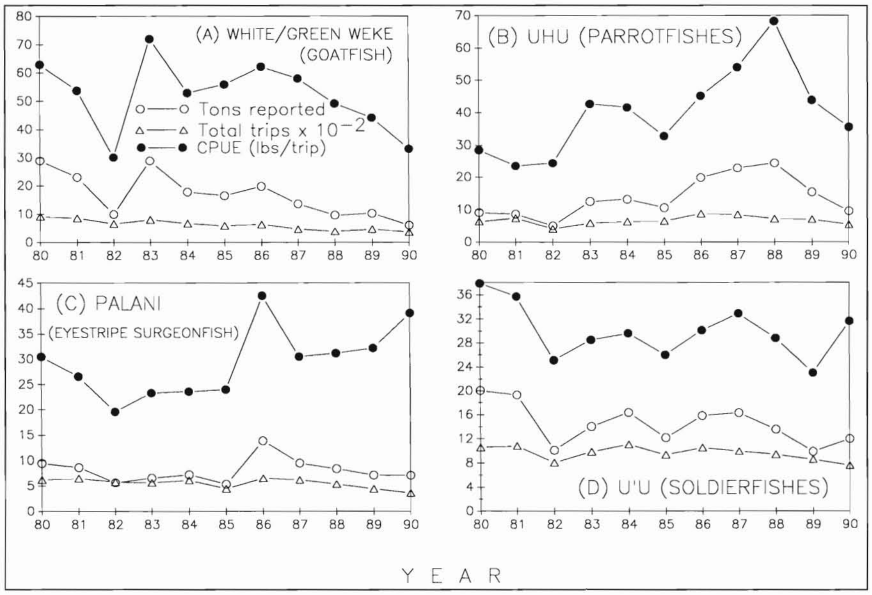

Figure 4.—Reported inshore commercial landings of selected species in the main Hawaiian islands.

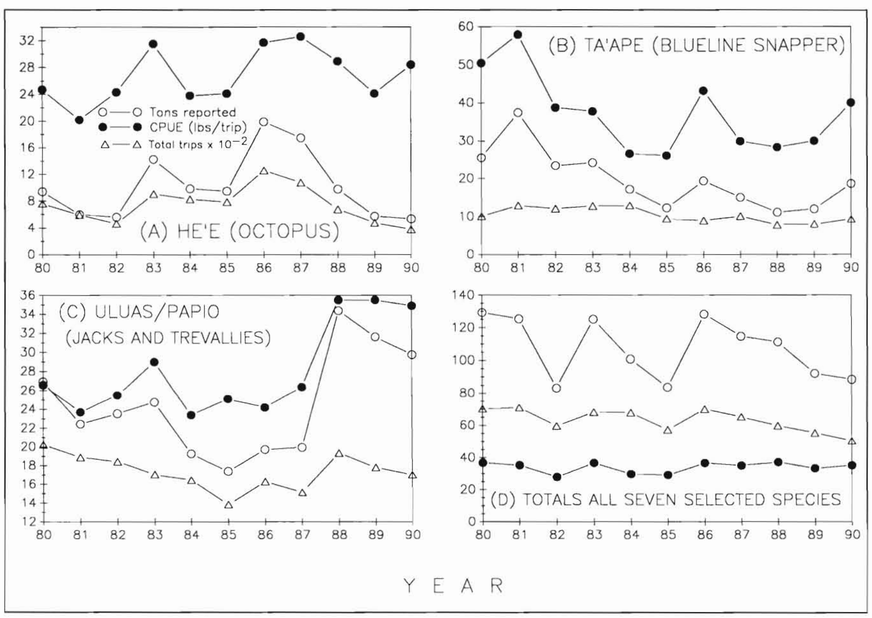

Figure 5.—Reported inshore commercial landings of selected species in the main Hawaiian islands.

The entire leeward coast of Oahu, windward and leeward Maui, and the Kailua-Kona Coast, have shown the highest landings of palani. U'u landings (Fig. 4D) have fluctuated over the years because of varying effort and CPUE.

He'e (octopus) is another reef species for which landings have fluctuated as a function of cyclical changes in the number of trips and the magnitude of CPUE. Figure 5A shows that the decline in reported landings since 1986 is due to fewer reported trips. However, this species is caught in large numbers by noncommercial fishermen (Everson[15]; Hamm and Lum[14]), and commercial trends do not tell the whole story. Kahului (Maui) registered the highest he'e landings in the state, followed by Kaneohe Bay (Oahu). Both are windward locations with a fairly wide shelf and reef area.

The introduced ta'ape are abundant everywhere, much to the dismay of residents who prefer native fishes (Kushima[20]). Reported landings (Fig. 5B) have been largely determined by fluctuations in CPUE. Ta'ape are caught in large numbers by surroundnet fishermen, who normally target akule. Their landings are limited primarily by the local market, which becomes flooded when too many fish are caught. Uluas were also important on all islands; however, noncommercial landings are an important component of this multi-species fishery. Ulua landings at Penguin Bank are roughly three times the volume recorded elsewhere, but the shelf area is also considerably larger. Figure 5C shows trends in ulua landings for all islands. The regional makeup of the catch by species indicates that the most diverse fisheries are found at Oahu and in the Maui Complex, followed by the Big Island, and finally Kauai. However, an in-depth evaluation of this group by species is limited by the tendency of fishermen to lump the fish together in their catch reports as simply "ulua" or "papio."

Total reported landings, trips, and CPUE for all seven species above are shown in Figure 5D, where an overall decline since 1986 is seen. While CPUE fluctuates or remains equivalent over the same period, the number of trips reported is steadily decreasing. The reason for this is unclear, but would seem not to indicate any cause for concern, since fishermen would appear to be voluntarily reducing their effort or merely switching to more lucrative offshore fisheries. However, it must be kept in mind at all times that reported commercial landings do not represent all inshore catch and effort. Another point worth noting is that the DAR began entering information on "no-catch" trips in the database in 1989. This information has not been included in the present summaries, but in the next decade its existence may allow a more accurate assessment of changes in CPUE.

[20]J. N. Kushima. 1989. Ta'ape market development project. Div. Aquatic Res., Dep. Land and Natl. Res., Hawaii, 29 p.

Additional Considerations

Aquarium Landings

Although the foregoing summaries provide a brief insight into the makeup of Hawaii's nearshore commercial fisheries, there is much room for further consideration. No attempt was made here to summarize catches by aquarium collectors. Van Poollen and Obara (1984) profiled early economic characteristics of the marine aquarium industry in Hawaii. Aquarium landings are reported to the DAR and have been summarized by Miyasaka[21]. There were 231 aquarium collectors with permits in the State in 1988 (DLNR, 1988), of which 42% were commercial collectors. These fishermen reported catching 249,625 small fishes and invertebrates comprising about 215 species during 1988, of which 53% were collected from inshore areas on the Big Island's Kona Coast. The commercial value of these landings was estimated at $411,425 (all islands).

This is a rapidly expanding industry, responsible for an increasing proportion of the market value of commercial landings. A recent analysis provided by the DAR to the Kaneohe Bay Master Planning Task Force (OSP[4]) showed that while the total weight of commercial landings in Kaneohe Bay has declined over the last 12 years, aquarium collectors have increased the value of these landings, primarily through the sale of reef invertebrates. The desire to increase profits, however, cannot overshadow the need for resource conservation. Juvenile fishes are collected from inshore reefs, particularly along the leeward coast of the Big Island. Recent regulatory measures (DAR[22]) are aimed at moderating the impacts of these fisheries by controlling them in certain locations. Although the importance of aquarium fisheries cannot be overlooked, this topic merits a separate review.

[21]A. Miyasaka. 1991. Hawaii's aquarium fish industry: A business profile. Div. Aquatic Res., Dep. Land and Natl. Res., Hawaii, 15 p.

[22]Div. Aquatic Resources, State of Hawaii. 1992. Regulations for the new Kona FMA. In press.

Markets

Local marketing opportunities for Hawaiian fishermen are limited, as might be expected in this isolated region. Each island has its own small markets, including spontaneous roadside ventures which spring up and disappear overnight. There are two principal auction houses, one on the island of Oahu and one on the Big Island. It is estimated that these two auctions are responsible for from 50 to 60% of fish sold commercially in the state. However, these markets cater to offshore fisheries and primarily service longline and bottom handline fishermen. Reef fishes are increasingly being sold directly to individual vendors.

A recent increase in the number of ciguatera poisoning incidents reported to the State Department of Health has resulted in alarm regarding the consumption of reef fish captured locally, dramatically reducing the marketability of some inshore species and shifting fishing effort to areas where there have been no reported incidents. Although the danger of ciguatera may be largely exaggerated, vendors prefer to err on the side of caution. Fish are also exported without passing through the local markets. The subject of markets and landings value will be treated in depth by another contributor to this volume and is also beyond the scope of the present review.

Nonconsumptive Uses of Marine Fisheries Resources

Other important considerations in Hawaii include a variety of commercial nonconsumptive uses of inshore fisheries resources. Tourists enjoy activities designed to allow observation of reef fishes in their natural environment. This may be done from a boat or submersible, or by actually entering the water using a mask and snorkel. The lucrative industry associated with the latter type of viewing activity may involve bringing large groups of relatively inexperienced swimmers into contact with shallow inshore reefs, causing extensive trampling of fragile corals and destruction of the reef habitat. Both types of fish-viewing commercial tours generally involve some means of feeding the fish in order to concentrate them in an area where they can be seen. The result can be localized increases in abundance of the more aggressive and omnivorous species.

One of the present challenges to fisheries management in Hawaii is to preserve a healthy and abundant reef ecosystem that tourists can enjoy and at the same time allow fishing to take place at a reasonable level. The use of motorized recreational vehicles, such as jetskis and water skis, drives fish from the immediate area. Fishermen are responding to increased daytime commercial recreation by switching to nighttime fishing activity. Presumably fish viewing, ocean recreation, and fishing can coexist peacefully. Modern management measures must include setting allowable levels for ocean recreation, in addition to limits to fishing.

Fisheries Management

Status of Biological Knowledge of Stocks

Despite the importance and multiuse orientation of inshore resources, surprisingly little is known about the abundance and status of fisheries in Hawaii. Even generalized summaries of trends, such as are reported here, have rarely been attempted for inshore species. An exhaustive study would have to evaluate trends in these fish communities altogether, as an ecosystem. Changes introduced by humans in inshore habitat over the years may exert extremely important influences on fish abundance.

A DAR[10] report provided one of the most comprehensive summaries to date of the complex cultural, traditional, ecological, and jurisdictional issues involved in the management of Hawaii's inshore fisheries. In a survey fishermen described gear conflicts and reduced catches. Both fishermen and scientists expressed concern regarding whether the decline in nearshore fish populations might be due to increased fishing pressure and habitat alteration. The status of fishery resources was, and continues to be, viewed as a "barometer for the condition of our aquatic ecosystem." An examination of available (commercial) data at that time showed that fluctuating inshore fisheries landings were neither increasing nor declining significantly despite increased fishing effort. While CPUE was declining, it appeared that an equivalent amount of landings was being shared among an increasing number of fishermen. Various management scenarios were envisioned which would optimize CPUE for different sectors of the fishery and protect habitats critical to fish populations from the impacts of coastal development. The need for a careful evaluation of multi-species and multi-gear fisheries was stressed, as was the need for more complete and reliable fisheries data.

Shomura[23] summarized data from the State's commercial landings database, documenting an apparent decline in nearshore and both neritic and pelagic catches since the early 1900's. As in the DAR report, the data summarized by Shomura was in the form of statewide totals for many species and a wide range of geographic areas. Furthermore, no index of fishing effort was provided, making it difficult to interpret apparent trends. Shomura indicated that while deep slope and offshore pelagic landings had increased significantly, inshore and coastal landings were declining. The increase in offshore landings could be attributed to the effect of increased market demands on fishing effort. Decreasing reef fish landings might conversely be attributed in part to low relative demand for certain reef fishes, because of their distinctive flavor and odor of marine algae. Although local residents and native Hawaiians enjoy these distinctive tastes, tourists and foreign markets do not appreciate them.

The present summary, like those before it, encompasses a great deal of complexity which merits a more in-depth examination. As such, this review is considered to be a contribution to the understanding of trends in Hawaiian fisheries, indicating that assessment and management should be examined on a regional basis. While total landings for the state may have decreased since the early 1900's, regional evaluations show a wide range of variation. Some inshore fisheries show short-term improvements, although increased reporting may contribute to this apparent trend. The most disturbing trend is towards steadily increasing fishing effort in inshore ecosystems that are already heavily exploited. Most fisheries managers agree that fishing pressure should be reduced or limited in some areas in Hawaii; but answers to questions such as where, how much, and in what manner are still being sought.

[23]R. Shomura. 1987. Hawaii's marine fishery resources: Yesterday (1900) and today (1986). U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Sci. Cent. Admin. Rep. H-87-21, 14 p.

Ongoing Research

A project presently in progress, the Main Hawaiian Islands Marine Resources Investigation (MHI-MRI), is beginning to consolidate information on inshore fisheries and evaluate abundance, CPUE, and life history data for key species and areas. This project of the DAR is being conducted in collaboration with other fisheries management and marine research agencies statewide. Participants include the University of Hawaii Sea Grant College Program, Marine Option Program, Hawaii Institute of Marine Biology, and Hawaii Institute of Geophysics; the NMFS Southwest Fisheries Science Center, Honolulu Lab; the Oceanic Institute; the Western Pacific Regional Fisheries Management Council; and the USFWS Hawaii Cooperative Fisheries Research Unit. The project also cooperates with the International Center for Living Aquatic Resources Management (ICLARM) in the context of FISHBASE, a worldwide computerized database of biological information on fishes (Pauly and Froese, 1991), to obtain jointly a complete coverage of the fishes of the Central Pacific.

MHI-MRI will reevaluate the management of inshore fisheries throughout the MHI, and produce long-term recommendations to improve resource abundance and ensure sustainable fisheries. Research in progress seeks to define the principal causes of the declining abundance of some inshore species and to identify mitigative measures to offset negative impacts as needed. Overfishing, increased erosion and sedimentation, and both alterations and pollution of inshore habitats are among factors under investigation. Early indications are that limitation of fishing pressure, localized stock enhancement, and protection of inshore nursery areas from further human impacts could all contribute to recovery of inshore fish populations in Hawaii.

Regulatory Measures

Existing regulatory measures for Hawaiian inshore fisheries include bag limits, seasonal closures, and minimum size restrictions for capture and sale. Gear restrictions inside harbors allow pole-and-line fishing using only one pole with two hooks per fisherman. Crab netting in these areas must be limited to ten (small circular) nets per fisherman. Fishing regulations are summarized for the public in a brochure, updated annually by the DAR (DAR[24]). In addition to these regulations, there are specific gear restrictions in areas designated as Fishery Management Areas (FMA's) and MLCD's.

FMA's are established in areas where fishing or resource use competition is a problem and generally involve restriction of fishing gears or uses. Examples include the Waikiki-Diamond Head Shoreline FMA (Oahu) and Hilo Harbor FMA (Hawaii), where net fishing is restricted. The Waikiki-Diamond Head FMA rules rotate gear restrictions annually. Pole-and-line, thrownet or handnet fishing, and daytime spearing are allowed during even numbered years. No fishing is allowed in odd numbered years. Hilo Harbor FMA is regulated differently, tailored to the needs of local fishermen. In addition to bag limits, no gill, surround, or cross netting is allowed at any time within the Hilo breakwall, but all types of fishing are permitted year-round outside this area. Measures that regulate fishing pressure, while maintaining fishing opportunities for a variety of users, are more widely accepted in local communities. The benefits of these measures are demonstrated by an almost immediate increase in resource abundance, as indicated by increases in estimated biomass, in average and maximum size of fish captured, and in CPUE (Yamamoto[16]; Kahiapo and Smith[5]).

Molokini Crater, southwest of Maui, is a State-regulated MLCD. Only trolling is presently allowed in this partially submerged crater, which is a popular tour site for divers; but measures are being considered to restrict trolling as well. Other MLCD's and FMA's dot the coasts of the MHI (DAR[25]; Oishi[2]). Regulations are site specific, but generally, where fishing is allowed, it is restricted to pole-and-line, hand methods, and throw netting.

As seen under fishing methods, gears such as longlines, gill nets and surround nets are responsible for a large volume of landings in relation to the number of trips and fishermen. This is fine as long as the resource is not over harvested. These fleets are small and in some cases, such as for longline fishing, limited entry schemes are being developed to conserve resources for future generations. Other fisheries, such as surround netting, are presently limited by social constraints worked out through "gentlemen's agreements" between fishermen. As fishing pressure increases because of immigration and population growth, the need to formalize these agreements becomes increasingly important.

Ancient Hawaiians practiced seasonal closure of certain areas to fishing. Traditional systems provided for seasonal, species, and area-specific harvesting. The practices of sharing the catch, leaving certain species to royalty, and never taking more than was needed contributed to the balance between fishing and conservation in early times (Titcomb, 1952; Johannes, 1978). The loss of the traditional Hawaiian fishery management system and the failure to replace it with something comparable when Hawaii became part of the United States (Jordan and Evermann, 1905; Titcomb, 1952; Johannes, 1978; DAR[10]; Smith and Pai, 1992) are impacts from which nearshore living resources may take a long time to recover. A "kapuku" plan proposed in the late 1970's (HMR[26]) was one of the first attempts to restore a system of rotating area closures; however, agreement could not be reached on the specific areas to be closed. Present regulations, with rotating FMA's and MLCD's parallel this type of system on a small scale, but it is apparent that more protection of inshore resources is needed.

Because the jurisdiction of fisheries regulatory agencies in Hawaii is determined by geographic boundaries which do not coincide with the boundaries of migratory organisms that make up its fisheries, collaboration and cooperation between these agencies is critical to successful management. Environmental protection is another increasing concern that has demonstrated value to the conservation of inshore fisheries resources. Collaboration is being developed, and economic, scientific, and enforcement resources pooled, in order to manage the resources more effectively. It is clear from the long hours dedicated by the public to meetings designed to guide management efforts that residents are concerned about maintaining their rich and diverse natural heritage. The improved management of inshore fisheries and fishery habitats is an issue which must be resolved before the end of the present decade, and Hawaii's residents and resource managers are rising to meet the challenge.

Acknowledgments

Special thanks are due to a number of local fisheries biologists for their

[24]Div. Aquatic Resources, State of Hawaii. 1991. Hawaii fishing regulations. Div. Aquatic Res., Dep. Land and Natl. Res. brochure, 43 p.

[25]Div. Aquatic Resources, State of Hawaii. 1991. Marine life conservation districts. Div. Aquatic Res., Dep. Land and Natl. Res. brochure, 30 p.

[26]Hawaii Marine Research, Inc. 1977. Plan of action for the implementation of the Kapuku Plan of Management. Prepared for Hawaii Dep. Land and Natl. Res. by Hawaii Marine Res., 47–267 Kokokahi Place, Kaneohe, HI 96744, 190 p.

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