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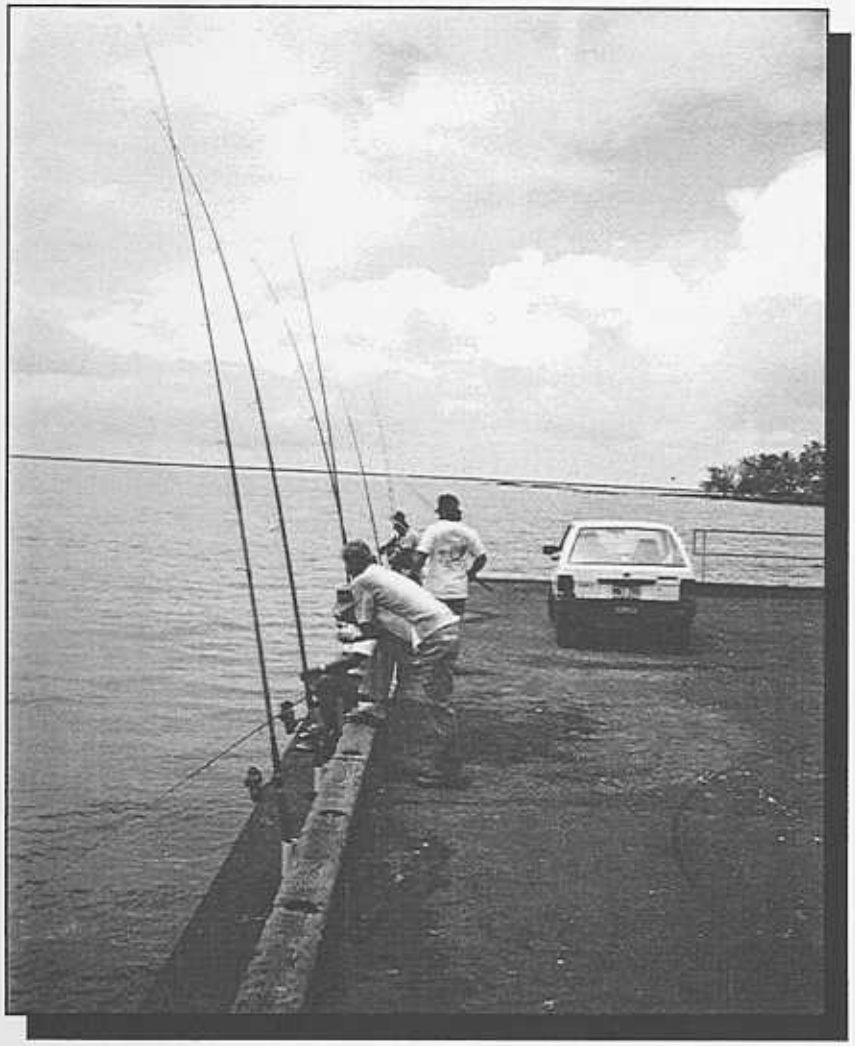

Department of Land and
Natural Resources

**Division of
Aquatic Resources**

Technical Report
94-02

Shoreline Creel Survey of Hilo Bay 1985-1990

May 1994

John D. Waihee
Governor

SHORELINE CREEL SURVEY OF HILO BAY HAWAII: 1985-1990

A report on research for the:
Main Hawaiian Islands Marine Resources Investigation (MHI-MRI)

DIVISION OF AQUATIC RESOURCES
Department of Land and Natural Resources
1151 Punchbowl Street, Room 330
Honolulu, HI 96813

by John Kahiapo and M. Kimberly Smith

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Shoreline Creel Survey of Hilo Bay, Hawaii: 1985-1990

John Kahiapo[1] and M. Kimberly Smith[2]

ABSTRACT

Shoreline fishing surveys ("creel surveys") were conducted in Hilo Bay from September, 1985, through June, 1990. The surveys covered Hilo Harbor Fisheries Management Area (FMA), Waiākea Pond Public Fishing Area (PFA), and the adjoining Keaukaha shoreline. The latter two areas were sampled from 6:00 a.m. to 6:00 p.m., and Hilo Harbor was surveyed throughout a 24-hour cycle. 4285 fishers were contacted over a five-year period, in a total of 2317 interviews. Those contacted fish primarily for recreation and home consumption, rather than commercially. This report summarizes data collected over all five years, emphasizing the changes in catch per unit effort (CPUE), species and size of fishes and invertebrates landed before and after the closure of Hilo Harbor to gillnetting in June, 1987.

An average of 470 interviews were conducted annually over the five-year period, but more interviews took place during the last year. For this reason the final year's data are considered to be more representative of overall fishing activity. An estimate of total landings in the Hilo area was made for the period from July, 1989, through June, 1990 (State Fiscal Year 1990), based on average hourly participation and CPUE for each area. The estimated total shoreline catch during FY 1990 was 46.5-168.8 short tons[3], of which approximately 30.7-121.4 tons were caught in Hilo Harbor FMA, 6.9-18.6 tons in Waiākea PFA, and 9.0-28.0 tons along the Keaukaha shoreline. 17.8 tons were reported commercially from the inshore Hilo area during the same period, giving a total of 64.3-186.6 tons harvested in this region by recreational and commercial sectors of the fishery. The range of shoreline landings estimates is broad because of the high variability of CPUE relative to sample size.

Sampling frequency prior to 1989 was insufficient to provide a reliable estimate of total landings for those years. Data from all five years were used to compare annual CPUE by area and geartype, and size structure of landings of key species. This comparison indicates there has been an increase in hourly catch rates and fish size in Hilo Harbor FMA since management measures were implemented. A sampling program is described which will provide a basis for the development of a more precise estimate of shoreline fishery landings at Hilo.

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1 Division of Aquatic Resources (DAR)
Department of Land and Natural Resources (DLNR)
75 Aupuni St., Rm. 220, Hilo, Hawaii 96720

2 DAR/DLNR
1151 Punchbowl St., Rm. 330
Honolulu, Hawaii 96813

3 1 short ton = 2000 lbs

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Shoreline Creel Survey of Hilo Bay, Hawaii: 1985-1990

John Kahiapo and M. Kimberly Smith

INTRODUCTION

The Study Area

Hilo Bay is a safe and popular recreational fishing site located on the northeast coast of the Island of Hawaii. Taken from the Hawaiian name for the first night of the new moon, Hilo, Hawaii, got its name because of the crescent shape of Hilo Bay (Pukui et al., 1976). Figure 1 shows the prominent coastal features of Hilo Bay, including the three study areas: 1) Hilo Harbor (coastal areas between Ale'ale'a Point and the seaward end of the Hilo breakwall), 2) Waiākea Pond Public Fishing Area (PFA), and 3) the Keaukaha shoreline, from outside the Hilo breakwall eastward to King's Landing (also known as Pu'u Maile or Lehia Park). Although close together geographically, these areas represent three ecologically distinct habitats within the broad spectrum of Hawaiian coastal ecosystems.

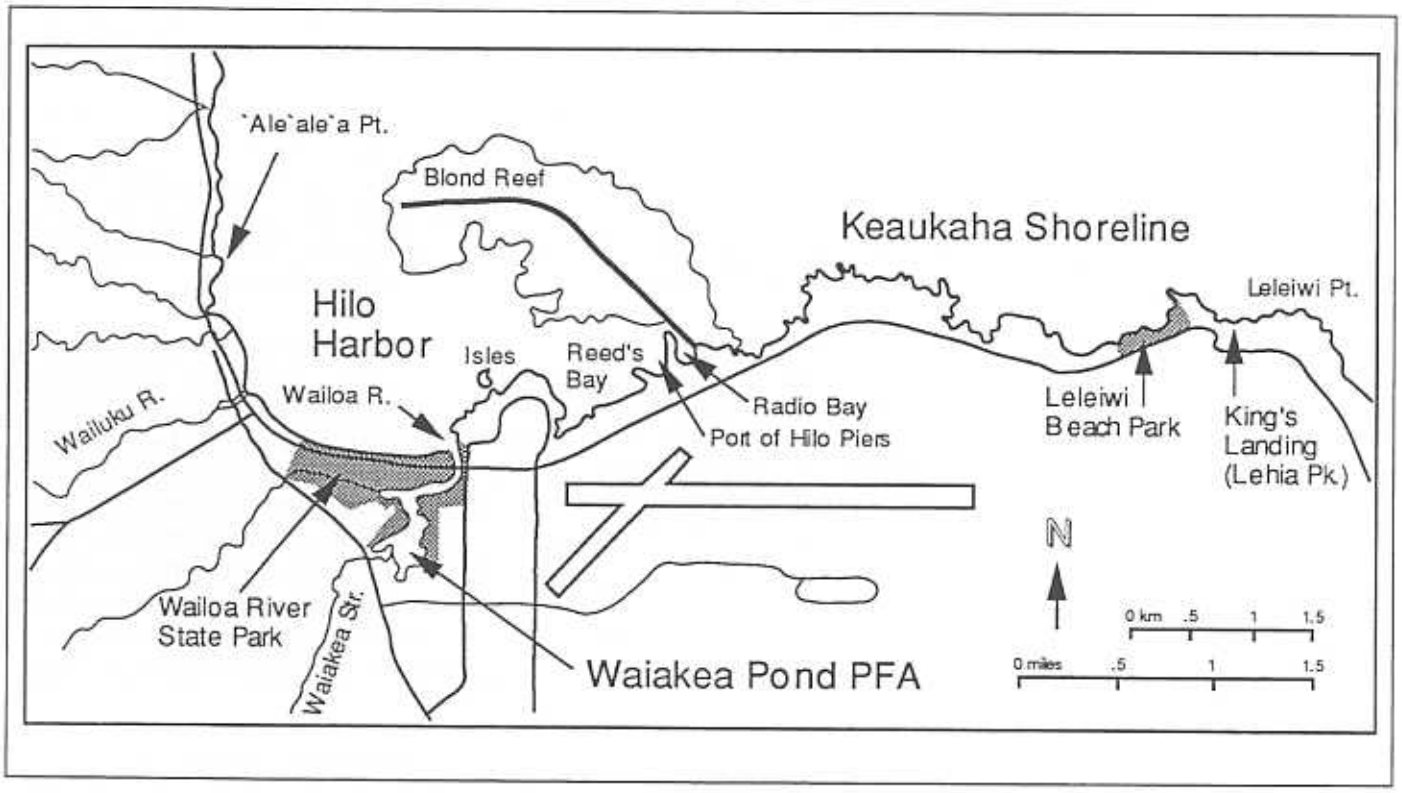
Hilo Harbor is one of the few natural estuaries in Hawaii, receiving freshwater input from the Wailuku and Wailoa Rivers (Kelly, Nakamura and Barreré, 1981). The Hilo breakwall dampens the influence on the Bay environment of marine currents driven by prevailing (northeasterly) trade winds, increasing the importance of input from various streams and rivers discharging within the Harbor. Salinities in the Harbor range from 0-8 ppt near shore and at the mouthes of streams to about 32 ppt at the Harbor mouth, averaging from 24-28 ppt (Dudley et al., 1991). Hilo Harbor supports a variety of estuarine and marine species, and important season and tide-related fisheries for species such as akule or big-eye scad (*Selar crumenopthalmus*), 'ama'ama or striped mullet (*Mugil cephalus*), and ulua or jacks (juveniles referred to as papio; primarily *Caranx ignobilis* and *Caranx melampygus*). Shoreline fishers in this region also target on marine crustaceans, known as kuahonu or white crabs (*Portunus sanguinolentus*).

Waiākea Pond, in the Wailoa River State Park is a shallow brackish pond which receives freshwater through streams and groundwater. Freshwater input dominates the Pond habitat. Salinities range from 0-3 ppt within the Pond, averaging about 0.33 ppt. Waiākea Pond opens into Hilo Harbor, allowing euryhaline species to enter the area, especially during the dry season. Ulua (and papio), 'ama'ama, and ahólehóle (*Kuhlia sandvicensis*) enter and leave Waiākea Pond freely throughout the year. The latter two are the principal species targeted by recreational fishers. The Samoan crab (*Scylla serrata*) also provides a source of food and sport fishing activity. Creel surveys covered the area between the mauka side of the double span bridge and 1400 feet up the flood control channel. Salinities near the bridge range as high as 10-25 ppt; hence the abundance of estuarine species in that area.

The **Keaukaha shoreline** is quite different ecologically than either Hilo Harbor or Waiākea Pond PFA. Located outside the Hilo breakwall, the area is characterized by a rocky (basalt) coastline and marine conditions (salinities up to 34-36 ppt). Frequent and intense wave action, and occasional storm surge, contribute to the high energy reef communities seen in this region. Wave action and the presence of the Hilo breakwall dampen the effects of freshwater output from Hilo Harbor. The presence of eel grasses (*Zoostera* spp.) and abundance of surgeonfishes, wrasses and other reef species are an indication of the predominence of the marine influence in this area. However, freshwater input through groundwater does reach Keaukaha. Salinities immediately on and near the shore range from 8-20 ppt, averaging about 14-16 ppt near shore and 22-28 ppt directly off shore

(Dudley et al., 1991). Freshwater can be seen flowing out through loose gravel onto beaches and is sometimes isolated in masses of cold water which eventually mix with marine waters found all along the coast. This is the only area in Hilo Bay where gillnetting is allowed.

FIGURE 1: HILO BAY



(Adapted from Clarke, 1985)

Fishing Regulations and the Purpose of Shoreline Creel Surveys

Since Hawaii Revised Statutes (HRS 189-3) only require that commercial landings be reported, the Hilo creel survey was designed to improve estimates of total landings of fish and invertebrates in Hilo Bay by acquiring additional data on catch and effort by shoreline recreational fishers. Recreational activity is important to the fishery at Hilo, which has an extensive and accessible shoreline. Many areas around Hilo are dominated by recreational fishers including, Reed's Bay, Isles, the Port of Hilo piers, the Hilo breakwall, Waiākea PFA and much of the shoreline inside Hilo Harbor.

Only recreational fishing is allowed in the Waiākea PFA, which was established in Waiākea Pond (Wailoa River State Park) in 1970 to protect one of the area's few fresh and brackish water fisheries for the benefit of the public. There are restrictions on the types of boats and fishing gear to be used in Waiākea, and on the amount of fish to be landed per fisher. The PFA is designated for hook and line fishing only; fishers are allowed no more than one line and one lure, or two single hooks. In addition, scoopnets (not exceeding 18 inches in diameter) are to be used only for assistance in landing catches within the PFA. Besides the rules of Waiākea Pond and the Hilo Harbor FMA, all of Hawaii's shoreline fishing regulations (DAR, 1992) apply in the three areas.

The Hilo creel survey began in 1985, in response to public concern regarding possible overfishing in Hilo Bay. Prior to 1985, there had been no studies of recreational landings in the Hilo area. The first shoreline creel census (referred to as the Pre-Amendment Survey) was conducted by Hilo Division of Aquatic Resources (DAR) personnel (Kuamo'o and Kaichi, unpublished) from September, 1985, through December, 1986. At that time Hilo Harbor Fisheries Management Area (FMA) was subject to limited gear restrictions, as dictated by Hawaii Administrative Rules, Chapter 47 of Title 13 (based on Regulation 35 of the Division of Fish and Game). Gillnetting was prohibited only in the Wailuku and Wailoa Rivers, and in a small portion of Hilo Harbor known as Radio Bay.

On June 1, 1987, following a petition by Hilo recreational fishermen, the Department of Land and Natural Resources (DLNR) amended the Hilo Harbor FMA regulations, prohibiting the use of gillnets anywhere within Hilo Harbor. A second series of creel surveys began in 1987, after gillnet fishing in the Harbor had been prohibited. These surveys were conducted by students of the University of Hawaii at Hilo (UH-Hilo) Marine Option Program (Walen and Mazarakis, unpublished), from September, 1987 through June, 1988 (Post-Amendment I Survey). A final phase (designated as the Post-Amendment II Survey) began in July, 1989, and continued through June, 1990. This survey was conducted by John Kahiapo, of the DAR, and was characterized by more frequent sweeps through the study area with around-the-clock interviews. Data from all three surveys are summarized in this report.

Because shoreline creel surveys began well before the Hilo Harbor FMA amendment and have continued for several years since the amendment was adopted, the results obtained from 1985-1990 provide an index of how landings and fishing activity in the Hilo area have changed since new management measures were implemented. The surveys also provided a means of establishing closer contact with local fishers to exchange ideas. Improved communication contributed significantly to the consensus building process which lead to the development of the FMA amendment.

Total fisheries landings from Hilo Bay are comprised of catches from three different "fleets": (1) large commercial fishing vessels (predominantly longliners, trollers and ikashibi boats), (2) small fishing vessels (primarily recreational fishers, targeting on resources such as akule, papio, and white crabs), and (3) shoreline fishers. Commercial landings, whether by large or small vessels (1 and part of 2, above), are reported to the DAR in the required Commercial Fish Catch Reports. Recreational small boat landings (the other part of 2, above) will be evaluated at a later date as personnel and funding allow. Creel surveys described in this report were intended to estimate shoreline landings (3), which are accomplished almost exclusively by recreational fishers.

METHODS

Sampling protocols were not fully developed at the beginning of the first survey in the Hilo area, but evolved gradually through the initiative of each group conducting the Pre-Amendment, Post-Amendment I, and Post-Amendment II Surveys. A successful creel survey depends on being able to obtain the trust and cooperation of fishers. Establishing this relationship was a major concern at the outset. Surveyors set about finding access, making contacts and conducting as many successful interviews as possible. This was especially difficult at the beginning, when transportation and personnel were most limited. For the above reasons, creel surveys were conducted infrequently during the first few years. As the value of the data being collected became evident, an increasing emphasis was placed on this activity.

As mentioned, creel surveys encompassed three different types of habitat with distinct management characteristics. All creel surveys covered the area from Ale'ale'a Point to Leleiwi Point (although with varying intensity), during daylight hours, weekdays and weekends. The Post-Amendment II survey was the first to include Waiākea Pond, and encompass early mornings, nights, and holidays. The goal of interviewing all fishers along a majority of the coastline was approached only in the Post-Amendment II survey, when a staff member was allocated almost full time to the project. Table 1 summarizes the number of interviews, fishers and locations surveyed from 1985 through 1990.

TABLE 1: SUMMARY OF CREEL SURVEY LOCATIONS, FISHERS CONTACTED AND INTERVIEWS CONDUCTED IN THE HILO AREA: SEPTEMBER 1985 - JUNE 1990

SURVEY: DATES	LOCATIONS COVERED	NUMBER OF INTERVIEWS	NUMBER OF FISHERS	PLACE OF RESIDENCE[4]		SEX OF FISHERS[5]		NUMBER OF FISH CAUGHT
				% HILO	% ELSEWHERE	% ♂	% ♀	
Pre-Amendment: Sept.1985-Dec.1986	Hilo Harbor Keaukaha Shoreline	139	223	92.6	7.4	89.7	10.3	622
Post-Amendment I: Sept.1987-June 1988	Limited Keaukaha Hilo Harbor FMA	241	412	88.4	11.6	73.1	26.9	428
Post-Amendment II: July 1989-June 1990	Hilo Harbor FMA Keaukaha Shoreline Waiākea PFA	1937	3650	79.3	20.7	88.4	11.6	13772
TOTALS:		2317	4285					14822

The survey questionnaire is shown in Appendix 1. Although the same form was used for all the surveys, the level of detail obtained from each interview increased progressively through the Pre-Amendment, Post-Amendment I, and Post-Amendment II Surveys. Geartype(s), total number of fish, average total length (from snout to tip of caudal fin), time spent fishing, age and place of origen of fishers were recorded. When possible, the number of fish and their lengths were recorded by species. More often, there was only enough time to record average size and total number of fish for each species.

Creel survey personnel drove or walked along the coast, approaching as many fishers as possible in areas that were accessible. Data were collected through interviews and direct

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[4] n = 136 fishers in the Pre-FMA, n = 233 for Post-FMA I, and n = 323 for Post-FMA II Surveys.

[5] n = 223 for Pre-FMA, n = 412 for Post-FMA I, and n = 2460 for Post-FMA II (not always recorded last year).

examination of the catch. Fishers were often interviewed individually. However, many groups of family and friends in the Hilo area fish together and throw all their catch into a single cooler or bucket. Furthermore, it is not the local custom to count or keep track of one's fish. The people of Hilo fish for enjoyment, to have something to eat or to share with their neighbors; not in the interest of competition. When groups which had thrown all their fish together were encountered and it was not possible to say who caught which fish, group interviews were conducted for up to 10 individuals on a single survey form.

General summaries of interviews and catch per unit effort (CPUE, per gear-hour) were made for each geartype, survey period and unique location. Although more detailed locational data were kept, the summaries presented in this report are based on the broad areas having unique regulations and regimes of fishing activity (i.e. Hilo Harbor FMA, the Keaukaha shoreline, and Waiākea PFA).

A summary of overall length-frequency distribution of landings by species was made for some of the most abundant species in each area, focusing for purposes of comparison on those which were sampled over a significant portion of each survey period and were registered in more than one of the three surveys. Since only mean length and number of fish were recorded during most interviews, approximate length-frequency distributions had to be reconstructed as follows:

1) a normal curve containing the number of fish registered in each interview was constructed around the mean length recorded.

2) the length and number of fish by size-class estimated in this manner were compiled for each of the three survey periods.

Post-Amendment II data were used to produce an estimate of annual shoreline landings for the period from July, 1989, through June, 1990 (State Fiscal Year 1990) in the following manner. Since time-stratified sampling had not been routinely conducted, representative sampling periods were selected *a posteriori*, based on observed differences in fishing activity throughout the day. The time of day at which interviews were conducted was assigned to one of six four-hour time intervals, making up a "typical" 24-hour day. Mean CPUE was calculated for each time interval and location. Since all or most fishers present in a given area were interviewed during the Post-Amendment II survey, the data recorded were considered representative of daily catch rates and fishing activity at each place and time. The mean sum of the number of fishers and hourly CPUE (number of fish and mean weight of the catch per fisher) for a given date, time and location were used as indices of average participation levels and average catch rates, respectively. Species-specific length-weight conversion factors, obtained from the literature and identified in a Basic program (Anonymous programmer, 1979), were used to estimate the weight of the catch by species. The weight of landings per fisher was estimated as the sum of the species-specific weights over all species caught.

The total weight of daily landings was summed for each area and time period. These values were averaged over the year for weekdays (class WD) versus weekends and holidays (class WE/H). Mean total shoreline landings for these two day-classes were estimated for each time period throughout the day. In this manner, an average 24-hour weekday or weekend/holiday during FY 1990 was reconstructed for each of the three fishing areas. Total landings were estimated by summing average daily landings for all 365 days of the year, based on the known number of weekdays versus weekend/holidays during FY 1990. The number of interviews conducted during the Pre-Amendment and Post-Amendment I surveys was not sufficient to make such an estimate.

RESULTS

Appendix 2 summarizes the number of interviews conducted at each location within the greater survey areas by survey period. The frequency and location of interviews during all three survey periods was determined by the availability of personnel and transportation, weather conditions, the relative accessibility of each location, and the fortuitous occurrence of fishing events and fishers. The area between Bayfront and the Waiākea Penninsula was sampled regularly in all three surveys. During the Post-Amendment I survey 17% of the interviews were conducted in the area near Suisan Dock. From Table 1, it can be seen that over 85% of the total fishers were interviewed during the Post-Amendment II survey. The Post-Amendment II survey was also the only one where a significant number of interviews were conducted northeast of the Waiākea Peninsula and along the Keaukaha shoreline. Because of the differences in coverage and timespan, data from each survey period are summarized separately.

Although detailed information on the place of origin of fishers was recorded for a subset of interviewees, the summary in Table 1 reflects only whether or not fishers were from the Hilo area or elsewhere. Those from anywhere outside Hilo were grouped into a single category (fishers from "elsewhere") for the purpose of this report. The largest proportion of fishers by far were Hilo residents. The second largest group were people from elsewhere on the Big Island, and there were a few tourists or visitors from neighboring islands. The proportion of fishers from outside Hilo using the area apparently increased after the FMA was amended. Improved catches in Hilo Harbor FMA relative to unmanaged areas at other locations and news of reduced competition with gillnetters are among factors which may have drawn more fishers to Hilo after the FMA amendment. There may also be an indirect effect, caused by Hilo-based gillnetters going elsewhere to fish.

Tables 2A-C show average CPUE by geartype, area and survey period. The principal gears used in Hilo Harbor are pole and line, scoop net, and thrownet. Outside the breakwall gillnets are allowed. Thrownets are also more commonly used along the Keaukaha coast, since the water is more transparent (less stream input) and reef species suited for capture by thrownet are more abundant. Geartypes and their uses in Waiākea Pond are determined primarily by the regulations described previously. The tables include a mean number of gears per fisher for each area. Most fishers utilize a single gear, even outside of Waiākea Pond. The exceptions to this are: 1) 10-20% of the pole and line fishers use two poles, or a handline and handpole, 2) crabnet fishers use up to five crabnets simultaneously, and 3) gillnetters operate a single net between two to five people. Although nets are not used within Waiākea Pond, some crabnetters were interviewed at the mouth of the Pond, on the Wailoa River near the bridge.

Appendix 3 is a glossary of local, common and scientific names of fish and invertebrate species encountered in the five-year survey period. The list is alphabetized by scientific name to assist the reader in finding the corresponding common or local name, since scientific names are used throughout most of the report. Appendices 4A-C summarize average length by species and sampling period. The data in Appendix 4 were ordered from most to least abundant (number of fish). As many as ten principal species were chosen for each fishing area and sampling period. These are listed in Table 3, with the rank of relative abundance they received in each survey.

TABLE 2A: MEAN HOURLY CPUE BY GEARTYPE HILO HARBOR

GEARTYPE	Pre-Amendment		Post-Amendment I		Post-Amendment II	
	CPUE* Std** (no.gears)	No. Fishers	CPUE* Std** (no.gears)	No. Fishers	CPUE* Std** (no.gears)	No. Fishers
Rod/Reel	2.04 14.92 (186)	150	0.36 0.82 (413)	357	1.28 2.81 (1496)	2450
	n = 1.24		n = 1.16		n = 0.61	
Handpole	3.50 4.19 (27)	13	4.91 4.08 (20)	14	5.14 6.66 (825)	505
	n = 2.08		n = 1.43		n = 1.63	
Spear	---	---	---	---	3.32 3.39 (6)	6
					n = 1.00	
Scoop net	13.07 10.03 (5)	4	---	---	--- (1)	---
	n = 1.25					
Gillnet	0.46 0.64 (7)	15	---	---	---	---
	n = 0.47					
Throwmet	1.63 1.58 (12)	6	1.85 2.34 (14)	15	15.12 30.41 (47)	42
	n = 2.00		n = 0.93		n = 1.12	
Handline	---	---	---	---	0.14 0.19 (7)	5
					n = 1.40	
Crabnet	---	---	---	---	0.80 1.13 (13)	2
					n = 6.50	
Unspecified	---	0		6		7
Total No. Fishers	188		392		3017	

TABLE LEGEND

CPUE = No. fish per gear-hour
Std = Standard deviation (units as CPUE)
n = average number of gears per fisher

TABLE 2B: MEAN HOURLY CPUE BY GEARTYPE KEAUKAHA SHORELINE

GEARTYPE	Pre-Amendment		Post-Amendment I		Post-Amendment II	
	CPUE* Std** (no. gears)	No. Fishers	CPUE* Std** (no. gears)	No. Fishers	CPUE* Std** (no. gears)	No. Fishers
Rod/Reel	0.18 0.33 (12)	15	0.40 0.41 (18)	19	1.25 2.61 (82)	72
	n = 0.80		n = 0.95		n = 1.14	
Handpole	---	---	---	---	1.38 1.29 (43)	37
					n = 1.16	
Spear	5.59 4.64 (12)	15	---	---	2.51 2.04 (9)	9
	n = 0.80				n = 1.00	
Gillnet	0.21 --- (2)	4	---	---	12.50 6.36 (3)	7
	n = 0.50				n = 0.43	
Thrownet	9.00 --- (1)	1	---	---	9.01 14.01 (48)	48
	n = 1.00				n = 1.00	
Handline	---	---	---	---	20.00 --- (2)	2
					n = 1.00	
Unspecified		0		1		5
Total No. Fishers	35		20		180	

TABLE LEGEND

CPUE = No. fish per gear-hour
Std = Standard deviation (units as CPUE)
n = average number of gears per fisher

TABLE 2C: MEAN HOURLY CPUE BY GEARTYPE WAIAKEA POND

GEARTYPE	Post-Amendment II	
	CPUE* Std** (no.gears)	No. Fishers
Rod/Reel	0.92 1.51 (422)	423
	n = 1.00	
Handpole	4.93 7.42 (19)	19
	n = 1.00	
Handline	0.81 0.32 (6)	4
	n = 1.50	
Crabnet* (Wailoa Bridge area)	0.00 0.00 (18)	4
	n = 4.50	
Unspecified		3
Total No. Fishers		453

TABLE LEGEND

CPUE = No. fish per gear-hour
Std = Standard deviation (units as CPUE)
n = average number of gears per fisher

There were notable differences in the predominant species, both within and between surveys and study areas. For Hilo Harbor, the akule (*Selar crumenophthalmus*), weke a'a (*Mulloides flavolineatus*), mullet (*Mugil cephalus*), ahólehóle (*Kuhlia sandvicensis*), white ulua/papio (*Caranx ignobilis*), and kuahonu or white crab (*Portunus sanguinolentus*) ranked consistently high on the list. However, the Hawaiian anchovy (*Encrasicholina purpurea*), which was the most abundant organism in Hilo Harbor during the Pre-Amendment survey, was not registered at all during the two Post-Amendment surveys. Anchovy abundance may have been unusually high during the Pre-Amendment survey period. Anchovies are known to undergo cyclical changes in abundance over periods of several years at a time; however, the differences are probably also due in part to sampling error, because of the small number of Pre-Amendment interviews. It is noted that the gold-spot herring, an introduced species not seen in either the Pre-Amendment or Post-Amendment I surveys, was fairly common in the Harbor FMA during the Post-Amendment II survey. Although cause and effect can't be shown, competition between these species may also be a factor.

Abundant species along the Keaukaha shoreline included ahólehóle, mullet, summer mullet (*Valamugil engeli*), false mullet or uouoa (*Neomyxus leuciscus*), manini (*Acanthurus triostegus*), mamo (*Abudefduf abdominalis*), the limpet or opihi (*Cellana sandwichensis*), and various wrasses, parrot and butterfly fishes. Many of these are also found in Hilo Harbor, but there was a higher proportion of reef fishes at Keaukaha.

Four species made up 90% of the landings registered in Waiākea Pond and vicinity. Three of these are caught in the Pond itself; the mullet, ahólehóle and Samoan crab (*Scylla serrata*). The fourth species, the akule, is caught along the Wailoa River Bridge at the mouth of Waiākea Pond. Since the survey wasn't extended to Waiākea PFA until the Post-Amendment II survey, information for previous two surveys is not available.

A summary of mean length per survey period for many of the more abundant species is provided in Table 4. Gaps in these data are due to changes in fish and invertebrate abundance, as well as in the frequency and location of interviews. The revised survey design (see discussion) will address this problem, striving to create a representative sampling procedure for all three fishing areas that will accurately reflect changes in abundance. Table 5 presents some additional data on the month(s) of peak abundance for several important species and the highest and lowest mean sizes registered during all three surveys.

Length-frequency distributions were constructed for all of the principal species in each area. Figures 2-7 show the distributions generated for six of these for Hilo Harbor. These length frequency distributions are based on the mean length and number of fish recorded in each interview (see methods). The new survey design will incorporate a more systematic method of recording length-frequency data than was used in the present survey, limiting these observations to the 8-10 species of primary importance in each fishing area.

Although length data were not registered with the intent of examining length-frequencies, the small amount of data recorded demonstrated an apparent trend towards increasing size for many species since the closure of the Harbor to gillnetting. The lowest mean sizes were registered during the Pre-Amendment and Post-Amendment I surveys. Either there was a slight decrease during the Post-Amendment I period relative to the previous survey, or organisms increased in size slightly. Nine of the 17 abundant species found in more than one survey showed significantly larger sizes during the Post-Amendment II survey, while only two had decreased in size and 10 showed no significant trend. Kolmogorov-Smirnoff tests (in Siegel, 1987) for differences in these distributions showed statistical significance at levels ranging from $\alpha = 0.01$ to $\alpha << 0.001$.

White crab and iheihe (needlefish) were two species showing a continuous decrease in size through all three surveys. Neither of these is affected by most management measures now in effect, since crabs are caught by a different type of net and iheihe by pole and line. While the iheihe is essentially a "trash fish", not sought by fishers, the white crab is enjoyed by many. The Samoan crab is another species which may require improved management. Although no trend towards increased or decreased size was observed, it should be noted that this species is harvested the year round and appears to show continuously low levels of abundance. Although there are both minimum size and bag limits for Samoan crab outside of Waiākea Pond, there are no restrictions on the number of fishers harvesting this species or the total number of crabs caught annually. More crabs are harvested each year as Hilo's population continues to grow. There is no bag limit for this species within Waiākea Pond, due to a loophole in the legislation which brought about the establishment of the Waiākea Public Fishing Area. Outside in Hilo Harbor the limit is 3 crabs daily per fisher. It is also worth noting that 60% of recorded landings of Samoan crab were under the legal size limit.

TABLE 3: RELATIVE ABUNDANCE OF PRINCIPAL SPECIES BY LOCATION AND SURVEY PERIOD

AREA: SPECIES	PRE-AMENDMENT	POST-FMA I	POST-FMA II
HILO HARBOR:			
Selar crumenophthalmus	2		1
Mulloides flavolineatus	3	1	2
Portunus sanguinolentus		10	3
Mugil cephalus		5	4
Kuhlia sandvicensis	7	8	5
Caranx ignobilis	5	2	6
Valamugil engeli			7
Lutjanus fulvus			8
Herklotsichthys quadrimaculatus			9
Polydactylus sexfilis			10
Encrasicolina purpurea	1		
Hemiramphus depaueratus	4		
Acanthurus dussumieri	6	6	
Kyphosus cinerascens		3	
Parupeneus porphyreus		4	
Acanthurus triostegus		7	
Scomberoides lysan		9	
KEAUKAHA SHORELINE:			
Kuhlia sandvicensis			1
Acanthurus triostegus	1		2
Thalassoma duperrey			3
Cellana sandwichensis			4
Neomyxus leuciscus			5
Valamugil engeli			6
Mugil cephalus		3	7
Abudefduf abdominalis			8
Ctenochaetus strigosus	2		
Chaetodon quadrimaculatus	3		
Scarus sordidus	4		
Parupeneus multifasciatus	5		
Panulirus marginatus	6		
Panulirus sp.	7		
Bodianus bilunulatus		2	
Lutjanus fulvus		5	
WAIAKEA POND PFA:			
Mugil cephalus	Note: *S. crumenopthalmus* in Waiākea PFA caught at or near Wailoa River Bridge.		1
Selar crumenophthalmus			2
Kuhlia sandvicensis			3
Scylla serrata			4

TABLE 4: MEAN TOTAL LENGTH OF SOME PRINCIPAL SPECIES BY SURVEY PERIOD

Area	Species	Inches Mean Total Length (Number of Fish)					
		Pre-Amendment		Post-Amendment I		Post-Amendment II	
HILO HARBOR	Surgeons:						
	Acanthurus triostegus	5.00	(1)	3.28	(16)	7.57	(28)
	Acanthurus dussumieri	12.34	(19)	10.56	(16)	11.46	(43)
	Goatfishes:						
	Upeneus arge	10.80	(5)	----	---	9.35	(31)
	Mulloides flavolineatus	6.16	(45)	2.89	(82)	6.37	(849)
	Parupeneus porphyreus	8.00	(1)	5.53	(23)	10.00	(16)
	Mullet & Moi:						
	Mugil cephalus	12.75	(4)	11.36	(20)	12.93	(242)
	Polydactylus sexfilis	8.50	(5)	----	---	11.12	(103)
	Scombrids, Carangids & Snappers:						
	Scomberoides lysan	14.00	(1)	15.77	(12)	12.28	(25)
	Selar crumenopthalmus	6.00	(127)	----	---	7.63	(8147)
	Caranx ignobilis	8.09	(23)	7.56	(108)	13.36	(223)
	Lutjanus fulvus	6.25	(6)	5.62	(4)	6.90	(120)
	Miscellaneous Fishes:						
	Encrasicholina purpurea	3.50	(190)	----	---	----	---
	Herklosichthys quadrimaculatus	----	---	----	---	5.81	(213)
	Kyphosus cinerascens	---	---	11.91	(37)	7.82	(45)
	Kuhlia sandvicensis	3.80	(12)	4.46	(13)	6.17	(231)
	Crustaceans:						
	Portunus sanguinolentus	7.00	(6)	5.10	(10)	4.06	(521)
KEAUKAHA SHORELINE	Surgeons & Butterflyfishes:						
	Acanthurus triostegus	7.10	(15)	----	---	6.82	(124)
	Ctenochaetus strigosus	6.00	(9)	----	---	6.00	(5)
	Wrasses, Goat & Parrotfishes:						
	Thalassoma duperrey	5.50	(2)	----	---	6.10	(123)
	Mulloides flavolineatus	12.00	(1)	----	---	9.00	(1)
	Parupeneus porphyreus	12.00	(1)	----	---	13.33	(3)
	Parupeneus multifasciatus	10.65	(5)	----	---	10.67	(3)
	Scarus sordidus	17.29	(7)	----	---	17.60	(5)
	Mullet:						
	Mugil cephalus	4.50	(1)	----	---	21.53	(43)
	Carangids and Snappers:						
	Caranx ignobilis	11.50	(2)	----	---	11.25	(4)
	Miscellaneous Fishes:						
	Kuhlia sandvicensis	10.50	(2)	----	---	6.30	(157)
WAIAKEA POND PFA	Goatfishes:						
	Mulloides flavolineatus					9.00	(5)
	Carangids & Snappers:						
	Selar crumenopthalmus					7.73	(258)
	Caranx ignobilis					8.00	(5)
	Lutjanus fulvus					6.00	(2)
	Miscellaneous Fishes:						
	Kuhlia sandvicensis					6.25	(122)
	Mullet:						
	Mugil cephalus					13.87	(987)
	Crustaceans:						
	Scylla serrata					6.20	(30)

TABLE 5: SUMMARY OF SEASONAL TRENDS IN ABUNDANCE AND SIZE

Species	Months of Peak Abundance	Mean Size (in.)		Overall Trend in Length
		Min	Max	
Acanthurus dussumieri		5	18	Increasing
Acanthurus triostegus	May	3	8	Increasing
Caranx ignobilis	Sep-Nov	3	54	Increasing
Etrumeus microps		5	9	No trend
Herklosichthys quadrimaculatus	Sep-Dec	4	8	No trend
Kuhlia sandvicensis	Sep-Jan	4	8	Increasing
Kyphosus cinerascens	Jan-Mar	6	18	No trend
Lutjanus fulvus	Jan-Mar	3	12	No trend
Mugil cephalus	Sep-Nov	7	22	Increasing
Mulloides flavolineatus		2		Apparently recovering to Pre-Amendment level; smallest oama caught with scoop net
Panulirus penicillatus		4	6	No trend
Parupeneus porphyreus		5	18	Increasing
Plectroglyphidodon sindonis		3	6	No trend
Portunus sanguinolentus	Jul-Nov/Dec	4	7	Decreasing
Scomberoides lysan		7	22	Increasing
Scylla serrata		4	8	No trend
Selar crumenopthalmus		6	12	Increasing
Upeneus arge	Sep-Dec	8	16	No trend

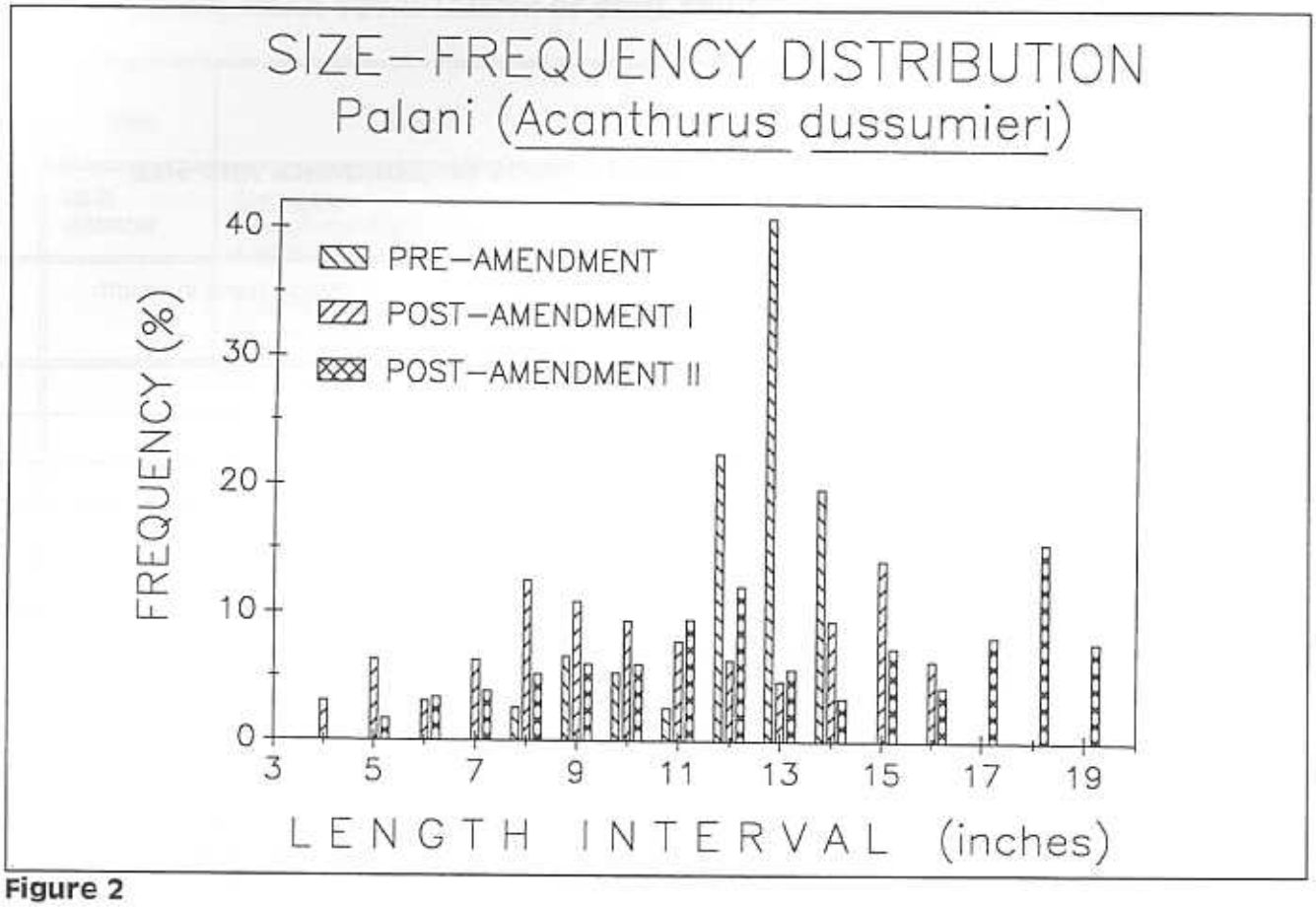

Figure 2

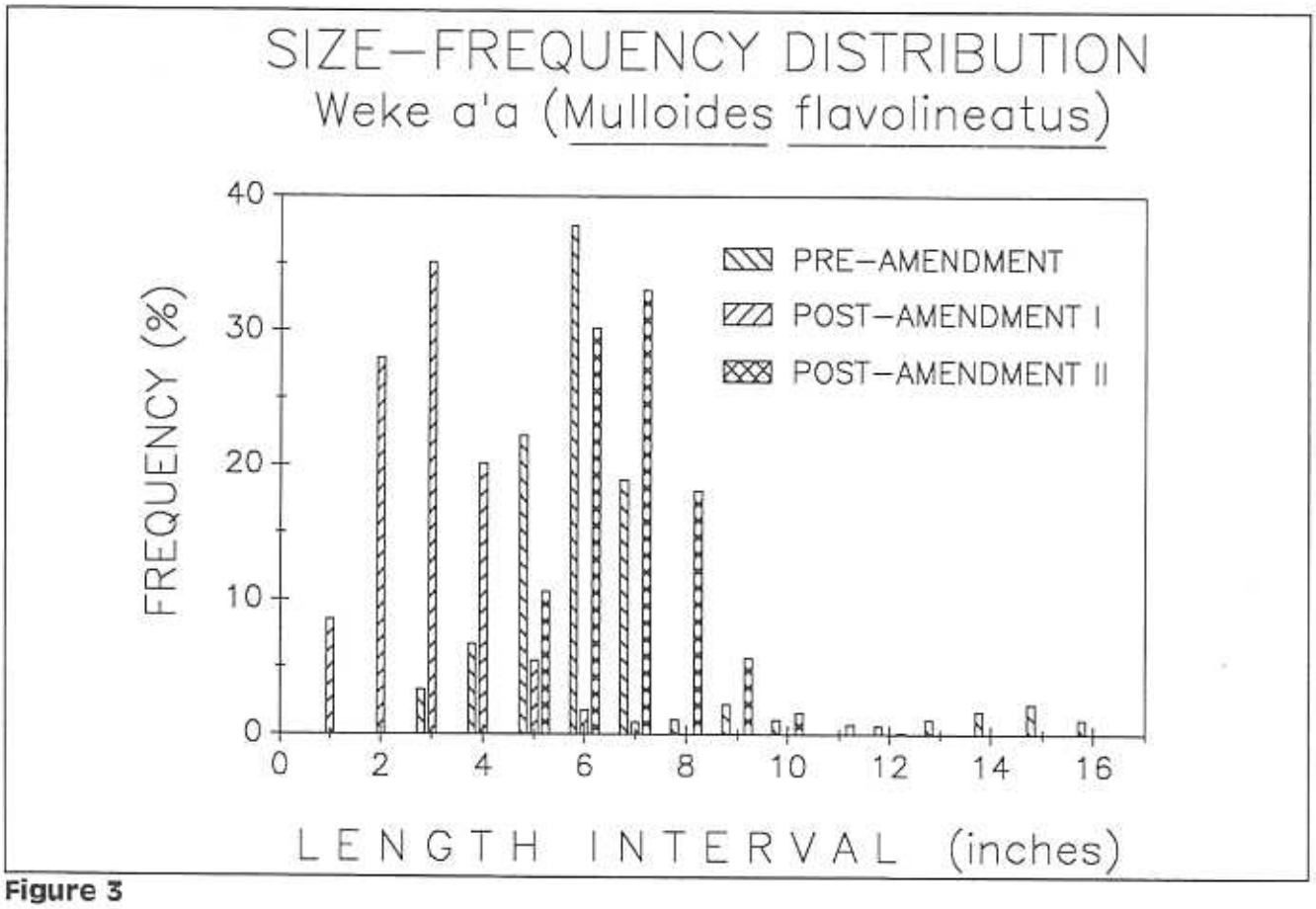

Figure 3

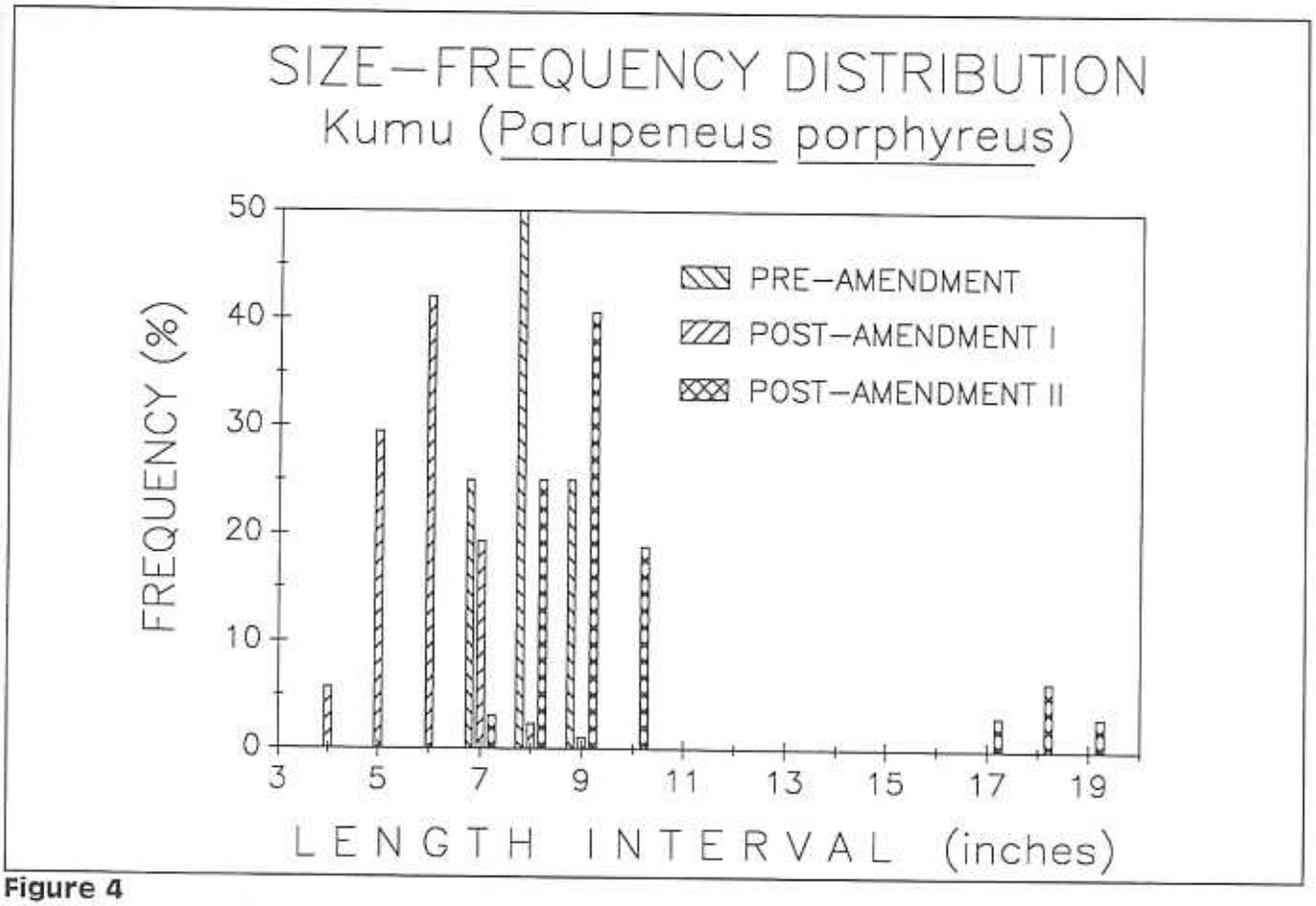

Figure 4

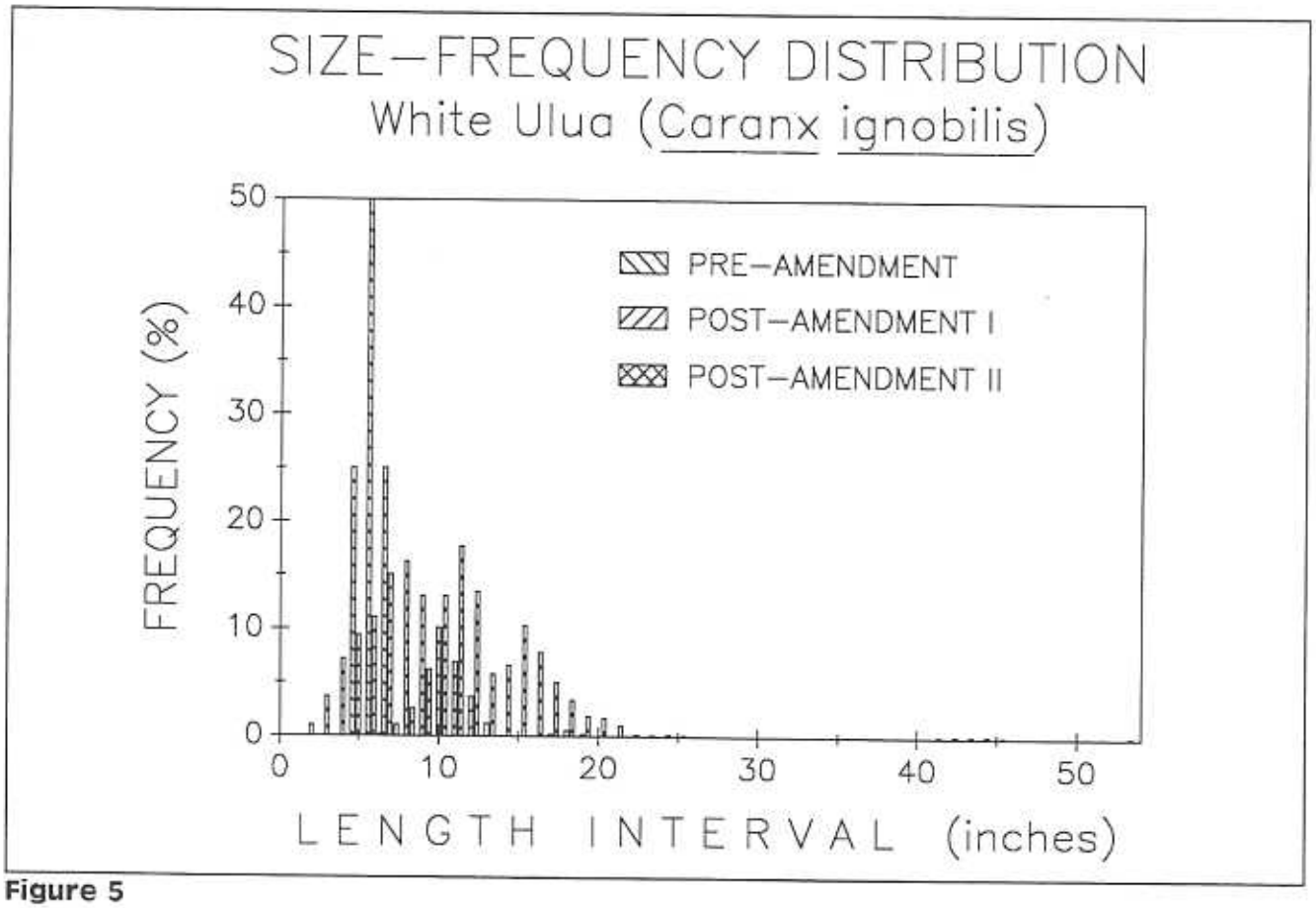

Figure 5

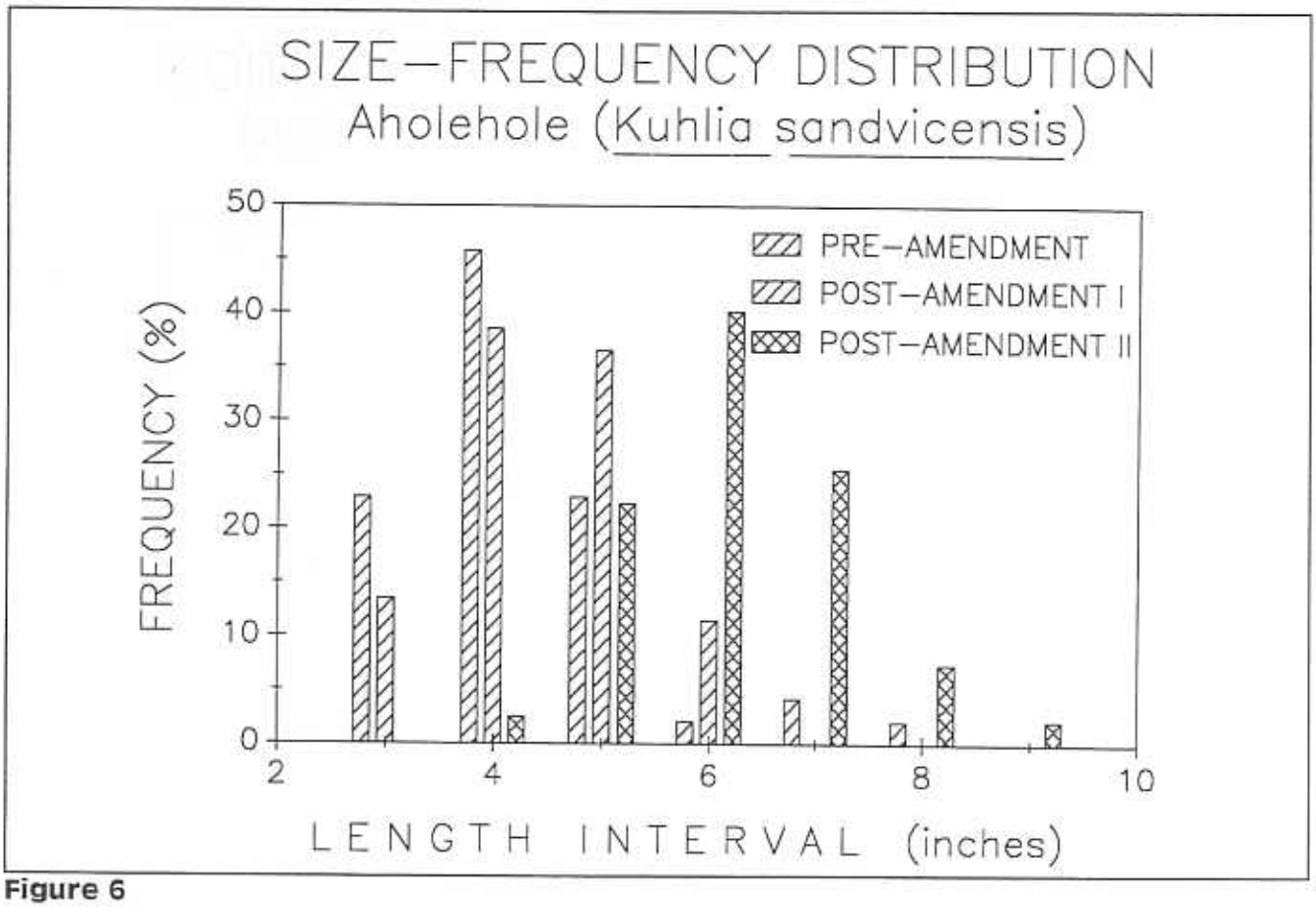

Figure 6

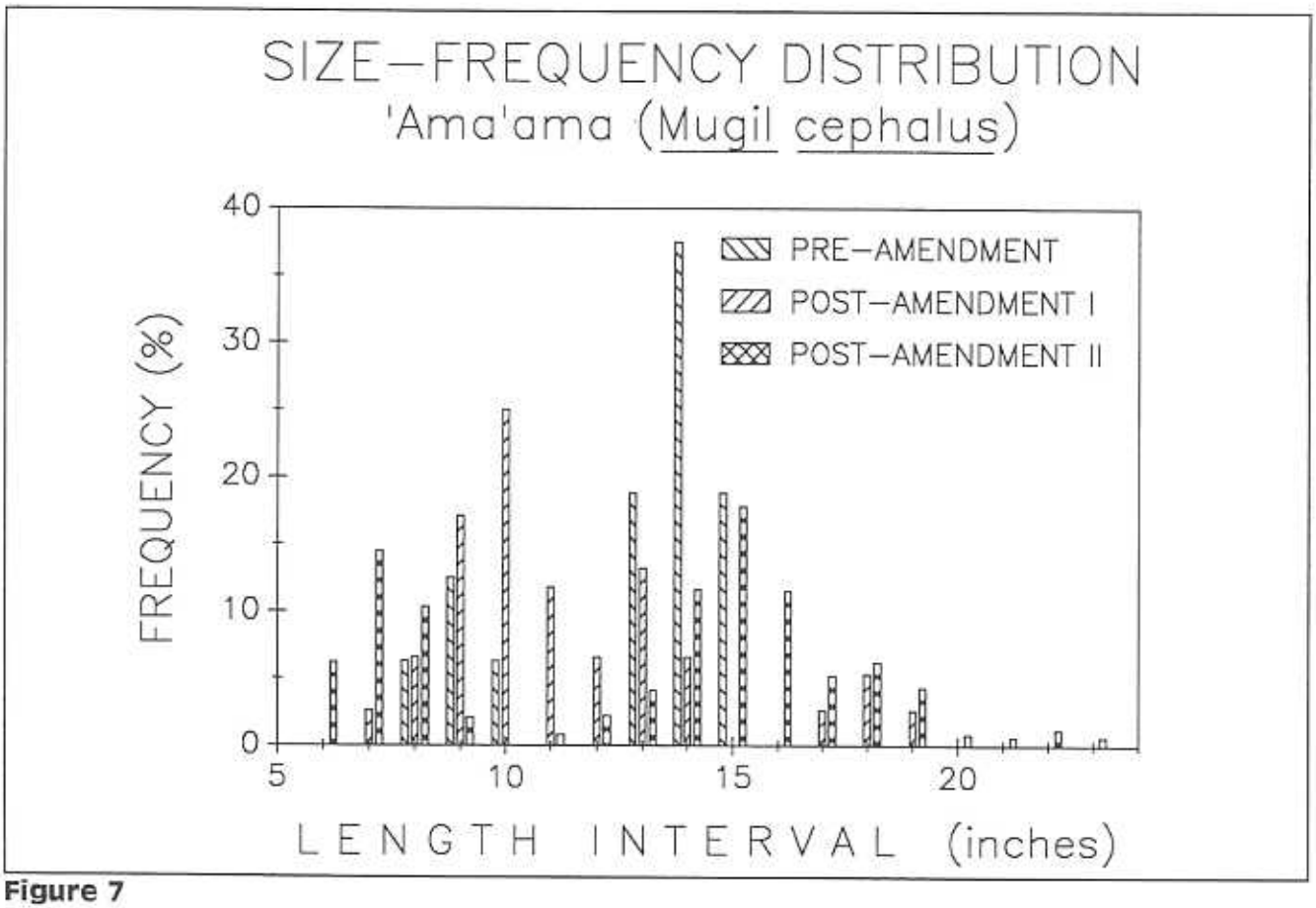

Figure 7

The mean number of fishers, fish caught, gears in operation, and CPUE (number of fish per gear-hour), were estimated irrespective of geartype for each of the three survey areas (Table 6). These values were calculated separately for weekdays versus weekends (or holidays), and for each time of day during which a significant change in fishing activity was observed. The time periods selected were: 1) 10:00 p.m. - 2:00 a.m., 2) 2:00-6:00 a.m., 3) 6:00 a.m. - 6:00 p.m., and 4) 6:00-10:00 pm. Fishing is allowed only between 6:00 a.m. and 6:00 p.m. in Waiākea Pond, and these were the only hours surveyed at Keaukaha, so those data were grouped within a single time period.

All these estimates were highly variable. The standard deviation ranged from only slightly larger to almost an order of magnitude greater than the mean, indicating that a much larger sample size is needed in order to adequately sample average landings. The number of fish caught per time period was the most variable parameter. Species-specific seasonal fluctuations in abundance are probably responsible for a lot of this variability; however, the limited number of interviews made in the same time period and location made it impossible to estimate seasonal means for landings and fishing activity.

TABLE 6: MEAN FISHING ACTIVITY BY SURVEY AREA, DAY OF THE WEEK, AND TIME PERIOD

Location	Weekday versus Wknd/Hol	Time of Day	Mean # Fishers (STD*)	Mean #Fish Caught (STD*)	Mean # Gear in Operation (STD*)	Mean CPUE** (STD*)	# Days Surv. (N)
Hilo Harbor	Weekend	10pm - 2am	7.3 (9.2)	18.7 (21.9)	10.3 (12.7)	0.57 (0.8)	2
Hilo Harbor	Weekend	2am - 6am	12.0 (16.0)	38.4 (72.6)	19.0 (26.6)	1.08 (1.1)	8
Hilo Harbor	Weekend	6am - 6pm	47.9 (242.7)	78.0 (394.5)	44.6 (101.7)	1.16 (7.8)	21
Hilo Harbor	Weekend	6pm -10pm	6.0 (---)	19.0 (---)	11.0 (---)	0.99 (---)	1
Hilo Harbor	Weekday	10pm -2am	9.9 (11.9)	19.9 (26.3)	15.5 (23.8)	1.20 (3.4)	3
Hilo Harbor	Weekday	2am - 6am	3.7 (2.4)	14.1 (27.7)	5.7 (4.6)	1.61 (3.0)	17
Hilo Harbor	Weekday	6am - 6pm	22.2 (213.2)	190.6 (1039.8)	20.8 (27.9)	3.42 (12.2)	96
Hilo Harbor	Weekday	6pm -10pm	18.0 (23.2)	49.1 (66.4)	22.5 (29.6)	1.71 (2.7)	5
Keaukaha	Weekend	6am - 6pm	18.8 (36.1)	77.8 (186.0)	21.1 (40.8)	2.71 (5.4)	13
Keaukaha	Weekday	6am - 6pm	4.5 (3.9)	16.1 (35.7)	4.7 (4.2)	5.62 (15.8)	18
Waiākea	Weekend	6am - 6pm	17.0 (24.5)	47.5 (202.6)	19.1 (35.6)	1.23 (6.2)	14
Waiākea	Weekday	6am - 6pm	11.2 (11.9)	39.4 (85.3)	11.1 (12.0)	0.93 (1.7)	37

TABLE LEGEND
STD* = Standard deviation
CPUE** = Catch per Unit Effort = number of fish per gear-hour
#Days Surv. = Number of Days Surveyed

Total landings were estimated for the same time periods and locations (Tables 7A-C) by multiplying average length and number of fish for each species by a species-specific length-weight conversion factor. These estimates must be viewed with caution, given the small sample size and high variability of daily estimates. The proportion of each geartype registered by area and time period is also included in the table; however, total landings estimates were made without regard for geartype, since the way the data were recorded on interview sheets (landings for all gears of a given fisher reported globally) made it impossible in some cases to accurately assess which gear caught which fish. The redesign of survey methodology to overcome this problem will be discussed.

TABLE 7A: ESTIMATED ANNUAL WEIGHT OF LANDINGS AND MEAN GEAR ABUNDANCE FOR HILO HARBOR

HILO HARBOR		10pm-2am		2-6am		6am-6pm		6-10pm		Daily Total
WEEKDAYS	Mean Wt. (lbs)	23.90		17.04		96.09		42.10		Mean: 179 lbs
	S.D.*	17.82		26.78		354.01		51.23		
	95% Conf.Int.	137.10		45.43		447.55		113.20		95% C.I.: 743 lbs
	n = # Days Surveyed	2		17		92		5		
	Rod/reel	8	58.1%	3	41.4%	9	37.8%	13	68.4%	
	Handpole	5	34.9%	2	32.1%	8	35.9%	5	26.3%	
	Thrownet	1	7.0%	1	13.3%	2	7.0%	1	5.3%	
	Scoop net			1	13.3%	0	---			
	Crab net					2	8.2%			
	Spear					2	6.7%			
	Handline					1	4.4%			
Total for 247 Weekdays						Based on Mean Wt. ---------->				44249 lbs
						Based on Upper 95% C.I. ---------->				183592 lbs
WEEKEND	Mean Wt. (lbs)	21.86		40.86		62.92		19.02		Mean: 145 lbs
	S.D.*	17.36		49.11		179.57				
	95% Conf.Int.	132.16		98.94		251.56		19.02		95% C.I.: 502 lbs
	n = # Days Surveyed	2		8		19				
	Rod/reel	6	66.7%	8	50.0%	24	70.3%	6	54.5%	
	Handpole	2	22.2%	8	50.0%	7	19.7%	5	45.5%	
	Thrownet	1	11.1%			1	4.1%			
	Handline					1	2.9%			
	Crab net					1	2.9%			
Total for 118 Weekend/Holidays:						Based on Mean Wt. ---------->				17069 lbs
						Based on Upper 95% C.I. ---------->				59197 lbs
Annual Total (365 Days):						Based on Mean Wt. ---------->				61318 lbs
						Based on Upper 95% C.I. ---------->				242789 lbs

TABLE LEGEND
S.D.* = Standard Deviation
95% C.I. = 95% Confidence Interval

TABLE 7B: ESTIMATED ANNUAL WEIGHT OF LANDINGS AND MEAN GEAR ABUNDANCE FOR THE KEAUKAHA SHORELINE

KEAUKAHA		6am - 6pm		Annual Total (6am-6pm only)
WEEKDAYS	Mean Wt. (lbs)	25.85		Mean: 6386 lbs
	Standard Deviation	41.58		
	95% Confidence Int.	70.44		95% C.I.: 17400 lbs
	n = # Days Surveyed	15		
	Rod/reel	3	20.6%	
	Handpole	4	31.6%	
	Spear	1	10.5%	
	Gillnet	1	7.9%	
	Thrownet	2	13.6%	
	Handline	2	15.8%	
WEEKEND/ HOLIDAYS	Mean Wt. (lbs)	97.98		Mean: 11562 lbs
	Standard Deviation	204.58		
	95% Confidence Int.	339.90		95% C.I.: 40108 lbs
	n = # Days Surveyed	8		
	Rod/reel	5	24.1%	
	Handpole	11	51.1%	
	Spear	2	6.8%	
	Gillnet	2	9.0%	
	Thrownet	2	9.0%	
Annual Total:		Based on Mean Wt. ---------->		17948 lbs
		Based on Upper 95% C.I. ---->		57508 lbs

TABLE 7C: ESTIMATED ANNUAL WEIGHT OF LANDINGS AND MEAN GEAR ABUNDANCE FOR WAIAKEA POND PUBLIC FISHING AREA

WAIAKEA POND		6am -6pm		Annual Total (6am-6pm only)
WEEKDAYS	Mean Wt. (lbs)	29.54		Mean: 7297 lbs
	Standard Deviation	39.45		
	95% Confidence Int.	69.77		95% C.I.: 17234 lbs
	n = # Days Surveyed	32		
	Rod/reel	7	66.8%	
	Handpole	2	14.6%	
	Handline	2	18.6%	
WEEKEND/ HOLIDAYS	Mean Wt. (lbs)	55.14		Mean: 6507 lbs
	Standard Deviation	106.10		
	95% Confidence Int.	169.72		95% C.I.: 20027 lbs
	n = # Days Surveyed	14		
	Rod/reel	12	35.6%	
	Handpole	2	5.9%	
	Handline	2	5.9%	
	Crab net	18	52.7%	
Annual Total:		Based on Mean Wt. ---------->		13804 lbs
		Based on Upper 95% C.I. ----->		37261 lbs

DISCUSSION

The results of this survey indicate a general increase in the size of fish landed in the Hilo area, following the closure of Hilo Harbor to gillnetting. Fish measured in Hilo Harbor, along the Keaukaha Shoreline and in Waiākea PFA were pooled for this evaluation, since most species inhabit the entire area during their seasonal migrations. Although the three zones surveyed have distinctive ecological characteristics, many stocks use the entire area during some phase of the life cycle.

Estimated annual landings for Hilo Harbor over a 24-hour period were in the range of 31-121 short tons. This total is based on an average of only 145-179 lbs of fish per day for the entire Harbor. Although this is only a rough estimate, clearly the small number of fish removed on a daily basis by shoreline fishers in this area constitutes a significant amount when compiled throughout the day, over all Hilo's fishers. The total harvest estimate may more than double when small boat landings are surveyed, since small boat fishers often use thrownets (with higher CPUE).

Problems and Solutions: Recommendations for a New Creel Survey Design

One of the purposes of this report was to evaluate the survey methodology and suggest any necessary modifications in the creel census procedure. Problems encountered during data analysis indicated the need for several major changes in survey methodology. Besides the need for more frequent sampling, the primary source of difficulty was the design of the survey forms themselves. The first specific recommendation is to redesign the survey form so that the catch, geartype and number of fishers are recorded in adjacent areas. As is seen in Appendix 1, the number of fishers, gears, species, number of fish, and mean length were recorded in three different areas of the survey form for the present survey. Thus, although this information was apparent during the interview, it was impossible to reconstruct catch per geartype or fisher from the survey form, once back in the office, without making a series of assumptions. Values of mean CPUE by geartype listed in Tables 2A-C were made, for example, based on the assumption that all fish registered on the form were caught on the first geartype listed on each survey form. This was correct in many cases, since only one gear was used; but there was no way to determine which catch corresponded to which gear in instances where several gears were registered. In some cases, there were several species and sizes to distribute between the gears and fishers listed. Although the surveyors felt they could figure this out to a certain extent from experience, it would have been invalid to subjectively classify the data on each form after the fact.

Another series of problems arose from the high variability of the survey effort. Interviews were not conducted with equal regularity over the various months, years and locations that data were collected. The location and frequency of interviews were both highly variable, being dependent upon the availability of vehicles and personnel. Thus, although some tentative comparisons of one month's data with another have been made, trends in the estimated volume of landings and effort, size or number of fish, must be interpreted with caution since the survey effort was not uniform. The wide margin of error in total landings estimates (Tables 7A-C) is largely due to the unequal and extremely small sample sizes at certain times and locations. The high variance in means for number of fishers, CPUE, etc., might have been reduced somewhat by grouping the data seasonally, but the small number of samples available throughout the year made this impossible.

Refinements in methodology to improve estimates of total landings will probably develop over time, but the general recommendation at this time is to develop a stratified random sample of the three unique fishing habitats encountered in the Hilo area: Hilo Harbor, Waiākea Pond and the Keaukaha Shoreline. Since the purpose of the surveys is to be able to estimate total landings, surveying should be stratified around fishing areas, geartypes, and times of the day or week when average values for these parameters are likely to vary significantly. Time strata should vary by location, according to the times when fishing activity changes notably within each area. Fishing activity in Hilo Harbor is most variable. For the Harbor, the 24-hour day would be divided into four time periods from: 1) 10:00 p.m. to 2:00 a.m., 2) 2:00-6:00 a.m., 3) 6:00 a.m. to 6:00 p.m., and 4) 6:00 to 10:00 p.m.. Fishing activity in Waiākea PFA and along the Keaukaha Shoreline is less variable. Waiākea PFA can be considered as a single stratum, from 6:00 a.m. to 7:30 p.m., and two time strata will be sufficient for Keaukaha, from: 1) 6:00 a.m. to 6:00 p.m. and 2) 6:00 p.m. to 6:00 a.m..

The number of interviews needed as a function of geartype, location, and time of day must be determined through surveys as well, but a much larger sample size is needed than has previously been available. Parameters such as CPUE and number of gears in operation may be more variable for some gears than for others. For example, gears such as throwmets can occasionally "get lucky" and capture a large number of fish. Spear fishing is a method which may require longer periods of observation in order to obtain a meaningful estimate of CPUE, since a great deal of time may be spent searching for fish, after which a large (or small) fish may be caught in a relatively short period of time.

There should be three separate survey forms, such as those shown in Appendix 5A-C, designed to:

1) record the total number of fishers by geartype in a given area during the time block that interviewing is taking place (Participation Survey, Form A),

2) register landings data by geartype, species and fisher (Interview Form B), and

3) maintain a monthly (or bi-weekly) tally of length-frequency data by geartype for the 10 principal species (Size-Frequency Data, Form C).

The data from Forms A and B would be used to estimate total landings. Form C would compile the information needed to evaluate length-frequency distributions and derive estimates of gear-specific fishing mortality (Pauly and Palomares, 1989; del Norte and Pauly, 1990). Data in Form C could be recorded separately for each fishing area. An adequate sample size for length-frequency data should be determined for each species and gear, based on observed variability. Once this number of fish was measured, subsequent measurements could be foregone until the following month.

Despite the difficulties in interpretation described in this report, creel survey data for fiscal years 1989-90 represent the most detailed information on the composition of recreational landings by species, size and geartype available for any inshore fishery in Hawaii prior to 1993. This report has merits as a basis for improvement of future surveys. In addition to providing feedback regarding the makeup of Hilo's shoreline fisheries, these surveys define the principal gears and species used recreationally and indicate that management measures that restrict gillnet fishing may indeed be helping to restore fish populations in the Hilo area.

ACKNOWLEDGEMENTS

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REFERENCES

Clarke, J.R.K. 1985.
Beaches of the Big Island. University of Hawaii Press, Honolulu, 171pp.

DAR 1990.
Hawaii Fishing Regulations. Hawaii Department of Land and Natural Resources, Division of Aquatic Resources, Information and Education Project. 43 pp.

Dudley, W.C., L.E. Hallacher, T. Hammond, S. Skipper, J. Kalua, S. Crane, S. Miller, R. Aina, A. Sagucio and K. Alspach. 1991.
Distribution and dispersion of sewage pollution in Hilo Bay and contiguous waters. Univ. of Hawaii, Hilo. Marine Option Program. Prepared for Hawaii County Dept. of Public Works. 61pp, 25 Tables, 175 Figs. + Appendices.

Kelly, M., B. Nakamura, D.B. Barrére 1981.
Hilo Bay: A Chronological History. Bernice Bishop Museum. Prepared for US Army Engineer District, Honolulu, Contract No. DACW84-80-C-0015. 341pp.

Kuamo'o, D.K. and M. Kaichi (unpublished ms)
Recreational creel census in Hilo Harbor, September, 1985 through June, 1988. Draft report. DAR/DLNR Hilo, 5pp + tables.

A.G.C. del Norte and D. Pauly 1990.
Virtual population estimates of monthly recruitment and biomass of rabbitfish, *Siganus fuscescens* of Bolinao, North Philippines. pp. 851-854. in: R. Hirano and I. Hanyu (eds.). The Second Asian Fisheries Forum, Asian Fisheries Society, Manila, Philippines. 991 pp.

Pauly, D. and M.L. Palomares 1989.
New estimates of monthly biomass, recruitment and related statistics of anchoveta (*Engraulis ringens*) off Peru (4-14°S), 1953-1985. pp. 189-206. in: D. Pauly, P. Muck, J. Mendo and I. Tsukayama (eds.). The Peruvian Upwelling Ecosystem: Dynamics and Interactions. 438 pp.

Pukui, M.K., S.H. Elbert and E.T. Mookini 1976.
Place Names of Hawaii. University Press of Hawaii, Honolulu, (2nd edition) 289pp.

Wallen, B. and L. Mazarakis (unpublished data)
Recreational fishing survey in Hilo Bay. in: Kuamo'o, D.K. and M. Kaichi (ms). University of Hawaii at Hilo, Marine Option Program student project for DAR Hilo.

APPENDIX 1: SURVEY QUESTIONNAIRE

NUMBER _____

BIG ISLAND RECREATIONAL FISHING CREEL CENSUS

DATE: __/__/__ DAY: S M T W TH F Sa Interview by:_____

LOCATION:_____ SEA STATE: 0 1 2 3

Time Started Fishing	Time of Interview		

METHODS (No. & Gear Type)

(1) rod/reel _____ (5) gillnet _____
(2) handpole _____ (6) surround _____
(3) spear _____ (7) thrownet _____
(4) scoop net _____ ( ) (other) _____

No. Fishers By Age Group	
Male	Female

Spp. Code	Species	No. Org.	Total Length (inches)

Spp. Code	Species	No. Org.	Total Length (inches)

Where do you live? _____

How often do you fish here? _____ times per _____

Comments: _____

_____

Total Hours Fished	Total No.of Fishers	Total Man-Hours	Total No.of Fish	CATCH PER UNIT EFFORT No. caught/man-hour

State of Hawaii, Div.Aquatic Resources 75 Aupuni St., Rm. 220, Hilo, HI 96720

APPENDIX 2: FREQUENCY AND LOCATION OF INTERVIEWS CONDUCTED BY SURVEY PERIOD

LOCATION	SURVEY PERIOD					
	PRE-FMA		POST-FMA I		POST-FMA II	
	Freq.	%	Freq.	%	Freq.	%
Waiākea Pond	---	---	---	---	388	20.0
Radio Bay	5	3.6	20	8.3	82	4.2
Pier 3	2	1.4	---	---	16	0.8
Reed's Bay	17	12.2	20	0.8	36	1.9
Isles Area	20	14.4	44	18.3	764	39.4
Bayfront	31	22.3	81	33.6	208	10.7
Ale'ale'a Point	---	---	12	5.0	12	0.6
Richardson's Park	3	2.2	---	---	17	0.9
Leileiwi Beach Park	7	5.0	---	---	60	3.1
Pier 2	10	7.2	11	4.6	31	1.6
Suisan Dock	7	5.0	41	17.0	69	3.6
Coconut Island	25	18.0	15	6.2	60	3.1
Wailuku Lighthouse	1	0.7	3	1.2	2	0.1
Pier 1	4	2.9	1	0.4	52	2.7
Liliuokalani Park	3	2.2	---	---	35	1.8
Bayview Banyan	---	---	---	---	2	0.1
Hilo Breakwater	4	2.9	10	4.1	2	0.1
Hilo Bay (unspecified)	---	---	1	0.4	---	---
King's Landing	---	---	---	---	4	0.2
James Kealoha Park	---	---	---	---	23	1.2
Onekahakaha Beach	---	---	---	---	12	0.6
Baker's Beach	---	---	---	---	62	3.2
TOTALS:	139		241		1937	

APPENDIX 3: COMMON AND SCIENTIFIC NAMES OF SPECIES CAPTURED IN HILO BAY

GROUP/COMMON NAME	LOCAL NAME	SCIENTIFIC NAME
Cardinalfishes (unspecified)	Upapalu	Family: Apogonidae
Triggerfishes (unspecified)	Humuhumu	Family: Ballistidae
Needlefishes (unspecified)	Aha	Family: Belonidae
Flounders/Flatfishes (left-eye)	Pakii	Family: Bothidae
Hawkfishes (unspecified)	Pilikoa	Family: Cirrhitidae
Stingrays (general)	Hihimanu/Lupe	Family: Dasyatidae
Wrasses (general)	Hinalea	Family: Labridae
Bigeye (not a tuna)	Aweoweo	Family: Priacanthidae
Parrotfishes (general)	Uhu	Family: Scaridae
Lizardfishes (general)	Ulae	Family: Synodontidae
Hawaiian sergeant	Mamo	*Abudefduf abdominalis*
Blackspot sergeant	Kupipi	*Abudefduf sordidus*
Achilles tang	Pakuikui	*Acanthurus achilles*
Spotted tang	Api	*Acanthurus guttatus*
Brown surgeonfish	Maiko	*Acanthurus nigroris*
Eye-stripe surgeonfish	Palani	*Acanthurus dussumieri*
Convict Tang	Manini	*Acanthurus triostegus*
Ringtail surgeon fish	Pualu	*Acanthurus mata*
Yellowfin surgeonfish	Pualu	*Acanthurus xanthopterus*
Bonefish	Oio	*Albula* sp.
Pearl wrasse	Opule	*Anampses cuvier*
Iridescent cardinalfish	Upapalu	*Apogon kallopterus*
Spotted cardinalfish	Upapalu	*Apogon maculiferus*
Stripebelly puffer	Makimaki	*Arothron hispidus*
Spotted puffer	O'opu-hue	*Arothron meleagris*
Hawaiian hogfish	'A'awa	*Bodianus bilunulatus*
Limpet	Opihi 'ālinalina	*Cellana sandwichensis*
Stareye parrotfish	Ponuhunuhu	*Calotomus carolinus*
Giant trevally	White ulua	*Caranx ignobilis*
Forskal's jack	Omilu	*Caranx melampygus*

APPENDIX 3 (continued): COMMON AND SCIENTIFIC NAMES OF SPECIES CAPTURED IN HILO BAY

GROUP/COMMON NAME	LOCAL NAME	SCIENTIFIC NAME
Black-tip shark	Mano	*Carcharhinus melanopterus*
Tahitian grouper	Roi	*Cephalopholis argus*
Blue-line butterflyfish	Kikakapu	*Chaetodon frembili*
Fourspot butterflyfish	Lau-hau	*Chaetodon quadrimaculatus*
Raccoon butterflyfish	Kikakapu	*Chaetodon lunula*
Milletseed butterfly	Lau wiliwili	*Chaetodon miliaris*
Milk fish	Awa	*Chanos chanos*
Red-legged swimming crab	Ala'eke	*Charybdis erythrodactyla*
Redbar hawkfish	Pilikoa	*Cirrhitops fasciatus*
Stocky hawkfish	Po'opa'a	*Cirrhitus pinnulatus*
White eel	Puhi uha	*Conger cinereus*
Goldring surgeon fish	Kole	*Ctenochaetus strigosus*
Mackerel scad	Opelu	*Decapterus macarellus*
Lionfish	(none)	*Dendrochirus barberi*
Spotted porcupine fish	Kokaka	*Diodon hystrix*
Spiny puffer	O'opu okala	*Diodon holocanthus*
Eleotrid goby	O'opu akupa	*Eleotris sandwicensis*
Hawaiian anchovy	Nehu	*Encrasicholina purpurea*
Round (Japanese) herring	Mikiawa (shaker)	*Etrumeus micropus*
Cornet fish	Nunu peke	*Fistularia commersoni*
Yellowspot trevally	Ulua pa'opa'o	*Gnathanodon speciosus*
Moray eel	Puhi paka	*Gymnothorax flavimarginatus*
Wavy-lined eel	Puhi lau milo	*Gymnothorax undulatus*
Halfbeak	Iheihe	*Hemiramphus depaueratus*
Blue-line herring	Gold-spot herring	*Herklotsichthys quadrimaculatus*
Bigeye (not a tuna)	Aweoweo	*Heteropriacanthus cruentatus*
Hawaiian flagtail	Aholehole	*Kuhlia sandvicensis*
Brown chub/Lowfin chub	Nenue	*Kyphosus bigibbus*
Brown chub/Lowfin chub	Nenue	*Kyphosus cinerascens*
Brown chub/Lowfin chub	Nenue	*Kyphosus vagiensis*
Blueline snapper	Taape	*Lutjanus kasmira*

APPENDIX 3 (continued): COMMON AND SCIENTIFIC NAMES OF SPECIES CAPTURED IN HILO BAY

GROUP/COMMON NAME	LOCAL NAME	SCIENTIFIC NAME
Blacktail snapper	Toau	*Lutjanus fulvus*
Black durgon	Humu eleele	*Melichthys niger*
Bigeye emperor	Mu	*Monotaxis grandoculis*
Striped Mullet	Amaama	*Mugil cephalus*
Yellowstripe goatfish	Weke a'a	*Mulloides flavolineatus*
Yellowfin goatfish	Weke ula	*Mulloides vanicolensis*
Brick soldierfish	U'u	*Myripristis amaena*
Bigscale soldierfish	U'u	*Myripristis berndti*
Goldfinned soldierfish	U'u	*Myripristis chryseres*
Bluespine unicornfish	Kala	*Naso unicornis*
Orangespine unicornfish	Umaumalei	*Naso lituratus*
False mullet	Uouoa	*Neomyxus leuciscus*
Day octopus	Tako/He'e	*Octopus cyanea*
Spotted trunkfish	Moa	*Ostracion meleagris*
Red spiny lobster	Red ula	*Panulirus marginatus*
Spiny lobster	Green ula	*Panulirus penicilatus*
Arc-eye hawkfish	Pilikoa	*Parcirrhites arcatus*
Whitesaddle goatfish	Kumu	*Parupeneus porphyreus*
Manybar goatfish	Moana	*Parupeneus multifasciatus*
Fantail filefish	Oiliuwiuwi	*Pervagor spilosoma*
Long-eyed swimming crab	Mo'ala crab	*Podophthalmus vigil*
Threadfin	Moi	*Polydactylus sexfilis*
White crab	Kuahonu crab	*Portunus sanguinolentus*
Bigeye (not a tuna)	Aweoweo	*Priacanthus meeki*
Silverside	Iao	*Pranesus insularum*
Tahitian squirrelfish	Alaihi	*Sargocentron tiere*
Hawaiian squirrelfish	Alaihi	*Sargocentron xantherythrum*
Parrotfish	Uhu	*Scarus formosus*
Bullethead parrotfish	Uhu	*Scarus sordidus*
Palenose parrotfish	Uhu	*Scarus psittacus*
Leatherback	Lae	*Scomberoides lysan*

APPENDIX 3 (continued): COMMON AND SCIENTIFIC NAMES OF SPECIES CAPTURED IN HILO BAY

GROUP/COMMON NAME	LOCAL NAME	SCIENTIFIC NAME
Scorpionfish	Nohu	*Scorpaenopsis cacopsis*
Samoan crab	Samoan crab	*Scylla serrata*
Slipper lobster	Ula papapa	*Scyllarides squamosus*
Bigeye scad	Akule/halalu	*Selar crumenophthalmus*
Barracuda	Kaku	*Sphyraena barracuda*
Barracuda	Kawalea	*Sphyraena helleri*
Hammerhead shark	Mano kihikihi	*Sphyrna zygaena*
Pacific gregory/ Yellow-eye damselfish	Mamo	*Stegastes fasciolatus* or *Plectroglyphidodon sindonis*
Crenate swimming crab	Blue-pincher crab	*Thalamita crenata*
Surge wrasse	Hau	*Thalassoma purpureum*
Saddle wrasse	Hinalea lauwili	*Thalassoma duperrey*
Christmas wrasse	Awela	*Thalassoma trilobatum*
Nightmare weke	Weke pueo	*Upeneus arge*
Davies' stingray	Hihimanu/Lupe	*Urotrygon daviesi*
Australian mullet	Summer mullet	*Valamugil engeli*

APPENDIX 4A: RECOMMENDED NEW CREEL CENSUS FORMS
PARTICIPATION SURVEY: TALLY OF FISHERS BY GEARTYPE
(FORM A)

Form Number-Letter: ___-__

Date: __/__/9_ Area (circle one): HILO HARBOR KEAUKAHA WAIAKEA PFA

DAY: S M T W Th F Sa Holiday Sea State: 0 1 2 3 Weather: Raining __ Dry __ Voggy __

Percent Cloud Cover: 0-25% __ 26-50% __ 51-75% __ >75% __

Time started tally _____ Time completed tally _____

Time Period (circle one):

HILO HARBOR	2200-0200 hrs	0200-0600 hrs	0600-1800 hrs	1800-2200 hrs
KEAUKAHA	0600-1800 hrs		1800-0600 hrs	
WAIAKEA PFA	0600-1930 hrs			

Geartype	Gear Code	Number of Fishers	
		Running Tally	Total
		Total Number Fishers This Area ------->	

APPENDIX 4B: RECOMMENDED NEW CREEL CENSUS FORMS
CPUE DATA/INDIVIDUAL OR GROUP INTERVIEWS
(FORM B)

Interview Number: _ - -_

Date: ___/___/9__ Location _____ Location Code _____

DAY: S M T W Th F Sa Holiday Interview Time: _____ Fishing from: Shoreline _____
Time Started Fishing: _____ Boat _____

Time Period (circle one):

HILO HARBOR	10:00pm-2:00am	2:00-6:00am	6:00am-6:00pm	6:00-10:00pm
KEAUKAHA	6:00am-6:00pm		6:00pm-6:00am	
WAIAKEA	6:00am-7:30pm			

No. of Fishers	Gear-Code	Geartype	No.of Gears	Hours Fished	Species Caught	Spp. Code	No. Fish	Weight (lbs)
Total # Fishers↓				Total # Gear-hrs↓		Total #Spp↓	Ttl.# Fish↓	Ttl. Wt ↓
		Total No. Gears →						

About how many hours do you fish per day? _____

About how many hours per day do you use each type of gear? ----------->

Geartype/Code	Hrs/day

Interviewed by: _____

APPENDIX 4C: RECOMMENDED NEW CREEL CENSUS FORMS
LENGTH-FREQUENCY DATA (FORM C)

Number _____

Species _____ Species Code _____ Geartype _____ Gearcode _____

Location Fished _____ Location Code _____ Month/Date(s) Covered _____ to _____

Length Interval (cm)	Running Tally (number of fish per length interval)	Total
	Total number of organisms measured ---------->	

Additional Observations: _____

_____

Funded in part by the Federal Aid in Sport Fish Restoration Program, through your purchase of fishing equipment and motor boat fuels.

The Department of Land and Natural Resources receives financial support under the Federal Aid in Fish and Wildlife Restoration and other federal programs. Under Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, and the laws of the State of Hawaii, the U.S. Department of the Interior and the State of Hawaii prohibit discrimination on the basis of race, color, religion, sex, national origin, age, and physical or mental handicap. If you believe that you have been discriminated against in any program, activity or facility, or if you desire information, please write to the U.S. Fish & Wildlife Service, Office for Human Resources, 1849 C Street NW, Room 3058, Washington, DC 20240.