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PRELIMINARY RESULTS OF THE HAWAII SMALL-BOAT FISHERIES SURVEY

David C. Hamm and Henry K. Lum

Honolulu Laboratory
Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96822-2396

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PREFACE

The fielding of this survey was funded by a Commercial Fisheries Research and Development Act (P.L. 88-309) grant from the National Marine Fisheries Service to the Hawaii Division of Aquatic Resources (HDAR). The survey was conducted by a private research firm under contract to HDAR. The survey results were compiled by the Western Pacific Fishery Information Network (WPACFIN) of the Honolulu Laboratory; WPACFIN was primarily responsible for preparing the summaries and analyzing the data. The data provided in this report are preliminary.

INTRODUCTION

Understanding and properly managing marine fisheries resources requires information on a broad range of factors that influence and impact the resources as well as the fisheries exploiting them. Catch and effort statistics from the commercial, recreational, and subsistence components of the fisheries are principal and fundamental pieces of information used in fisheries management. These data had not been systematically collected in Hawaii for the recreational and subsistence small-boat fisheries for about 10 years, but a survey was conducted recently to obtain them for the island of Oahu, Hawaii, where the majority of the State's population resides. This report makes available some of the basic summary data and preliminary results of the survey that was conducted from March 1990 to May 1991. A more thorough survey description and a more complete data analysis will be available later. Although other information can be extracted from the data collected during the survey, the principal purpose of conducting this survey was to estimate the annual catch and effort of the small-boat fleet on Oahu.

METHODS

Survey Design

Simply stated, the survey consisted of counting boats and interviewing fishermen at eight public launching facilities on Oahu during selected days of each month and using the sample data collected to estimate island-wide catch and effort during some time period. Only small-boat activity was monitored at these eight ports during each sample day. The term "small-boat" refers to any size of vessel moored or launched at any of the eight public ports on Oahu, except for certain easily identifiable commercial vessels, such as the aku sampans, large-scale charter boats, and longliners, which occasionally use these eight ports. The sample included commercial and recreational small boats. A large portion of the small-boat fishing activity on Oahu originates at the eight sampled public marinas and launching ramps, but no attempt was made to document the amount of activity which originates elsewhere on the island. The data in this report represent only that portion of fishing activity occurring out of the eight sampled ports; therefore, the results are conservative estimates of island-wide activity.

Sampling activity was stratified by port and by day type (weekday versus weekend or holiday), because significant differences exist between ports and participation is considerably higher during weekends and holidays than the average weekday. For data collection and expansion purposes, fishing method was also important because participation and catch per unit effort (CPUE) vary considerably between methods. Therefore, **sample strata** are combinations of data for each **port and day type**, whereas **expansion strata** are combinations of data for each **port, day type, and fishing method.**

The eight sampled ports were divided into four major and four minor ports, depending on the perceived amount of boat activity (Fig. 1). Since large commercial vessels were excluded from the sample, so were Kewalo and Honolulu Harbors where large vessels comprise most of the total port activity and no public launching ramp exists. One major port was selected for each coast of Oahu, and two minor ports occurred on the east and south coasts. No minor ports exist for the west and north coasts. One minor and two major ports were simultaneously sampled on any given sample-day. Sampling at a specific port and day is defined as a port-day. Available funding for the data collection program permitted four sample-days per month with a fifth sample-day occasionally added. To ensure that every major port combination was sampled within each 3-month period, major ports were sampled during two weekdays and two weekend/holiday days monthly, and the combination and order of ports were randomly selected without replacement. To ensure that each minor and major port combination was sampled at least once every 6 months, minor ports were randomly paired with major ports without replacement. This sampling strategy was selected to document the relationships among ports to improve the design for future surveys. A total of five 3-month periods were sampled beginning March 1990 and ending May 1991.

Sampling at a designated port was conducted from 1 hour before sunrise until 1 hour after sunset. Two principal activities were accomplished during each port-day: (1) vessels leaving and returning to the port were counted and identified, and (2) as many returning vessel operators as possible were interviewed for catch, effort, and species composition. Figure 2 shows the boat log sheet used to record each time a vessel left or returned to the port area and what, if any, fishing method was used--information that was the top priority of each sampler. Figure 3 shows the offshore creel survey form used to record data on total catch, effort, and species composition for each fishing method used from as many returning vessel operators or knowledgeable occupants as possible.

Data Collecting and Processing

Data collection and initial data entry were conducted by a local research survey company under contract to the Hawaii Division of Aquatic Resources (HDAR). The HDAR staff coordinated training of port samplers and generally oversaw the fielding of the survey. Extensive data verification, quality control, and editing were done by the National Marine Fisheries Service, Honolulu Laboratory, Western Pacific Fishery Information Network

(WPACFIN), which also handled all computer programming, data processing, report summarization, analysis, and presentation. Figure 4 summarizes the major data processing steps and the significant data-base files used. A mainland consulting company specializing in fisheries surveys was contracted by WPACFIN to review the survey design and data expansion algorithms to ensure the statistical validity of the calculations.

Assumptions

Any survey requires certain assumptions regarding the samples taken and the data collected, if the sample data are to be expanded to estimate what happened in the whole population. The sample must be representative of the population and must contain adequate coverage of each stratum. The proportion of the total population included in the sample must be known, and all recorded data must be complete, unbiased, and accurate in all respects, or distorted expansions may result. Although considerable effort was expended to ensure these conditions were met, as with any survey, they were not fully met.

Limitations and Problems

Determining an adequate level of sampling depends on the variability of the parameters being measured and the desired level of confidence in the results. Unfortunately, the true variability of the catch and effort parameters in the entire population of small-boat fisheries on Oahu was unknown, and funds to conduct the field sampling were limited. Therefore, the maximum sample size was based on available funds. The level of confidence in the results was statistically determined after the survey was completed.

Some data were not recorded accurately. Port samplers varied in their interpretation and understanding of some of the survey questions. Other data recording problems occasionally occurred as well; species were misidentified, boat numbers on the vessel log sheets were incomplete, fishing methods were misidentified or were not indicated on the log sheets, or interviews were not completed. Some fishermen refused to provide information on the intended disposition of their catch, while others refused to be interviewed at all. One other problem was the lack of interviews recording any species composition of the catch. Therefore, to provide reasonable species composition figures for each fishing method, interviews were pooled across day types for each port. If no interviews containing species identification were made during the year for a port and fishing method but catch had been estimated, then all of the estimated catch was allocated to an appropriate miscellaneous species category for that method (i.e., trolling to pelagics (misc.), bottomfishing to bottomfish (misc.), spearfishing to reef fish (misc.), and so on). Some of the rare fishing methods have too few interviews for the entire sample period to be representative of true species composition. Data recording problems were identified by WPACFIN's data quality-control programs; WPACFIN staff rectified the problems if possible or, when appropriate, eliminated the data from the expansion and analysis phases to reduce possible distortions.

Expansion Process and Algorithms

The following briefly describes the procedures used to expand the sample data to island-wide estimates of catch, effort, and species composition (Appendix A; Fig. 5). All effort is reported in number of trips, even though effort, through expansion, can be presented in hours for active fishing methods. Although it is possible to expand the survey data by any whole-month time period, selecting combinations other than the 3-month sample blocks or contiguous combinations thereof is not recommended because unusual port combinations and inadequate coverage may result. Quarterly and annual expansion results are presented.

In the expansion process, data for each sample stratum (port and day type combination) are handled separately, and within each sample stratum, each fishing method is expanded separately, thus creating the expansion strata (port, day type, method). The expansion stratum is used because most fisheries parameters vary significantly between methods (e.g., mean catch, effort, CPUE, and species composition are very different for trolling, bottomfishing, spearing, netting, and so on). Whenever the number of interviews for any expansion stratum is less than two, the mean CPUE in the expansion algorithm is based on the average aggregate catch per trip for all interviews collected for a particular fishing method during the 15-month survey period. In the expansion process, the average daily number of trips for each expansion stratum is multiplied by the number of days in the time period, to estimate the total effort. The estimated total effort (i.e., the number of trips) is multiplied by the average catch per trip to estimate the total catch (e.g., for each stratum: avg. trips * days = total effort; total effort * avg. catch = total catch). To determine the species composition of the total catch for each expansion stratum, the estimated total catch is multiplied by the percent species composition of the sampled catch (e.g., total catch * avg. species = total catch per species). Variances of the mean daily effort, mean catch per trip, and estimated total catch are calculated by using standard formulas for variance of a mean, variance of a ratio estimator, and variance of products, respectively (Cochran 1977, Malvestuto 1991, and Meyer 1975). Summary statistics are created by summing the calculated values and variances across strata.

RESULTS

The following tables and graphs provide some of the basic information available from the summaries and analysis of the survey data. They are by no means exhaustive of the types of summaries that can be produced. Although it is not the intent of this preliminary report to analyze and interpret these summary statistics, some general comments follow regarding the tables and figures. The reader is reminded that these are considered preliminary results and that the estimates are for that portion of Oahu covered during the sampling program. Not all table columns will total, because of rounding.

Tables 1 through 4 and Figure 6 provide catch and effort statistics for each of the five 3-month sample periods. Catch and effort in the fifth quarter of the 15-month sample period was relatively low, perhaps because of the relatively high number of poor weather days that seemed to occur on the sample days randomly selected for this time period. These tables also provide two estimates of annual statistics for March 1990-February 1991: One estimate is the sum of the strata across the first four quarterly periods, and the other is the annual expansion of combined data for the same period. Interestingly, the annual estimates calculated by these two methods vary only slightly in their expanded numbers, and as expected, the coefficients of variation are slightly better for the annual estimates created by summing across the four quarters. All remaining tables and figures present annual data expanded by the second method.

The most frequently used fishing method was trolling, which accounted for 53% of the total number of estimated trips (Table 1; Fig. 7). This method was followed by bottomfishing (12%), spearfishing (11%), and spin casting (8%). The combined netting methods accounted for 7% of the trips, and akule and opelu trips accounted for another 5%, with a mixture of other methods making up the remaining 4% of the trips. A slightly different picture of importance of fishing methods is apparent when the weight of harvest is compared (Table 2; Fig.7). Trolling is still the most important fishing method and is responsible for about 55% of the total estimated annual harvest. And bottomfishing is still second, with about 9% of the catch. However, the various netting methods account for over 19% of the total catch by weight, with spearfishing accounting for only 6%, akule and opelu for about 5%, and spin casting for about 1% of the total catch. The remaining 5% of the catch is caught by a mixture of fishing methods.

The most popular port from which to fish is Pokai Bay on the leeward coast; it accounted for 37% of the total number of trips and 38% of the total catch reported during the year (Tables 3-4; Fig. 8). The second most used port is Heeia Kea on the windward coast; it accounted for almost 18% of the trips and over 20% of the total catch. One minor port, Keehi Lagoon, should have been considered a major port for sample design purposes, as it ranked third in trips (12.3%) and total catch (11.8%) during the year. Although Ala Wai Harbor accounted for almost 7% of the fishing trips, it had less than 3% of the catch. Effort for Kahana Bay was even lower than expected; the almost inconsequential level of effort and catch may have resulted from the small sample size and particularly bad weather on several sample days, thereby creating a nonrepresentative sample for that port. Anecdotal information seems to indicate that the Kahana Bay port is used more than our survey recorded.

Nearly 75,000 lb of catch were sampled during 1,356 interviews made in the first 12 months of the survey (Table 5). The most important ecological group in the catches was pelagic fishes which comprised 55% of the total landings (Fig. 9). This group was followed by the nearshore pelagic fishes (akule and opelu; 18%), reef fish (15%), miscellaneous fishes and invertebrates (>6%), and bottomfish (<6%). If the species are ranked by frequency of occurrence (e.g., how many times an interview recorded at least one of the species), the number one species is skipjack tuna, followed by mahimahi, goatfish, papio, akule, octopus, and yellowfin tuna. When species are ranked by weight, skipjack tuna slips to fourth place behind akule, mahimahi, and yellowfin tuna and is followed by blue marlin, goatfish, and bigeye tuna.

Some species recorded for certain methods (e.g., bottomfish species for the trolling method) probably were due to improper recording of the fishing method during the interviewing process (Table 6). This sometimes occurred when more than one method was used during a fishing trip, but the interviewer recorded only one method. The most productive port for many species was Pokai Bay (notably akule, skipjack and yellowfin tunas, and blue marlin), whereas Heeia Kea by far produced the most mahimahi (Table 7). Only akule, taape, papio, and weke were recorded at all eight ports.

Surprisingly, a considerable portion (41%) of the catch was identified as destined to be sold (Tables 8-9). This number is believed to be conservative. Since State law prohibits catch sales without a valid commercial fishing license and since a fair number of fish are believed to be sold by non-licensed fishermen, it was not surprising that some fishermen would not answer the sales question. Nor was it surprising that some answers were obviously untrue. The 41% of the sampled catch that was sold was landed by only 22% of the fishermen interviewed. Among the major fishing methods, traps (65%) and nets (53%) had the highest proportion of sales. Although Pokai Bay had nearly twice the amount of total estimated catch as Heeia Kea, it only had a slightly larger commercial catch (Table 9). Ala Wai Harbor was the least sampled commercial port.

Commercial fishermen (those who sold at least a portion of their catch) caught over 3 times as many fish per successful trip as the purely recreational fishermen (Tables 10-11). The high catch rates of recreational net fishermen are probably a result of untrue responses to the sales question. A quick analysis of the average length of successful fishing trips, for which the hours fished were recorded, revealed that commercial trips lasted 8.5 hours and recreational trips lasted 6.0 hours. Therefore, the longer average trip of the commercial fishermen was responsible for some of the increased catch per trip, but most of the increased catch was due to their much higher catch rates.

CONCLUSION

Although the execution of this survey had several shortcomings, much useful data were collected and much more information can be obtained through additional analysis. This report provides only preliminary basic summaries of the fisheries, and we have not analyzed the survey for ways to improve its design or execution in the future. This survey has demonstrated that the access point method of surveying boat-based fisheries activities in Hawaii is a viable alternative to data collection. This method of sampling can provide estimates of catch and effort with relatively narrow confidence limits, even at fairly low sampling rates.

CITATIONS

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Table 1.--Estimated number of boat trips, by method of fishing and 3-month sample period, sample year, or expanded total, for eight ports combined on Oahu, Hawaii. Table is arranged in descending order according to the annual importance of the fishing method as estimated from expanding across the entire year (e.g., March 1990 to February 1991). In parentheses are the coefficients of variation (CV; standard deviation divided by the estimate, expressed as a percent).

Method	Boat trips (No.)									Percent of total trips
	Mar-May 1990	Jun-Aug 1990	Sep-Nov 1990	Dec 1990-Feb 1991	Mar-May 1991	Annual trips (Mar 1990-Feb 1991)		Expanded (Mar 1990-Feb 1991)		
Trolling	10,904	12,465	10,554	7,963	6,616	41,886	(5)	41,609	(5)	53.1
Bottomfishing	2,309	1,780	2,672	2,843	1,096	9,604	(9)	9,757	(9)	12.5
Spearing	1,956	2,217	2,356	2,358	1,449	8,887	(8)	8,794	(8)	11.2
Casting (spin)	962	1,423	2,387	1,423	783	6,195	(14)	6,294	(15)	8.0
Akule/opelu	1,086	442	1,190	978	798	3,696	(14)	3,651	(15)	4.7
Net (lay, gill)	290	200	601	1,039	415	2,130	(18)	2,193	(22)	2.8
Nets (misc.)	283	186	487	92	80	1,048	(16)	1,013	(20)	1.3
Mid-depth handline	158	261	267	262	13	948	(27)	1,012	(30)	1.3
Net (aquarium)	107	177	209	301	735	794	(20)	816	(20)	1.0
Net (purse)	319	185	50	96	43	650	(16)	677	(23)	.9
Other (misc.)	136	51	263	57		507	(17)	564	(23)	.7
Net (crab)	159	25	115	100	140	399	(23)	409	(25)	.5
Traps (misc.)	117	106	58	96	44	377	(23)	383	(24)	.5
Trap (fish)	98	129	60	59		346	(26)	380	(29)	.5
Octopus lure	63	39	209	41	208	352	(22)	299	(41)	.4
Other (jigging)		32	16	81	13	129	(49)	140	(54)	.2
Tuna handline	32	31	10	21		94	(42)	89	(40)	.1
Trap (lobster)		32		35		67	(60)	78	(62)	.1
Net (lobster)	15		29	29		73	(36)	65	(51)	.1
Bottomfish longline			8	37		45	(67)	42	(63)	.1
Net (throw)	15	9		10		34	(56)	37	(57)	.1
Total	19,009	19,789	21,540	17,919	12,432	78,261	(3)	78,299	(3)	100.1

Table 2.--Estimated total catch (in pounds), by method of fishing and 3-month sample period, sample year, or expanded total, for eight ports combined on Oahu, Hawaii. Table is arranged in descending order according to the annual importance of the fishing method as estimated from expanding across the entire year (e.g., March 1990 to February 1991). In parentheses are the coefficients of variation (CV; standard deviation divided by the estimate, expressed as a percent).

	Total catch (lb)							
Method	Mar-May 1990	Jun-Aug 1990	Sep-Nov 1990	Dec 1990-Feb 1991	Mar-May 1991	Annual trips (Mar 1990-Feb 1991)	Expanded (Mar 1990-Feb 1991)	Percent of total catch
Trolling	466,809	657,130	500,237	192,819	283,107	1,816,995 (8)	1,713,509 (8)	55.2
Bottomfishing	49,660	35,693	67,428	108,198	10,619	260,979 (18)	281,978 (14)	9.1
Net (purse)	92,621	81,688	15,721	15,056	13,422	205,086 (20)	254,082 (30)	8.2
Net (lay, gill)	22,955	16,720	55,394	83,627	24,202	178,696 (23)	246,163 (51)	7.9
Spearing	41,216	42,325	42,760	29,728	28,539	156,029 (15)	195,803 (24)	6.3
Akule/opelu	60,392	23,576	42,502	43,052	41,271	169,522 (18)	159,892 (19)	5.1
Nets (misc.)	21,694	15,571	40,785	7,736	6,689	85,786 (26)	79,960 (51)	2.6
Casting (spin)	5,316	12,913	22,125	5,784	4,199	46,138 (21)	45,961 (27)	1.5
Traps (misc.)	10,621	9,689	5,240	8,702	3,963	34,252 (38)	34,881 (46)	1.1
Tuna handline	8,385	7,969	2,660	5,392		24,406 (54)	23,140 (60)	.7
Mid-depth handline	2,381	3,478	4,513	3,877	192	14,249 (28)	13,684 (38)	.4
Other (misc.)	3,926	2,898	4,837	1,335		12,996 (26)	12,412 (29)	.4
Net (crab)	6,291	728	2,795	2,062	9,410	11,876 (39)	12,117 (37)	.4
Trap (fish)	33	4,935	1,163	2,155		8,286 (53)	11,367 (58)	.4
Octopus lure	877	553	3,785	569	1,351	5,784 (35)	5,059 (49)	.2
Trap (lobster)		1,680		2,016		3,696 (69)	4,367 (68)	.1
Net (lobster)	995		1,900	1,878		4,773 (69)	4,190 (84)	.1
Other (jigging)		1,213	597	1,568	501	3,378 (68)	3,828 (72)	.1
Net (aquarium)	309	647	605	827	2,117	2,388 (21)	2,750 (25)	.1
Net (throw)	492	288		316		1,096 (0)	1,171 (0)	<.1
Bottomfish longline			145	524		669 (80)	646 (76)	<.1
Total	794,970	919,693	815,190	517,221	429,582	3,047,079 (6)	3,106,959 (7)	100.0

Table 3.--Estimated number of boat trips, by port and 3-month sample period, for Oahu, Hawaii. In parenthesis are the coefficients of variation (CV; standard deviation divided by the estimate, expressed as a percent). Table is arranged in descending order of importance of the annual number of trips per port.

Port	Boat trips (No.)									Percent of total trips
	Mar-May 1990	Jun-Aug 1990	Sep-Nov 1990	Dec 1990-Feb 1991	Mar-May 1991	Annual trips (Mar 1990-Feb 1991)		Expanded (Mar 1990-Feb 1991)		
Pokai Bay[a]	7,629	8,521	8,263	5,106	4,922	29,519	(5)	29,174	(6)	37.3
Heeia Kea[a]	2,589	3,123	3,532	4,847	2,114	14,091	(9)	13,894	(8)	17.7
Keehi Lagoon	2,490	832	3,519	2,266	1,645	9,107	(9)	9,612	(10)	12.3
Hawaii Kai[a]	2,403	1,909	1,646	2,178	1,177	8,136	(9)	8,172	(9)	10.4
Haleiwa[a]	2,392	2,160	1,823	1,363	1,240	7,738	(8)	7,887	(9)	10.1
Ala Wai	969	1,755	1,203	1,216	1,183	5,143	(8)	5,231	(11)	6.7
Lanikai	475	1,342	1,555	839	182	4,211	(19)	3,918	(23)	5.0
Kahana Bay	63	147		103		313	(24)	412	(31)	0.5
Total	19,009	19,789	21,540	17,919	12,462	78,258	(3)	78,299	(3)	100.0

[a]Major ports for sampling purposes.

Table 4.--Estimated total catch (in pounds), by port and 3-month sample period, for Oahu, Hawaii. In parenthesis are the coefficients of variation (CV; standard deviation divided by the estimate, expressed as a percent). Table is arranged in descending order of importance of the annual catch per port.

	Total catch (lb)									
Port	Mar-May 1990	Jun-Aug 1990	Sep-Nov 1990	Dec 1990-Feb 1991	Mar-May 1991	Annual trips (Mar 1990-Feb 1991)		Expanded (Mar 1990-Feb 1991)		Percent of total catch
Pokai Bay[a]	299,322	462,159	276,734	159,854	175,721	1,198,069	(9)	1,176,942	(10)	37.9
Heeia Kea[a]	122,851	141,773	215,356	110,487	80,596	590,467	(16)	629,012	(18)	20.2
Keehi Lagoon	116,751	59,653	122,832	78,227	54,044	377,463	(15)	368,122	(24)	11.8
Hawaii Kai[a]	73,651	90,955	89,220	78,495	66,296	332,321	(18)	341,475	(17)	11.0
Haleiwa[a]	100,859	95,059	51,367	39,935	43,730	287,220	(17)	295,661	(16)	9.5
Lanikai	60,535	21,930	44,186	23,626	1,789	150,277	(24)	183,305	(37)	5.9
Ala Wai	15,722	36,600	15,497	22,766	7,450	90,585	(13)	88,440	(18)	2.8
Kahana Bay	5,279	11,563		3,832		20,674	(55)	24,002	(63)	.8
Total	794,970	919,693	815,190	517,221	429,627	3,047,076	(6)	3,106,959	(7)	99.9

[a]Major ports for sampling purposes.

Table 5.--Annual (March 1990-February 1991) statistics for sampled and expanded species composition. Species are listed in order of their general ecological or ecosystem groups; e.g., pelagics, nearshore pelagics (akule and opelu), bottomfish, reef fish, followed by all other miscellaneous fishes and invertebrates.

Species	No. of interviews	Sampled pounds	Expanded pounds	Expansion rate	Percent species composition: Sampled	Percent species composition: Expanded
Pelagic fish (misc.)	1	250.00	11,028.09	44.11	0.3348	0.3549
Rainbow runner (kamanu)	3	11.00	429.06	39.01	0.0147	0.0138
Mahimahi	220	11,706.00	464,442.18	39.68	15.6752	14.9485
Barracudas (kaku)	12	203.75	5,316.27	26.09	0.2728	0.1711
Wahoo (ono)	84	3,000.00	114,854.49	38.28	4.0172	3.6967
Tunas (misc.)	2	185.00	5,674.06	30.67	0.2477	0.1826
Skipjack tuna (aku)	317	7,569.00	289,791.39	38.29	10.1355	9.3272
Yellowfin tuna (ahi)	88	8,905.00	340,085.02	38.19	11.9245	10.9459
Bigeye tuna (ahi)	76	3,220.50	132,969.72	41.29	4.3125	4.2797
Black skipjack (kawakawa)	83	1,105.00	43,552.34	39.41	1.4797	1.4018
Frigate tuna	1	2.00	77.50	38.75	0.0027	0.0025
Blue marlin (au)	36	7,342.00	281,116.84	38.29	9.8315	9.0480
Black marlin (au)	1	300.00	11,555.60	38.52	0.4017	0.3719
Striped marlin (au)	1	35.00	1,543.13	44.09	0.0469	0.0497
Shortnose spearfish (au)	4	180.00	7,461.01	41.45	0.2410	0.2401
Sharks	3	258.00	4,397.72	17.05	0.3455	0.1415
Bigeye scad (akule)	161	12,273.50	505,026.14	41.15	16.4352	16.2547
Mackerel scad (opelu)	40	1,052.25	43,622.09	41.46	1.4090	1.4040
Bottomfish (misc.)	13	316.00	9,048.82	28.64	0.4231	0.2912
Jacks (misc.)	12	305.00	10,258.44	33.63	0.4084	0.3302
Amberjack (kahala)	14	250.00	9,339.39	37.36	0.3348	0.3006
White ulua	7	168.00	6,661.05	39.65	0.2250	0.2144
Giant sea bass (hapuupuu)	3	53.00	1,373.15	25.91	0.0710	0.0442
Blue spot grouper	3	11.50	455.70	39.63	0.0154	0.0147
Snappers (misc.)	4	144.50	3,971.14	27.48	0.1935	0.1278
Blue lined snapper (taape)	65	1,913.75	70,055.46	36.61	2.5627	2.2548
Red snapper (ehu)	13	133.00	3,337.43	25.09	0.1781	0.1074
Flower snapper (gindai)	2	1.50	43.68	29.12	0.0020	0.0014
Pink snapper (kalekale)	1	1.50	54.25	36.17	0.0020	0.0017
Silverjaw (lehi)	2	2.00	68.36	34.18	0.0027	0.0022
Red snapper (onaga)	12	261.50	7,064.17	27.01	0.3502	0.2274
Pink snapper (opakapaka)	18	1,438.00	37,859.44	26.33	1.9256	1.2185
Gray snapper (uku)	40	723.25	19,380.77	26.80	0.9685	0.6238

Table 5.--Continued.

Species	No. of interviews	Sampled pounds	Expanded pounds	Expansion rate	Percent species composition	
					Sampled	Expanded
Reef fish (misc.)	38	832.25	126,486.18	151.98	1.1144	4.0711
Reef jacks (papio)	172	1,772.12	79,829.43	45.05	2.3730	2.5694
Squirrelfish (u'u)	37	397.00	12,490.36	31.46	0.5316	0.4020
Trumpetfish (nunu)	1	1.00	39.98	39.98	0.0013	0.0013
Scorpionfish (nohu)	4	6.50	286.40	44.06	0.0087	0.0092
Mountain bass (aholehole)	5	44.00	4,515.49	102.62	0.0589	0.1453
Bigeyes (aweoweo)	20	172.00	8,522.64	49.55	0.2303	0.2743
Goatfish (weke)	214	3,551.25	184,045.08	51.83	4.7554	5.9236
Rudderfish (nenue)	4	40.75	1,398.23	34.31	0.0546	0.0450
Damselfish (kupipi)	3	16.35	629.97	38.53	0.0219	0.0203
Hawkfish (po'opa'a)	3	6.00	163.18	27.20	0.0080	0.0053
Wrasse (a'awa)	31	113.00	3,654.44	32.34	0.1513	0.1176
Parrotfish (uhu)	30	395.50	23,734.89	60.01	0.5296	0.7639
Gobies ('o'opu)	1	0.50	22.17	44.34	0.0007	0.0007
Surgeon/tangs (kala)	41	681.73	27,274.31	39.95	0.9142	0.8778
Triggerfish (humuhumu)	5	28.25	799.14	28.29	0.0378	0.0257
Filefish ('o'ilepa)	3	24.00	969.98	40.42	0.0321	0.0312
Miscellaneous	1	15.00	270.23	18.02	0.0201	0.0087
Rays (hihimanu)	1	5.00	199.91	39.98	0.0067	0.0064
Eels (puhi)	1	3.00	123.48	41.16	0.0040	0.0040
Leatherback (lai)	13	45.75	3,221.41	70.41	0.0613	0.1037
Ten pounder (awa awa)	6	35.60	1,936.78	54.40	0.0477	0.0623
Bonefish (o'io)	14	83.50	6,625.06	79.34	0.1118	0.2132
Milkfish (awa)	9	51.25	2,305.85	44.99	0.0686	0.0742
Needlefish (aha)	7	64.50	2,076.04	32.19	0.0864	0.0668
Threadfin (moi)	6	47.25	3,641.34	77.07	0.0633	0.1172
Mullet (ama ama)	2	390.00	34,925.59	89.55	0.5222	1.1241
Lobster (misc.)	6	233.00	2,613.43	11.22	0.3120	0.0841
Spiny lobster (ula)	9	188.50	10,745.48	57.01	0.2524	0.3459
Slipper lobster (ulapapapa)	2	4.00	351.72	87.93	0.0054	0.0113
Crabs (misc.)	14	322.50	12,421.78	38.52	0.4319	0.3998
Octopus (tako)	90	1,752.75	106,115.74	60.54	2.3471	3.4154
Squid (ika)	3	32.00	2,506.12	78.32	0.0429	0.0807
Stony corals	1	0.75	91.51	122.01	0.0010	0.0029
Sea urchins (wana)	1	0.25	9.09	36.36	0.0003	0.0003
Total	2,140[a]	74,678.30	3,106,959.00	41.60[b]	100.0000	100.0000

[a]Total number of species identifications made during 1,356 interviews.
[b]Average calculated by dividing expanded pounds by sampled pounds.

Table 6.--Annual (March 1990-February 1991) species composition (pounds) for the major fishing methods on Oahu, Hawaii. Species are listed in order of their general ecological or ecosystem groups; e.g., pelagics, nearshore pelagics (akule and opelu), bottomfish, reef fish, followed by all other miscellaneous fishes and invertebrates.

Species	Species composition (lb)								
	Trolling	Bottom fishing	Spearing	Spin cast	Nets	Traps	Akule opelu	Combined others	Total
Pelagic fish (misc.)	11,028								11,028
Rainbow runner (kamanu)	340	89							429
Mahimahi	454,774	1,079		8,590					464,442
Barracudas (kaku)	2,869	227		556				1,665	5,316
Wahoo (ono)	114,854								114,854
Tunas (misc.)	4,813							861	5,674
Skipjack tuna (aku)	279,746	319		8,412				1,315	289,791
Yellowfin tuna (ahi)	335,521							4,564	340,085
Bigeye tuna (ahi)	116,361	890						15,718	132,970
Black skipjack (kawakawa)	40,343	237		2,453			519		43,552
Frigate tuna	78								78
Blue marlin (au)	281,117								281,117
Black marlin (au)	11,556								11,556
Striped marlin (au)	1,543								1,543
Shortnose spearfish (au)	7,461								7,461
Sharks	2,769	213			1,416				4,398
Bigeye scad (akule)	207	88,184		2,783	275,375		132,625	5,851	505,026
Mackerel scad (opelu)	388	12,706		79	8,494		20,693	1,263	43,622
Bottomfish (misc.)	4,068	4,942						40	9,049
Jacks (misc.)	5,564	4,695							10,258
Amberjack (kahala)	3,650	3,623	1,351					716	9,339
White ulua	2,116	1,119	1,439				1,557	431	6,661
Giant sea bass (hapuupuu)		1,373							1,373
Blue spot grouper			85			370			456
Snappers (misc.)		3,720	51		173			26	3,971
Blue lined snapper (taape)	476	18,758			46,291	684	2,658	1,188	70,055
Red snapper (ehu)	164	3,174							3,337
Flower snapper (gindai)	14	30							44
Pink snapper (kalekale)	54								54
Silverjaw (lehi)		26		42					68
Red snapper (onaga)	55	7,010							7,064
Pink snapper (opakapaka)	818	37,042							37,859
Gray snapper (uku)	1,454	16,401	1,155	279				92	19,381

Table 6.--Continued.

Species	Species composition (lb)								
	Trolling	Bottom fishing	Spearing	Spin cast	Nets	Traps	Akule opelu	Combined others	Total
Reef fish (misc.)		3,835	19,122	211	74,376	22,237		6,707	126,486
Reef jacks (papio)	25,276	17,407	6,825	13,912	11,130	329	907	4,043	79,829
Squirrelfish (u'u)		5,124	2,998	590	2,174	719	885		12,490
Trumpetfish (nunu)		40							40
Scorpionfish (nohu)	14		273						286
Mountain bass (aholehole)			728		3,787				4,515
Bigeyes (aweoweo)		1,689	4,892		1,903			38	8,523
Goatfish (weke)	279	38,097	32,271	4,308	99,245	2,947	47	6,851	184,045
Rudderfish (nenue)		270	484		644				1,398
Damselfish (kupipi)			523					107	630
Hawkfish (po'opa'a)		163							163
Wrasse (a'awa)		2,717	96	842					3,654
Parrotfish (uhu)		124	18,998	191	2,293	2,130			23,735
Gobies ('o'opu)	22								22
Surgeon/tangs (kala)			7,896	699	11,946	6,732			27,274
Triggerfish (humuhumu)		799							799
Filefish ('o'ilepa)		133	837						970
Miscellaneous		270							270
Rays (hihimanu)		200							200
Eels (puhi)						123			123
Leatherback (lai)	1,023	104	126	133	1,835				3,221
Ten pounder (awa awa)	1,382			455				100	1,937
Bonefish (o'io)	479	239		628	5,222			56	6,625
Milkfish (awa)	404			736	918			248	2,306
Needlefish (aha)	425	1,588		63					2,076
Threadfin (moi)					3,641				3,641
Mullet (ama ama)					34,926				34,926
Lobster (misc.)			191		1,349	1,074			2,613
Spiny lobster (ula)			6,851		1,570			2,324	10,745
Slipper lobster (ulapapapa)					352				352
Crabs (misc.)			8		11,360	1,054			12,422
Octopus (tako)		3,031	86,396			12,215		4,474	106,116
Squid (ika)		297	2,209						2,506
Stoney corals								92	92
Sea urchins (wana)					9				9
Total	1,713,509	281,978	195,803	45,961	600,430	50,615	159,892	58,768	3,106,959

Table 7.--Annual (March 1990-February 1991) species composition, by port, on Oahu, Hawaii. Species are listed in order of their general ecological or ecosystem groups; e.g., pelagics, nearshore pelagics (akule and opelu), bottomfish, reef fish, followed by all other miscellaneous fishes and invertebrates.

	Species composition (lb)								
Species	Pokai Bay	Heeia Kea	Keehi Lagoon	Hawaii Kai	Haleiwa	Lanikai	Ala Wai	Kahana Bay	Total
Pelagic fish (misc.)		11,028							11,028
Rainbow runner (kamanu)	89		285	55					429
Mahimahi	73,508	240,095	20,703	57,996	55,572	1,147	15,421		464,442
Barracudas (kaku)	1,742	1,438		838	180	1,118			5,316
Wahoo (ono)	22,499	36,255	1,190	12,413	33,539	4,013	4,946		114,854
Tunas (misc.)	5,674								5,674
Skipjack tuna (aku)	221,992	29,422	5,854	13,914	14,742	3,726	141		289,791
Yellowfin tuna (ahi)	166,512	64,819	24,033	24,773	54,444	5,503			340,085
Bigeye tuna (ahi)	47,398	55,207	13,469	1,501	3,600	11,466	330		132,970
Black skipjack (kawakawa)	28,138	1,898	5,636	3,323	2,907	860	791		43,552
Frigate tuna	78								78
Blue marlin (au)	198,499	20,331	20,369	11,459	30,459				281,117
Black marlin (au)	11,556								11,556
Striped marlin (au)		1,543							1,543
Shortnose spearfish (au)	3,271	4,190							7,461
Sharks				213	2,769			1,416	4,398
Bigeye scad (akule)	200,799	67,025	64,365	60,965	37,639	57,324	12,743	4,166	505,026
Mackerel scad (opelu)	40,701	249		459	901		1,313		43,622
Bottomfish (misc.)	3,857	479	320	4,027	225		141		9,049
Jacks (misc.)	5,670		3,188	265	1,135				10,258
Amberjack (kahala)	2,150		3,295	2,303	207		1,385		9,339
White ulua	4,103		1,945	319		294			6,661
Giant sea bass (hapuupuu)		130		1,063	180				1,373
Blue spot grouper				85			370		456
Snappers (misc.)		26		3,771		173			3,971
Blue lined snapper (taape)	38,097	4,407	7,327	12,846	2,887	3,127	1,176	188	70,055
Red snapper (ehu)				2,237	162		939		3,337
Flower snapper (gindai)	30			14					44
Pink snapper (kalekale)	54								54
Silverjaw (lehi)	42			26					68
Red snapper (onaga)			400	6,512			153		7,064
Pink snapper (opakapaka)	59			37,008	793				37,859
Gray snapper (uku)	1,787		80	15,487	1,698	313	17		19,381

Table 7.--Continued.

Species	Pokai Bay	Heeia Kea	Keehi Lagoon	Hawaii Kai	Haleiwa	Lanikai	Ala Wai	Kahana Bay	Total
	Species composition (lb)								
Reef fish (misc.)	31,706	17,930	23,867	6,227	19,873	780	11,684	14,418	126,486
Reef jacks (papio)	15,083	12,830	17,507	14,463	2,513	13,909	3,412	112	79,829
Squirrelfish (u'u)	3,585	929	3,235	1,942	904	588	1,308		12,490
Trumpetfish (nunu)			40						40
Scorpionfish (nohu)		159		31	97				286
Mountain bass (aholehole)		286	3,883			347			4,515
Bigeyes (aweoweo)	2,311		4,270	1,162	588		191		8,523
Goatfish (weke)	13,175	22,651	77,084	26,757	8,184	24,838	7,713	3,641	184,045
Rudderfish (nenue)	165	963			270				1,398
Damselfish (kupipi)				511	11		107		630
Hawkfish (po'opa'a)	30			133					163
Wrasse (a'awa)	119	571		1,468	1,293	156	47		3,654
Parrotfish (uhu)	4,800	4,329	6,576	4,894	191	353	2,592		23,735
Gobies ('o'opu)		22							22
Surgeon/tangs (kala)	2,442	1,658	11,790	3,899	2,660	926	3,899		27,274
Triggerfish (humuhumu)	712			33	54				799
Filefish ('o'ilepa)				167			803		970
Miscellaneous					270				270
Rays (hihimanu)			200						200
Eels (puhi)							123		123
Leatherback (lai)		123	2,811	83		93	112		3,221
Ten pounder (awa awa)	100	455				1,382			1,937
Bonefish (o'io)	388	2,410	2,046	362		1,363		56	6,625
Milkfish (awa)	632	248	1,035	104		287			2,306
Needlefish (aha)	1,102		95	532	18		330		2,076
Threadfin (moi)		644	2,997						3,641
Mullet (ama ama)			531			34,395			34,926
Lobster (misc.)		191	1,600				823		2,613
Spiny lobster (ula)	497	127	2,082		2,680	5,360			10,745
Slipper lobster (ulapapapa)					178	173			352
Crabs (misc.)		2,602			9,816			4	12,422
Octopus (tako)	21,480	21,215	31,932	4,746	2,019	9,291	15,433		106,116
Squid (ika)	297	127	2,082						2,506
Stoney corals				92					92
Sea urchins (wana)	9								9
Total	1,176,942	629,012	368,122	341,475	295,661	183,305	88,440	24,002	3,106,959

Table 8.--Annual (March 1990-February 1991) summary statistics on the proportion of the catch to be sold, listed by fishing method, on Oahu, Hawaii. Table includes only those interviews in which the catch and the disposition of the catch were recorded.

Method	Total number of interviews	Total sampled (lb)	Number of "sold" interviews	Sample "sold" (lb)[a]	Percent of catch sold[b]	Estimated expanded total catch (lb)[c]	Estimated commercial catch (lb)[d]
Trolling	668	41,803	156	16,679	40	1,713,509	685,404
Bottomfishing	290	9,742	53	3,315	34	281,978	95,873
Spearing	125	3,137	14	929	30	195,803	58,741
Casting (spin)	66	677	3	41	6	45,961	2,758
Nets (misc.)	14	1,512	6	556	37	79,960	29,585
Net (lay, gill)	30	3,918	8	2,349	60	246,163	147,698
Net (purse)	11	4,087	6	2,234	55	254,082	139,745
Net (lobster)	2	130	0	0	0	4,190	0
Net (crab)	11	283	3	165	58	12,117	7,028
Net (throw)	1	32	0	0	0	1,171	0
Net (aquarium)	9	33	8	31	94	2,750	2,585
Traps (misc.)	3	364	2	338	93	34,881	32,440
Trap (lobster)	3	160	2	39	24	4,367	1,048
Trap (fish)	7	314	5	170	54	11,367	6,138
Tuna handline	2	520	2	460	88	23,140	20,363
Other (misc.)	12	271	1	35	13	12,412	1,614
Akule/opelu	77	3,668	33	1,501	41	159,892	65,556
Mid-depth handline	23	355	5	117	33	13,684	4,516
Bottomfish longline	3	56	0	0	0	646	0
Octopus lure	8	162	0	0	0	5,059	0
Other (jigging)	5	201	1	41	20	3,828	766
Total	1,370	71,408	308	28,999	41	3,106,959	1,273,853

[a]Calculated by summing across individual interviews the amount of fish to be sold (e.g., percent sold times total trip weight).
[b]Calculated by dividing the total estimated sold sampled weight by the total sampled weight.
[c]Estimated annual expanded catch by method from Table 2.
[d]Calculated by multiplying the percent sold column by the estimated expanded catch.

Table 9.--Annual (March 1990-February 1991) summary statistics on the proportion of the catch to be sold, listed by fishing port, on Oahu, Hawaii. Table includes only those interviews in which the catch and the disposition of the catch were recorded.

Port	Total number of interviews	Total sampled (lb)	Number of "sold" interviews	Sample "sold" (lb)[b]	Percent of catch sold[c]	Estimated expanded total catch (lb)[d]	Estimated commercial catch (lb)[e]
Pokai Bay[a]	502	27,986	107	9,316	33	1,176,942	388,391
Heeia Kea[a]	217	12,526	58	7,205	58	629,012	364,827
Keehi Lagoon	121	6,007	31	1,993	33	368,122	121,480
Hawaii Kai[a]	210	12,396	48	5,527	45	341,475	153,664
Haleiwa[a]	180	7,844	42	3,049	39	295,661	115,308
Lanikai	45	2,047	9	1,137	56	183,305	102,651
Ala Wai	88	1,920	12	297	15	88,440	13,266
Kahana Bay	7	700	1	475	68	24,002	16,321
Total	1,370	71,408	308	28,999	41	3,106,959	1,273,853

[a]Major ports for sampling purposes.
[b]Calculated by summing across individual interviews the amount of fish to be sold (e.g., percent sold times total trip weight).
[c]Calculated by dividing the total estimated sold sampled weight by the total sampled weight.
[d]Estimated annual expanded catch by port from Table 4.
[e]Calculated by multiplying the percent sold column by the estimated expanded catch.

Table 10.--Comparison of commercial and recreational annual (March 1990-February 1991) catch rates by fishing method for Oahu, Hawaii. Table includes only those interviews in which the catch and the disposition of the catch were recorded.

	Commercial		Recreational	
Method	Number of interviews	Pounds per trip	Number of interviews	Pounds per trip
Trolling	156	135	512	40
Bottomfishing	53	78	237	24
Spearing	14	95	111	16
Casting (spin)	3	19	63	10
Nets (misc.)	6	176	8	57
Net (lay, gill)	8	315	22	64
Net (purse)	6	413	5	322
Net (lobster)	0	0	2	65
Net (crab)	3	60	8	13
Net (throw)	0	0	1	32
Net (aquarium)	8	4	1	2
Traps (misc.)	2	178	1	9
Trap (lobster)	2	60	1	40
Trap (shrimp)	0	0	0	0
Trap (fish)	5	40	2	58
Tuna handline	2	260	0	0
Other	1	35	11	21
Akule/opelu	33	67	44	33
Mid-depth handline	5	29	18	12
Bottomfish longline	0	0	3	19
Octopus lure	0	0	8	20
Hand-limu, opihi	0	0	0	0
Other (jigging)	1	45	4	39
Total	308	119	1,062	33

Table 11.--Comparison of commercial and recreational annual (March 1990-February 1991) catch rates by port for Oahu, Hawaii. Table includes only those interviews in which the catch and the disposition of the catch were recorded.

Port	Commercial		Recreational	
	Number of interviews	Pounds per trip	Number of interviews	Pounds per trip
Pokai Bay[a]	107	111	395	41
Heeia Kea[a]	58	146	159	25
Keehi Lagoon	31	83	90	38
Hawaii Kai[a]	48	151	162	32
Haleiwa[a]	42	90	138	29
Lanikai	9	167	36	15
Ala Wai	12	47	76	18
Kahana Bay	1	500	6	33
Total	308	119	1,062	33

[a]Major ports for sampling purposes.

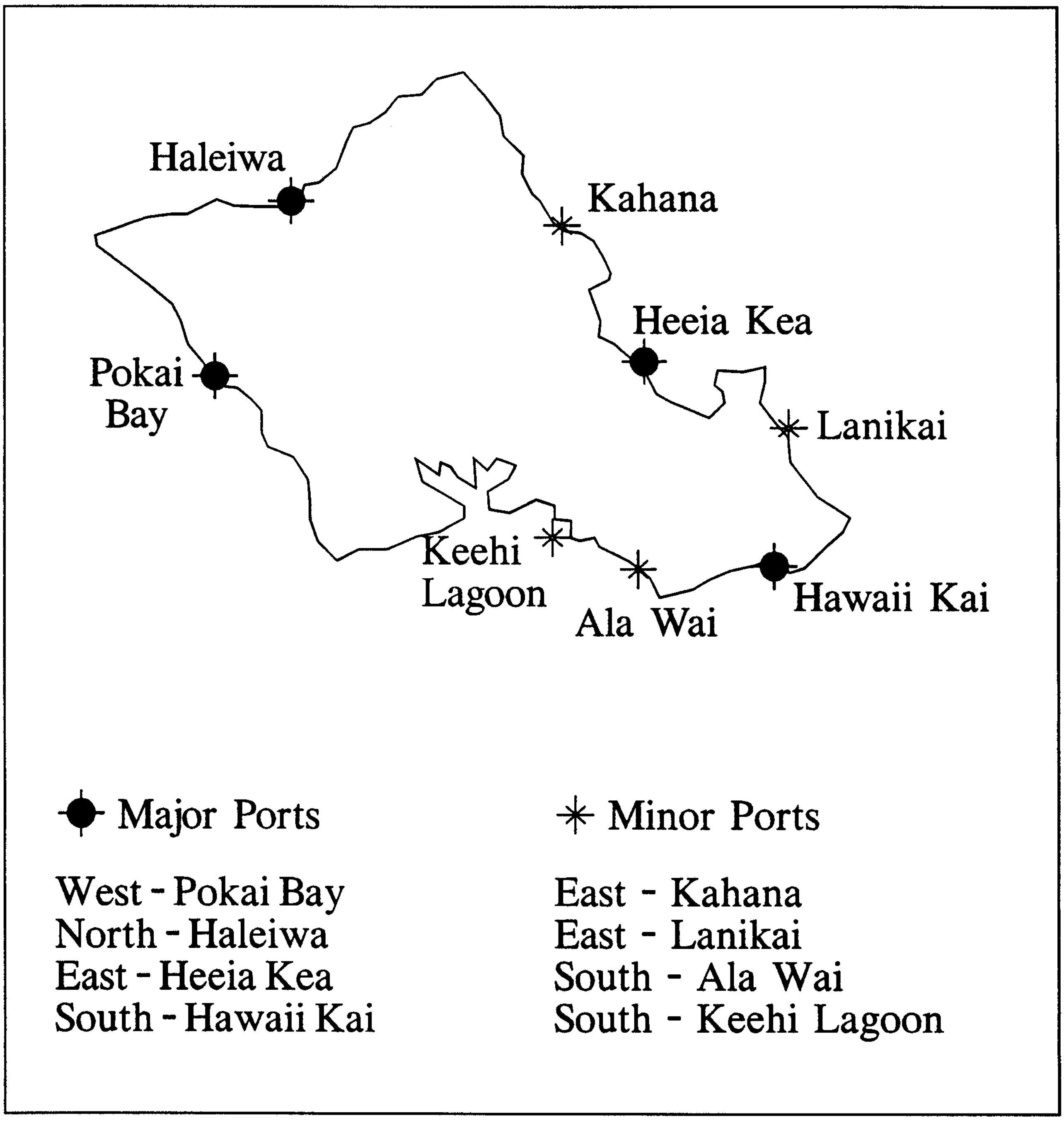


Figure 1.--Port sampling sites on Oahu, Hawaii.

Figure 2

BOAT LOG SHEET

Port (____)________________ Date _____/_____/_____ (Month / Day / Year)

Interviewer (____)________________

Sampling Time Begin ________ Time End ________ Page ____ of ____

	Boat Name	Boat No.	Time Depart	Time Return	Fishn? Y/N	Meth. Code	Int'vw No.	REMARKS
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

Survey by Omnitrak Group for the Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii, 1990

Figure 3

Rev. 6/22/90

OFFSHORE CREEL SURVEY INTERVIEW FORM

Port (___)______________ Date: ____/____/____ (Month Day Year) Interview #_______

Interviewer (____)______________ Time ________ Page ____ of ____

For Fishing Boats

Boat Name/No. __________ / _______ Boat Length ________ ft. Was Fishing Done? Yes / No

Time Depart ______ Time Return _______ How Many People Fished? ___________

Method Used	Hours	Catch (lbs)	Method Used	Hours	Catch (lbs)
10. Trolling			50. Net (Type________)		
20. Bottomfishing			60. Trap (Type________)		
30. Spear			70. Tuna Handline		
40. Casting (spin)			80. Other ________		

Disposition of catch? % Keep _______ % Sell ________ % Other ________

Est. max miles from shore? _______ Buoys fished? Yes / No Which ones? (___) (___) (___)

(*For Heeia-Kea Interviews Only:* Did you fish - Inside Kaneohe Bay?____ Outside?____ Both?____)

(Show map and explain boundary; ask fisherman if fish caught in or out of bay, then please note in REMARKS below)

Rain? Yes / No Wind (est. mph)__________ Seas (est. ft.)__________

Catch by Method

Meth. Code	All? Y/N	Species/ Group	No. Landed	Act/ Est	Lb. Landed	Act/ Est	Est. Lb not Landed	REMARKS

Survey by OmniTrak Group Inc. for the Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii, 1990

Figure 4

Data Processing Overview

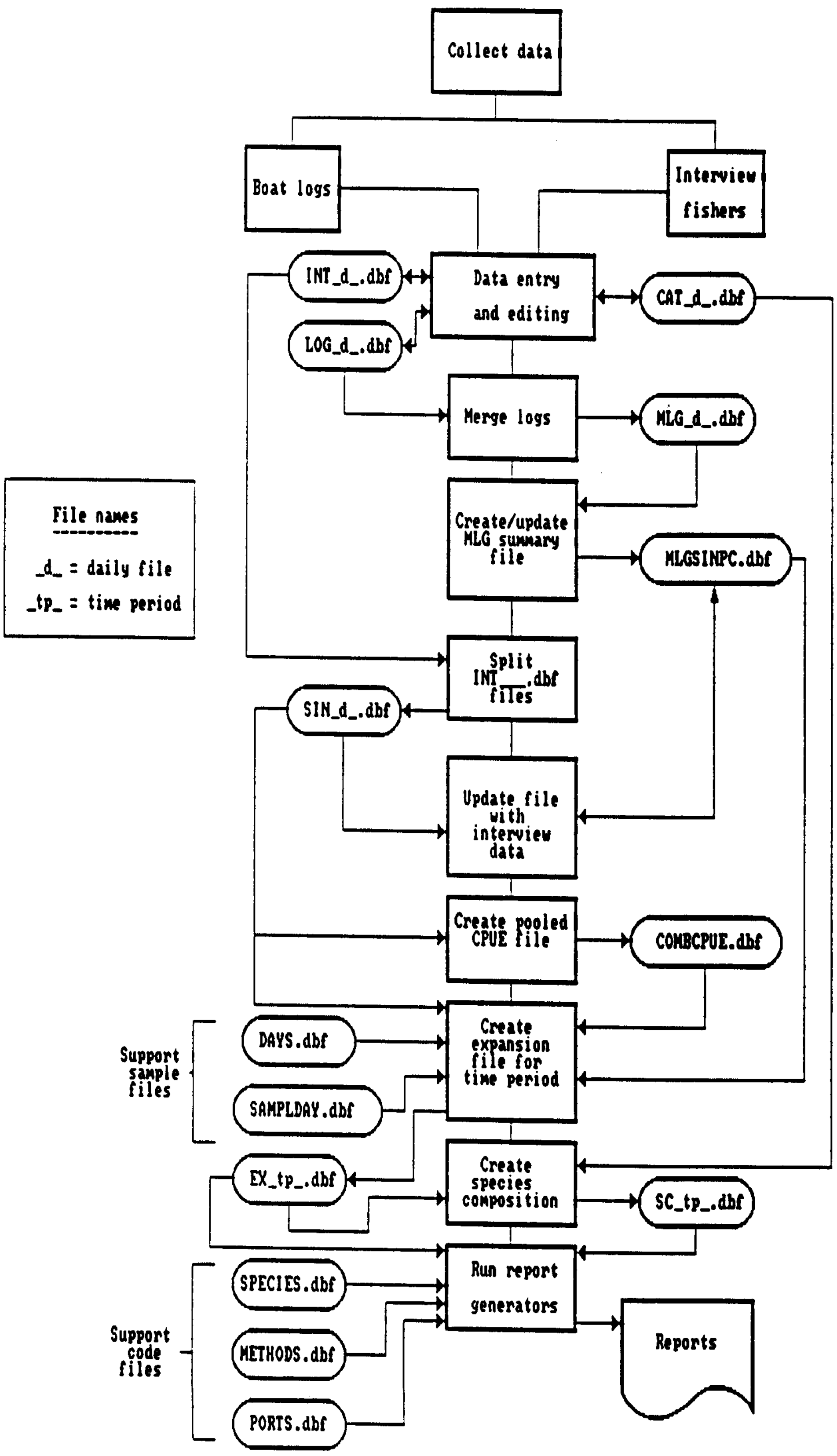


Figure 5

Survey Data Expansion Process

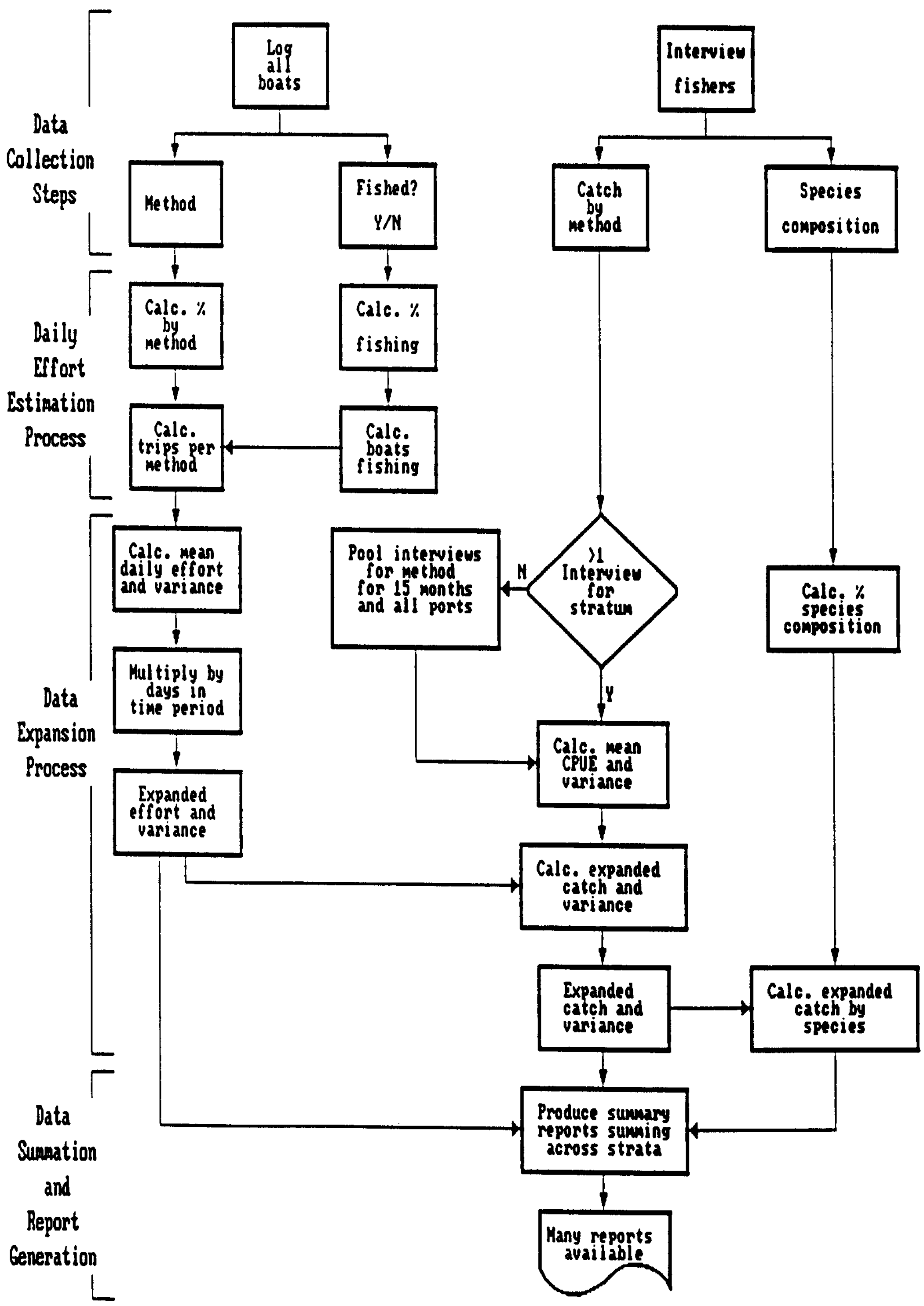


Figure 6

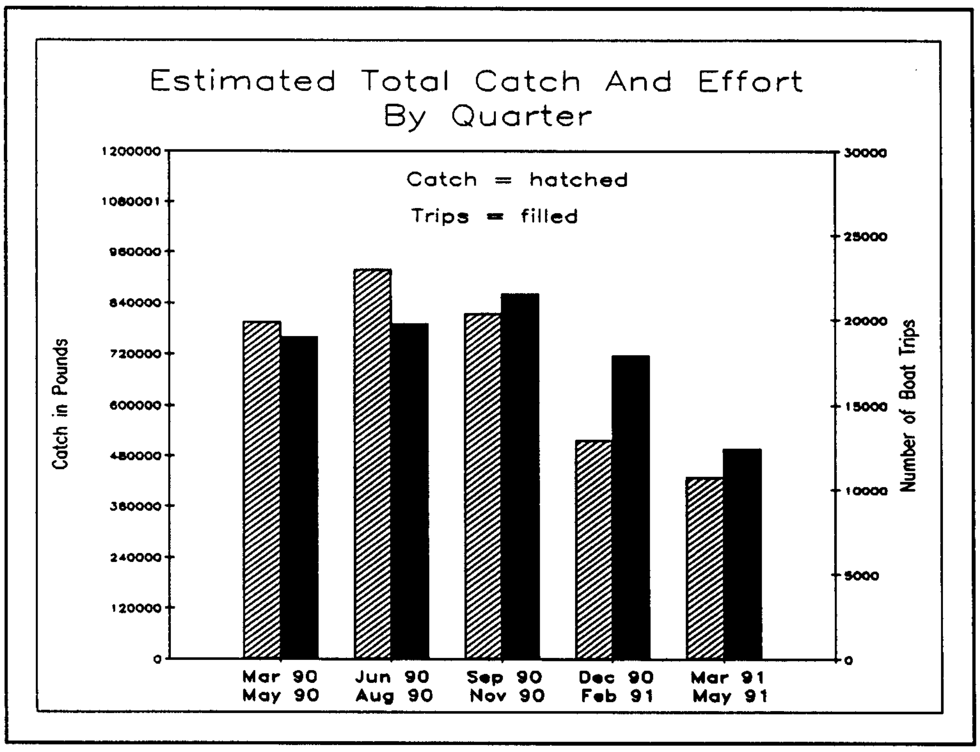


Figure 7

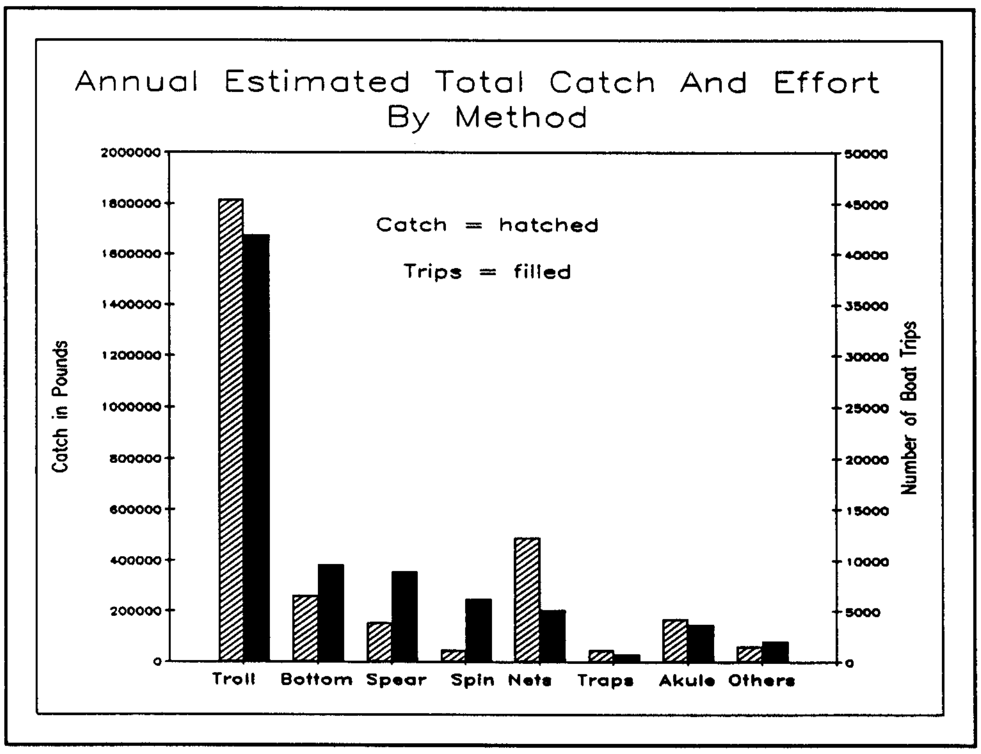


Figure 8

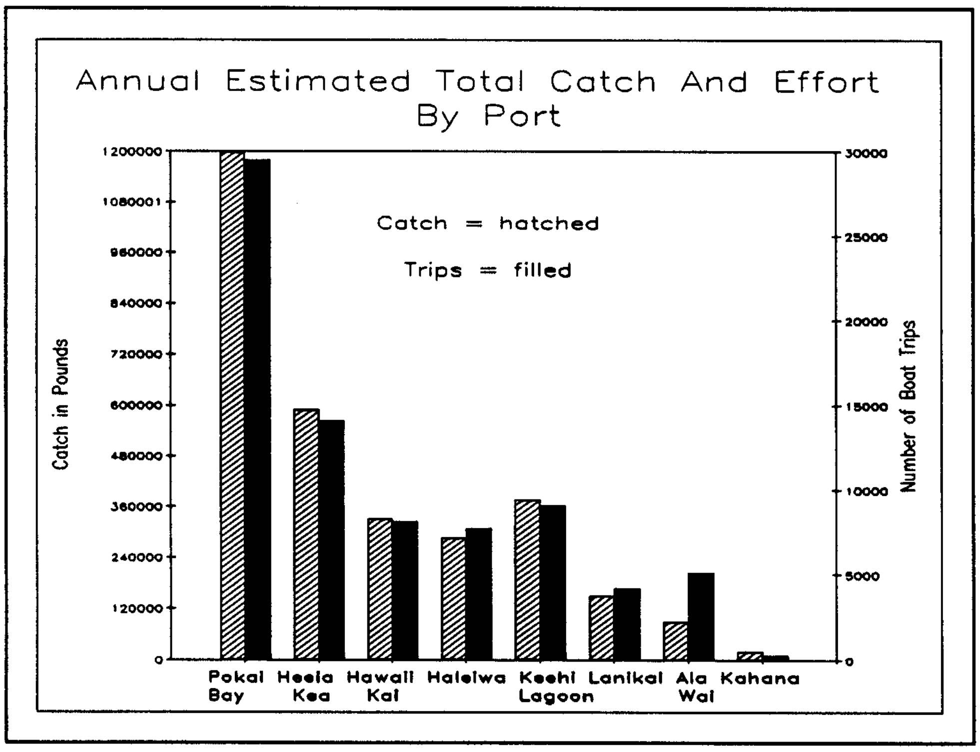
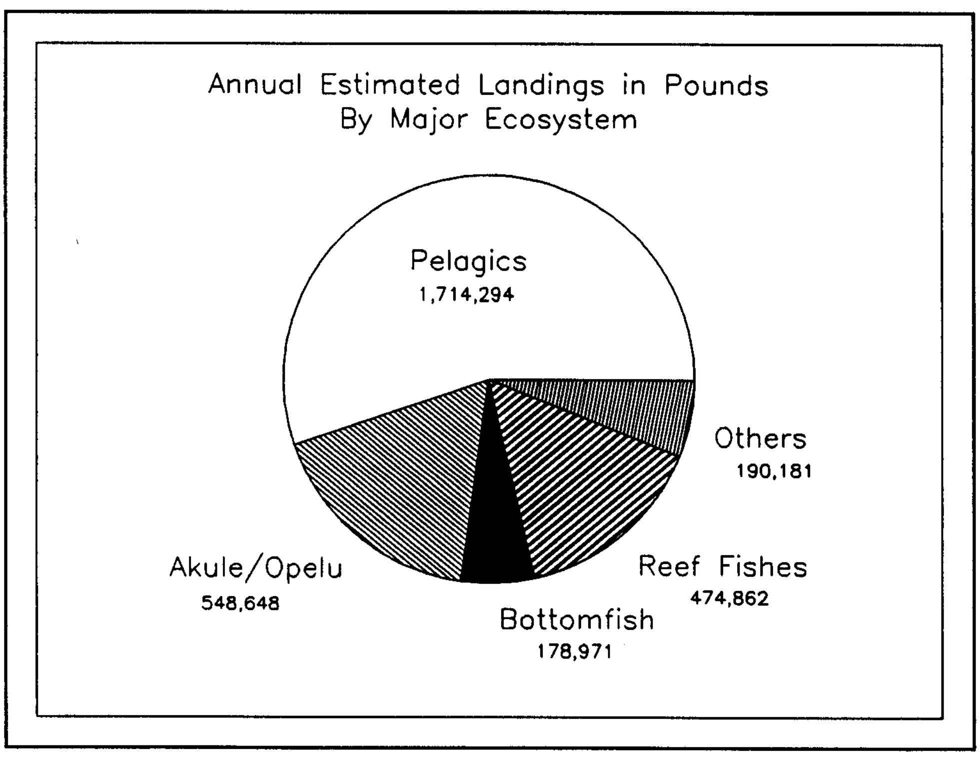


Figure 9



Appendix A.--Data expansion process.

Explanation of the Data Expansion Process

The process of creating estimates of total catch and effort from sample data is generally referred to as the data expansion process. In this survey, the expansion process involves two distinctly different procedures: one estimates a "measurement" without variance of daily effort for each expansion stratum (e.g., a port, type day, and method combination), and the other calculates averages with variances of catch and effort parameters and then expands them to estimate the total catch and effort and to divide the catch into estimates of species composition (Fig. 5).

To estimate daily effort, the total number of boats counted in a day is allocated into various use categories based on data collected from the vast majority of the boats. For example, if 100 boats are counted during the day and fishing activity is determined for 80 of them, the information from the 80 boats is then used to estimate the fishing activity of the 20 for which no information has been collected.

Total effort is estimated by multiplying the average daily number of trips for each expansion stratum by the number of days in the time period. Total catch is estimated by multiplying the average daily number of trips by the average catch per trip. Species composition of the total catch for each stratum is calculated by multiplying the estimated total catch by the percent species composition of the sampled catch. Variances of the mean daily effort, mean catch per trip, and estimated total catch are calculated using standard formulas for variance of a mean, variance of a ratio estimator, and variance of products, respectively (Cochran 1977, Malvestuto 1991, and Meyer 1975). Summary statistics are created by summing values and variances across strata.

The following is a detailed description of the individual steps, inherent complications, and formulas to estimate daily effort and expand the data. Referring to the survey instruments (Figs. 2 and 3) and the data processing and expansion flowcharts (Figs. 4 and 5) will assist in understanding the explanation.

The Daily Effort Estimation Process

Each sample day, the port sampler was required to log every vessel departing from or returning to the port, and record the boat name or number, time, whether fishing was intended or done, and the fishing method used or intended (Fig. 2). To obtain all of the required information, the sampler needed to speak to someone on every vessel at the time of departure and return, but as is common in fisheries surveys, this was not always logistically or physically possible. Therefore, information from vessels for which activities were identified is used to estimate activity of vessels for which information was missing.

The first step in processing the daily log data is to merge all departure and return log entries for each boat (Fig. 4). Some of the resultant merged records include information for a full trip, but some include only departure or return data.

To estimate daily effort, the first step (Fig. 5) is to calculate the percentage of boats that fished on that particular sample day (F_o):

$$F_o = \frac{F}{(NF + F)};$$

where F is the number of "yes-fish" boats on merged log sheets, and NF is the number of "no-fish" boats on merged log sheets.

Next, to estimate the total number of fishing boats active at the port on a port-day, the known fishing boats identified on the log sheets are counted, and then an estimated number of fishing boats is added to account for the boats for which no "fished yes/no" information is available. The total number of fishing boats for the sample port-day (E) is calculated as

$$E = F + (B * F_o);$$

where

B is the number of blank "fished yes/no" boats on merged log sheets

The next step is to calculate the percent usage of each method (T_o) by dividing the total number of "full," "return only," and "depart only" fishing trips for each logged fishing method by the total number of boats whose fishing method has been logged for that port-day:

$$T_o = \frac{\Sigma \text{ all boats logged using a particular method}}{\Sigma \text{ all boats with logged method(s)}}.$$

Because more than one fishing method can be used by a single boat on each trip, each method used is counted once in the numerator, but the boat is counted only once in the denominator. Therefore, if multiple-method trips are logged during the day, the sum of the percentages (T_o) will be greater than 100%; otherwise, an insufficient amount of effort will be allocated to the methods used on fishing trips with mixed methods.

The final step is to calculate the estimated number of boat trips using each of the fishing methods (T_I) logged during the day:

$$T_I = E * T_o.$$

This estimate of participation is considered to have no measurement without variance, just as if the port sampler had physically and logistically obtained the necessary fishing information from every boat that used a port on a particular day.

The Data Expansion Process

The first step in the data expansion process is to calculate the mean daily number of boat trips for each stratum ($\bar{T}$) by summing the individual day participation estimates over all sampled days during the time period. The result is divided by the number of days sampled:

$$\bar{T} = \frac{\sum_{I=1}^{n} T_I}{n};$$

where T_I is the number of boat trips for each day sampled, and n is the number of days sampled in the time period.

The variance of $\bar{T}$ is calculated using the standard formula for variance of a mean as adjusted by the finite population correction (fpc) factor (Cochran 1977), since the proportion of the number of days sampled in the time period sometimes exceeds 5%:

$$VAR\ (\bar{T}) = \left(\frac{\sum_{I=1}^{n} T_I^2 - \frac{\left(\sum_{I=1}^{n} T_I\right)^2}{n}}{\frac{(n-1)}{n}} \right) X \left(1 - \frac{n}{N}\right);$$

where N is the number of days in the sample period, n/N is the sample rate (e.g., 3 of 30 weekend days), and $(1 - n/N)$ is the fpc.

The expansion is accomplished by multiplying the mean daily effort by the number of days in the time period:

$$\hat{T} = \overline{T} \times N;$$

where T is the estimated number of boat trips for the time period for a fishing method, type day, and port

The variance of the expanded effort for each stratum is calculated by

$$VAR(\hat{T}) = VAR(\overline{T}) \; X \; (N)^2.$$

The other major parameters to be calculated in the data expansion process--mean catch per trip and percent species composition--are obtained from the fishermen interviewed by the port sampler. Because the number of expansion strata was large relative to the number of interviews collected for most strata on any given port-day, the interview data were pooled over time to obtain a large enough number of interviews to be representative of the parameters being estimated. Even so, a sufficient number of interviews did not exist for many of the lesser used methods for each 3-month or even 12-month period, even if "sufficient" was defined as only two (or more) interviews.

When the mean catch per trip is calculated, if sufficient interviews do not exist within the time period being expanded, interview data for the fishing method in question are pooled across ports for the entire 15-month sample period. This island-wide, 15-month average catch per trip is used in the expansion algorithm whenever an expansion stratum has fewer than two interviews. The mean catch per unit effort ($\overline{U}$) is calculated by using a ratio estimator for each stratum or pooled strata:

$$\overline{U} = \frac{\sum_{J=1}^{n} C_J}{\sum_{J=1}^{n} T_J};$$

where C is the catch of a single fishing method for the trip, J is the individual interview for a method, n is the number of interviews, and T_J = Effort of each trip for which an interview has been made.

In the current case where the unit of effort of each fishing trip is the trip itself (e.g., effort = 1), the formula is simplified to the sum of the total interviewed catch divided by the number of interviews made:

$$\overline{U} = \frac{\sum_{J=1}^{n} C_J}{n}.$$

Similarly, the standard formula for estimating the variance of a ratio estimator--as given in Cochran (1977) for cluster sampling of elephant populations and modified by Malvestuto (1991) to represent fisheries catch per unit effort (hours fished)--can be simplified by using trips as the unit of effort. Additionally, adjustment by the fpc is not needed in this case because the number of interviews typically represents a small fraction of the total number of trips in the stratum or pooled strata. If effort is measured in hours and fpc is needed, the variance of the mean catch per unit effort (hour) is:

$$VAR(\overline{U}) = \frac{1}{n\left(\frac{\sum_{J=1}^{n} e_J}{n}\right)^2} \left(\frac{\sum_{J=1}^{n}(C_J^2) - 2(\overline{U})\sum_{J=1}^{n}(C_J)(e_J) + (\overline{U})^2\sum_{J=1}^{n}(e_J^2)}{(n-1)}\right) X \left(1 - \frac{n}{N}\right);$$

where e_J is effort measured in hours fished for each interview, n is the number of interviews or trips, and N is the total trips over the time period (e.g., the population).

The other parameters are as previously defined. However, since for the current report, trip was selected as the unit of effort and the fpc is not needed, the formula for the variance of the mean catch per trip (var $(\overline{U})$ is simplified:

$$VAR(\overline{U}) = \frac{1}{n}\left(\frac{\sum_{J=1}^{n}(C_J^2) - \left(2(\overline{U})\sum_{J=1}^{n}(C_J)\right) + (n(\overline{U})^2)}{(n-1)}\right).$$

To complete the catch and effort data expansion process, the estimated total catch for each expansion strata ($\hat{C}$) is calculated by multiplying the expanded trips by the mean catch per trip:

$$\hat{C} = \hat{T} \; X \; \overline{U};$$

where T is the estimated expanded number of trips, and $\bar{U}$ is the average catch per trip.

The variance of the estimated total catch ($Var\ (\hat{C})$) is calculated by the formula for the variance of products (Meyer 1975):

$$VAR\ (\hat{C}) = (VAR(\hat{T})\ (\overline{U})^2) + (VAR(\overline{U})\ T^2) + ((VAR(\hat{T}))(VAR(\overline{U}))).$$

To obtain summary information, expansion data are summed across strata, as are their variances. For instance, to obtain an estimate of total catch and effort at a port, the $\hat{C}$ and T and their respective estimated variances are summed over all methods for both weekdays and weekends/holidays.

The final step in the data expansion process is to partition the estimates of total catch by method into estimates of catch for each species identified during the sampling process. This is done by calculating the percent species composition for the port, method, and time period being estimated. First the sum of the total sampled weight of an individual species is divided by the sum of the weight of all identified catch. The resultant percent is then multiplied by the estimated total catch for that port-method strata:

$$\hat{C}_s(x) = \left(\frac{\sum_{J=1}^{n} pounds\ of\ species(x)}{\sum_{J=1}^{n} pounds\ all\ species} \right) X\ \hat{C};$$

where $\hat{C}_s(x)$ = Estimated catch of species (x) for a port and method, and $\hat{C}$ is the estimated catch for the port and method.

J and n refer to only those interviews which contain species breakdown of the catch. No formula for estimating the variance at the species level is currently available, but the variance should be fairly high because of the small sample size and the extreme variability in the species mix of catches, even within a single method.

Summary species composition data are obtained by simply summing the individual species estimates across the port, method, or time period strata. For example, to obtain the estimated total catch of mahimahi island-wide for a 1-year period using quarterly expansion data, a species composition data base would have been created during the data expansion process that contains one record for each species for each method for each port for each quarter in the year. A simple summation would then be performed across all strata for the particular species in question:

$$Island\text{-}wide\ \hat{C}_s(x) = \left(\sum_{Q=1}^{4} \left(\sum_{P=1}^{8} \left(\sum_{M=1}^{23} \hat{C}_s(x)\right)\right)\right);$$

where M is the method of fishing, P is the port sampled, and Q is the quarterly expansion data.

A useful statistical descriptor commonly used in presentation of fisheries surveys data is the coefficient of variation (CV). The CV of any summary estimate gives a relative measure of the variability and a perception of the "quality" of the estimate and is defined as a percentage proportion of the standard deviation (square root of the variance) of the estimate to the estimate, as shown by:

$$CV(x) = \left((\frac{\sqrt{var(x)}}{\hat{x}} \right) X\,100;$$

where $CV(x)$ is the coefficient of variation of parameter x, x is any stratum parameter or sum across strata, and x is the estimate of parameter x.