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ANALYSIS OF CATCH STATISTICS OF THE HAWAIIAN SKIPJACK FISHERY

By Daniel T. Yamashita

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ABSTRACT

The catch statistics of the Hawaiian skipjack fishery and its associated live-bait fishery for the period 1900 through 1953 are brought together from all available records.

The various facets of the live-bait fishery, the only important one in the central Pacific, the methods of data collection for the skipjack and live-bait fisheries, and the completeness and accuracy of the catch records, are analyzed. Skipjack records in terms of weight caught were nearly complete for 1945 through 1953, as an estimated 94 percent of the catch was reported compared with an estimate of only two-thirds to three-fourths of the catch in earlier records. The bait-catch records for 1946 through 1953 were approximately 75 percent complete.

A description of the 1953 fishing fleet and the essential specifications of the sampans in the Territory of Hawaii, information which may be useful in evaluating future changes in catch per unit of effort, are presented.

CONTENTS

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BUREAU OF COMMERCIAL FISHERIES

The skipjack or aku, *Katsuwonus pelamis* (Linnaeus), is widely distributed over the world, occurring in most tropical and subtropical seas. It supports the largest fishery in Hawaii, both in weight and value of fish taken. The Pacific Oceanic Fishery Investigations (POFI) of the United States Fish and Wildlife Service has studied the Hawaiian fishery and the general biology of the skipjack in this region as a part of its general program of research on the tuna resources of the central Pacific.

This report presents and analyzes the available catch statistics for the Hawaiian skipjack fishery and associated live-bait fishery for the period 1900–1953. It includes historical data necessary to an interpretation of the statistics, and also provides a description of the 1953 fishing fleet, which may be helpful in evaluating future changes in catch per unit of effort. It supplements a previous report by June (1951), in which he described the methods used in the skipjack fishery.

The basic statistics used in this report, unless otherwise stated, have been collected by the Hawaiian Division of Fish and Game, and some have been published in the form of biennial reports and monthly catch reports. The collection of such data is done routinely for fish of all species caught in Hawaiian waters.

I am particularly indebted to Vernon E. Brock, Director of the Hawaiian Division of Fish and Game, for making the catch records available for this analysis, and to Yoshio Yamaguchi and Tamotsu Shimizu for their generous help with this study.

THE SKIPJACK FISHERY

From a modest beginning, when the fish were dried or sold on the fresh market, the Hawaiian skipjack fishery has developed into one of the important industries of Hawaii, with most of the fish now being canned. The present Honolulu cannery was established in 1917 and incorporated in 1922 as the Hawaiian Tuna Packers, Ltd. The Nawiliwili Canning Co., Ltd., began operation in 1951 at Nawiliwili, Kauai, but the cannery closed in 1954. At present, the Honolulu cannery and the fresh market are able to utilize all of the skipjack landed, which annually amounts to about 50 to 70 percent by weight of the total fish taken in the Territory.

The available statistics on these landings are presented in figure 1 and tables 1 and 2. These data show landings of less than a million pounds in 1900 and 1903, an annual average of about 5 million pounds from 1928 to 1936, and a pre-World War II peak of more than 13 million pounds in 1940. After the war the landings built up, with minor interruptions, from a low of less than a million pounds in 1944 to a peak of 12.9 million pounds in 1951, which was followed by a poor catch in 1952 and another good year in 1953.

TABLE 1.—*Weight and value of Hawaiian skipjack* (Katsuwonus pelamis) *landed before and during early period of World War II*

[Landings: in thousands of pounds; price: per pound]

Year	Market		Cannery		Total landings	Average price/pound
	Landings	Price	Landings	Price		
1900	422	$0.100			422	$0.100
1903	761	.041			761	.041
1928 [1]	2,878	.069	1,547	$0.020	4,425	.052
1929 [1]	2,964	.071	374	.026	3,338	.066
1930 [1]	3,918	.053	2,319	.023	6,237	.042
1931 [1]					6,123	
1932 [1]					3,162	.058
1933 [1]	2,892	.046	2,669	.020	5,561	.034
1934 [1]	2,982	.047	4,942	.023	7,924	.032
1935 [1]	4,873	.044			4,873	.044
1936 [1]	4,674	.038	[2] 989	[2] .037	5,663	.038
1936 [3]			2,071	.036	2,071	.036
1937	403	.053	12,384	.038	12,787	.039
1938	494	.054	9,228	.040	9,722	.041
1939	407	.058	8,198	.040	8,605	.041
1940	2,112	.036	11,308	.040	13,420	.039
1941	1,050	.040	2,602	.040	3,652	.040
1942					10	.278

[1] Fiscal year ending June 30.
[2] January to June 1936.
[3] July to December 1936.

NOTE.—Approved for publication April 4, 1957. Fishery Bulletin 134.

TABLE 2.—*Weight and value of Hawaiian skipjack* (Katsuwonus pelamis) *landed March 1944 to December 1953*

[Based on catch records of the Hawaiian Division of Fish and Game]

Year	January	February	March	April	May	June	July
1944:							
Pounds sold			41,668	68,914	132,524	76,751	35,882
Price/pound			$0.293	$0.278	$0.242	$0.258	$0.273
1945:							
Pounds sold	71,065	74,278	84,747	99,384	160,199	135,327	532,071
Price/pound	$0.272	$0.250	$0.251	$0.251	$0.262	$0.270	$0.253
1946:							
Pounds sold	206,952	249,643	108,119	245,018	612,493	981,592	743,267
Price/pound	$0.240	$0.275	$0.276	$0.274	$0.262	$0.157	$0.154
1947:							
Pounds sold	441,911	163,975	232,612	267,894	316,017	620,835	1,108,642
Price/pound	$0.205	$0.263	$0.272	$0.256	$0.226	$0.146	$0.139
1948: [1]							
Pounds sold	672,053	439,680	236,582	344,552	568,140	1,136,811	2,034,804
Price/pound	$0.172	$0.168	$0.194	$0.187	$0.192	$0.155	$0.145
Pounds caught	602,142 (678,841)	395,448 (444,121)	233,327 (238,972)	335,862 (348,032)	534,758 (573,879)	999,302 (1,148,294)	2,038,345
1949:							
Pounds sold	68,413	116,327	120,615	235,465	1,016,826	2,255,535	1,690,860
Price/pound	$0.319	$0.261	$0.309	$0.304	$0.138	$0.119	$0.124
Pounds caught	68,683	116,625	121,717	236,392	1,020,457	2,260,284	1,696,565
1950:							
Pounds sold	154,562	141,213	186,494	399,497	579,600	982,714	1,942,838
Price/pound	$0.211	$0.204	$0.228	$0.190	$0.152	$0.140	$0.126
Pounds caught	157,066	141,932	187,740	400,973	581,851	985,410	1,948,585
1951: [2]							
Pounds sold	87,123	86,382	94,178	525,796	2,287,977	2,577,022	2,312,616
Price/pound	$0.238	$0.238	$0.379	$0.182	$0.132	$0.128	$0.127
Pounds caught	87,489	87,583	97,094	529,374	2,295,651	2,584,710	2,323,489
1952:							
Pounds sold	28,771	89,606	55,721	384,925	573,965	814,238	1,649,956
Price/pound	$0.276	$0.273	$0.352	$0.186	$0.165	$0.141	$0.133
Pounds caught	29,054	89,958	55,867	387,141	577,992	818,345	1,654,397
1953:							
Pounds sold	195,193	203,203	575,884	862,125	1,236,649	2,237,334	1,507,242
Price/pound	$0.248	$0.204	$0.148	$0.134	$0.128	$0.125	$0.125
Pounds caught	200,197	204,139	576,345	863,700	1,239,585	2,241,430	1,509,773
Weighted average price/pound	$0.211	$0.224	$0.226	$0.196	$0.160	$0.136	$0.137

Year	August	September	October	November	December	Total catch	Weighted average price/pound
1944:							
Pounds sold	59,233	99,016	123,744	33,921	62,359	734,012	
Price/pound	$0.254	$0.254	$0.259	$0.231	$0.278		$0.259
1945:							
Pounds sold	760,035	663,842	662,358	436,738	227,258	3,907,302	
Price/pound	$0.282	$0.275	$0.253	$0.255	$0.264		0.264
1946:							
Pounds sold	720,829	589,146	655,367	400,981	116,844	5,630,251	
Price/pound	$0.136	$0.147	$0.141	$0.237	$0.326		0.187
1947:							
Pounds sold	634,219	507,044	373,019	465,272	460,096	5,591,536	
Price/pound	$0.146	$0.145	$0.160	$0.178	$0.179		0.174
1948: [1]							
Pounds sold	1,290,683	878,024	422,843	234,227	78,552	8,336,951	
Price/pound	$0.144	$0.152	$0.175	$0.225	$0.253		0.162
Pounds caught	1,296,645	879,362	423,636	234,840	78,974	8,052,641 (8,383,941)	
1949:							
Pounds sold	2,421,441	1,035,291	490,509	255,122	157,605	9,864,009	
Price/pound	$0.121	$0.129	$0.153	$0.186	$0.178		0.138
Pounds caught	2,426,601	1,038,151	491,960	258,735	158,516	9,894,686	
1950:							
Pounds sold	1,801,779	1,174,012	1,020,678	706,048	391,867	9,481,302	
Price/pound	$0.136	$0.133	$0.134	$0.132	$0.153		0.142
Pounds caught	1,805,031	1,176,794	1,022,590	708,271	395,179	9,511,422	
1951: [2]							
Pounds sold	2,672,960	1,384,488	410,181	247,062	188,489	12,874,274	
Price/pound	$0.125	$0.117	$0.136	$0.164	$0.189		0.134
Pounds caught	2,683,270	1,387,647	411,595	248,094	190,313	12,926,309	
1952:							
Pounds sold	1,751,162	983,537	574,324	109,792	248,022	7,264,019	
Price/pound	$0.129	$0.134	$0.136	$0.202	$0.214		0.146
Pounds caught	1,758,153	986,554	575,603	110,138	248,649	7,291,851	
1953:							
Pounds sold	2,138,806	1,278,507	1,196,400	217,364	381,830	12,030,537	
Price/pound	$0.123	$0.129	$0.132	$0.161	$0.144		0.132
Pounds caught	2,142,181	1,281,278	1,199,164	218,077	383,537	12,059,406	
Weighted average price/pound	$0.138	$0.145	$0.157	$0.190	$0.194		0.154

[1] Summarized late reports for pounds caught not available for January through June 1948. Adjusted catches, in parentheses, based on weight sold; future references to total catches for 1948 will be based on these figures.

[2] Published monthly catch statistics changed from pounds sold to pounds caught in November 1951.

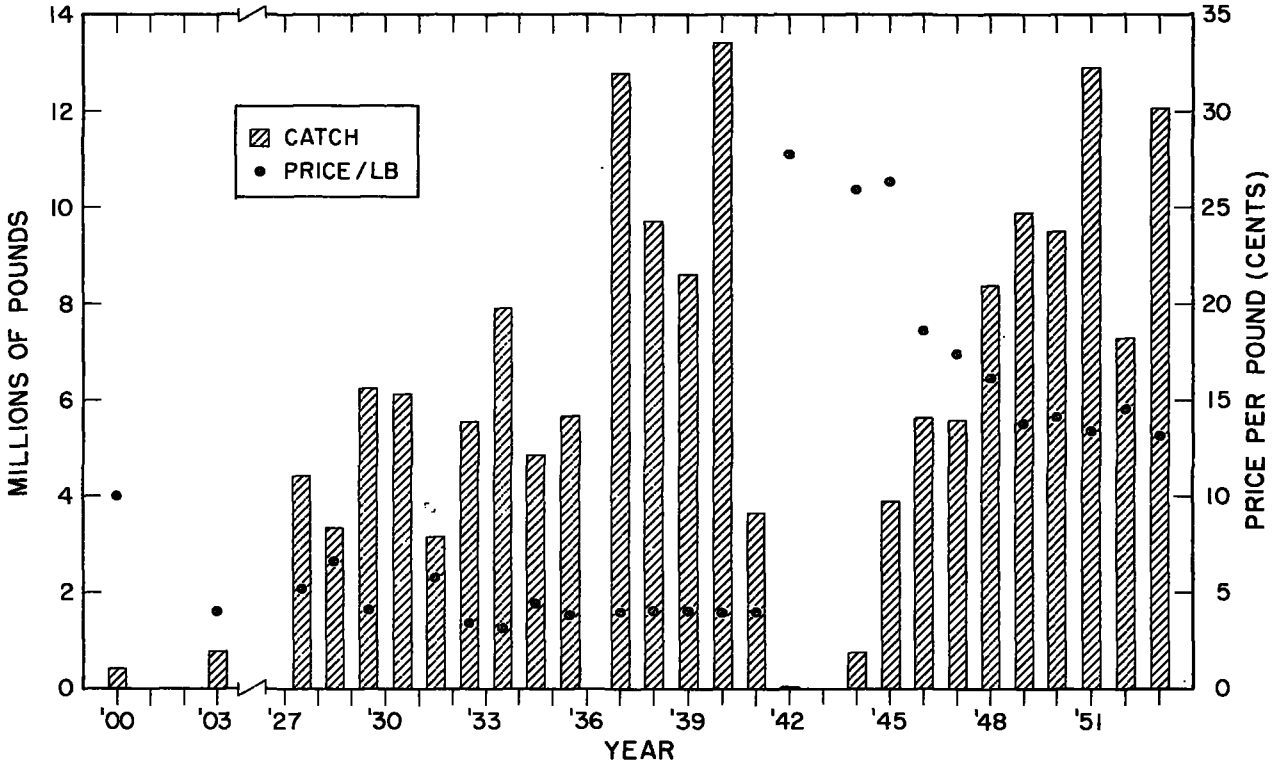

FIGURE 1.—Annual Hawaiian skipjack catch (weight sold) and price per pound for all available years, 1900–1953. The data for 1928–36 are by fiscal years (July to June); data for 1937–53 are by calendar years.

The number of boats (sampans) engaged in the local fishery has varied only slightly in recent years. There were 26 boats actively fishing for skipjack in 1953 as compared with 32 in 1948 (June 1951). This apparent decrease during the 5-year period may have resulted from a change in the interpretation of what constitutes a skipjack vessel. Many of the smaller craft that fish for skipjack on a part-time basis may not have been included in the 1953 records. Between 1948 and 1953 only 2 new sampans joined the fleet, but 2 of the older boats (not included in the total count) were wrecked and lost during 1953.

The size and design of the sampans are essentially as described by June (1951). The boats range from 58.3 to 80.5 feet in registered length and generally are of wooden construction—only two have steel hulls. All are equipped with diesel engines and are driven by a single screw. A major change in recent years has been the replacement of some of the older engines with new high-speed engines rated up to 450 horsepower. As fishing is usually done close to port and the catch is landed within a few hours of capture, the sampans do not have mechanical refrigeration systems but some carry ice. The basic specifications and distribution, by islands, of the 26 full-time skipjack boats operating in 1953 are given in appendix table 1, page 272.

The usual sequence of operations of a Hawaiian skipjack sampan is to catch bait on 1 or more days, depart for the fishing grounds early in the morning, fish, then return to port and unload the catch that night. If sufficient bait remains, the boat may depart the next day for the fishing grounds; if not, the operational sequence is repeated.

CATCH STATISTICS

Methods of Collection

The systematic collection of fishery statistics in Hawaii has evolved from occasional surveys through a stage of regular but relatively incomplete coverage to the present system, which endeavors to record the complete commercial production in the Territory.

The first statistics on the Hawaiian fishery, for 1900 and 1903, were believed to be complete by Cobb (1902, 1905), who collected them. In 1925,

the legislature enacted a law requiring catch reports of fish dealers in the ports of Honolulu and Hilo. These reports, estimated to be two-thirds to three-fourths complete (Hawaii Commissioners of Agriculture and Forestry, 1946), were used in the compiling of the 1928 to 1942 catch records. It is probable that even after this legislation the reporting of catch data was still somewhat erratic, and that in the late 1920's and early 1930's the portion of the total catch reported may have been even smaller than this estimate.

In 1945 the 1925 law was amended to require catch reports from all fish dealers in the Territory; furthermore, a new law enacted in the same year required all owners or agents of licensed fishing craft to report their catches. Although this amendment was not passed until 1945, fish catch statistics from the major islands have been available since 1943. However, the catches for the period January 1943 through February 1944 were reported only in terms of the combined weight of all species landed.

The skipjack-catch report form has gone through a number of revisions since its introduction in March 1944. The initial form applied to all types of fishing on a monthly basis, whereas the present form provides for detailed information on individual fishing trips and is issued for skipjack reporting only (see appendix figs. 1–5, pp. 273-277). The catch statistics were compiled manually until 1947, when the punch-card method using IBM machines was introduced. This change has resulted in the preparation of more complete skipjack statistics since 1948.

In addition to the regular catch reports, interviews on 2 or 3 days a week with captains of the sampans were started in July 1949 (see appendix fig. 6, for a sample of the interview form). These interviews have been continued, during the summer months primarily, in order to obtain a better estimate of the catch per unit of effort of both skipjack and bait. The system was further modified in June 1953 by placing interview sheets on boats with the more cooperative captains who agreed to fill them in routinely. These sheets are collected and checked for additional information.

Completeness and Accuracy

It is apparent from the review of collection methods that the statistics for the Hawaiian skipjack fishery have been collected in a variety of ways and with varying degrees of completeness and accuracy. An evaluation of the more recent catch statistics requires consideration both of the routine followed in the fishery (p. 255) and of the methods by which the statistics are reported.

The skipjack are sold to the cannery on a weight basis, and it is the responsibility of the fishermen or their agents to report the exact weight sold and the price received, together with an estimate of the total weight and number of skipjack caught. The total weight caught must be estimated, since the fish used for home consumption are usually not weighed, nor are those fish weighed that spoiled before they reached the cannery. As the amount caught totals only about 1 percent more than the weight sold, errors in the estimate of total weight are relatively unimportant. The number of fish caught is calculated from an estimate of the average weight of the fish and the total weight of the catch. These reports are required of all persons possessing commercial fishing licenses; however, reports are required only for productive trips.

An important source of error in the catch statistics results from the occasional failure of fishermen to report their catches. An estimate of the unreported catches has been derived from a comparison of interview records and catch reports for 1952. The unproductive trips, which are often reported in the interview records but are not included in the catch reports, have been omitted from this analysis.

To evaluate the accuracy of the skipjack catch records, the extent of agreement between the interview records and the catch reports was determined by comparing the dates and sizes of skipjack catches and the dates and sizes of the bait-fish catches in each. The localities of catch for skipjack and bait were occasionally used as criteria of agreement. Bait-catch localities were usually in agreement in the two sets of reports, but oftentimes discrepancies arose in the reporting of the localities of skipjack catches (see p. 258). Based on the extent of agreement between them, the interview and the catch records were classified into five categories.

The first category is that in which an interview record matches a catch report for a given catch. An interview record was considered to match a catch report when (1) the date of catch as determined by interview was not more than 2 days before the reported date of landing; (2) the bait

catch given in the interview was made on the same day, in the same locality, and in about the same quantity as in the catch report; and (3) the estimated catch in the interview was within 75 percent of the reported catch.

The second category, in which more than 1 day's catch as determined by interviews is included in a single catch report, occurred occasionally when skipjack were caught on successive days without rebaiting. Reports falling in this category were recognized by (1) agreement in size and location of bait catch; (2) agreement (within 75 percent) between the sum of two or more consecutive interview estimates of skipjack catches and the total in the catch report; and (3) correspondence in date (within 2 days) between the last interview and the catch report.

The third category, in which catches listed in catch reports are much higher than those listed in the interview records, occurred in a few instances. Such catches were regarded as suspiciously high if the catches from individual trips of other boats operating during the same period of time were known to be small. In these instances it is believed that the catches shown on the interview records were combined into one catch report with other catches not covered by interviews. The part of the catch probably corresponding to that estimated in the interview was calculated by applying the ratio of weighed to estimated catch for the appropriate month (table 3, col. 8).

The fourth category includes interview records that were definitely not included in the catch reports. They were recognized when a check of all catch reports precluded the possibility of placing them in any one of the first three categories.

The fifth category includes the few instances in which the catch reported is not within 75 percent of the estimated catch from interviews and there is no evidence that would permit classifying the catch reports as category 3. Only 2.8 percent of the reports fell in this category, and these interview and catch records were eliminated from further consideration. Categories 3 and 5 were differentiated by determining whether the catch reports could have included catches not covered by the interview records. If there was any possibility, judging by the available records, of additional catches having been included in the catch report, the reports were placed in category 3.

From the comparison of catch reports and interview records the percentage of trips and the percentage of catch reported have been estimated for these different categories and are summarized in table 3. The trips for which there were interviews, exclusive of unproductive trips and those falling in category 5, have been listed in column 1. Column 2 lists the catches reported separately (category 1), and column 3 the catches reported in combined form (categories 2 and 3). Column 4 shows the percentage of trips reported

TABLE 3.—*Comparison of interview records and catch reports for the Hawaiian skipjack* (Katsuwonus pelamis) *fishery, 1952*

Month	Trips					Catch (in pounds)						
	1	2	3	4	5	6	7	8	9	10	11	12
	Number of trips interviewed [1]	Catch reports, category 1	Catch reports, categories 2 and 3	Percent of trips separately reported	Percent of all trips reported	Estimated catch shown on interview record, category 1	Weighed catch shown on catch report, category 1	Ratio of weighed/estimated catch	Catch shown on interview records, categories 1, 2, 3, and 4	Computed catch all trips interviewed [2]	Catch shown on catch reports, categories, 1, 2, 3, and 4	Percent of catch reported [3]
May	7	5	0	71.4	71.4	20, 800	21, 489	1.033	25, 100	25, 928	21, 489	82.9
June	26	22	0	84.6	84.6	98, 200	104, 179	1.061	101, 400	107, 585	104, 179	96.8
July	39	34	6	61.5	76 9	98, 500	103, 522	1.051	155, 090	163, 000	145, 086	89.0
August	50	36	11	72.0	94.0	313, 600	321, 674	1.026	409, 400	420, 044	403, 354	96.0
September	40	32	6	80.0	95.0	201, 720	219, 585	1.089	238, 870	260, 129	251, 080	96.5
October	40	28	7	70.0	87.5	76, 850	81, 526	1.061	99, 450	105, 516	92, 654	87.8
November	7	4	2	57.1	85.7	9, 000	10, 873	1.208	11, 500	13, 892	12, 379	89.1
Total	209	151	32			818, 670	862, 848		1, 040, 810	1, 097, 014	1, 030, 221	
Average				72.2	87.6			1.054				93.9

[1] Exclusive of unproductive trips and category 5.
[2] Column 8×column 9.
[3] Column 11÷column 10.

separately and column 5 the percentage of trips reported both separately and in combined form. On the average, 87.6 percent of the trips recorded by interview were reported in the catch reports; only 72.2 percent were reported as separate trips.

In order to estimate the total catch from the reported catch, it was necessary first to establish the relation between the fisherman's estimate of his catch and the true weight of the catch (table 3, cols. 6, 7, and 8). The results show that the weighed catch averages 1.054 times the estimated catch reported in the interview records since the tendency of the fishermen is to underestimate their catch. The total catch estimated by the fishermen in all interviews (col. 9) has been multiplied by the monthly ratios (col. 8) to obtain a computed total catch that should have been reported for all trips covered by interviews (col. 10). Column 11 includes the total catch from all catch reports that correspond to the interviews (col. 9). The percentage of catch reported (col. 12) averaged 93.9 percent of the probable total catch. This value is somewhat higher than that for percentage of trips reported (87.6 percent), and suggests that the fishermen tended to overlook the small catches in their catch reports. If it is assumed that the percentage by weight reported has been constant for the years 1945 to 1953, then the total annual catch may be estimated as shown in table 4.

A peak catch of 13.7 million pounds was estimated for 1951. If we assume that the prewar peak of 1940 was only three-fourths complete and actually totaled 17.9 million pounds instead of the reported 13.4 million, then the fishery has yet to attain the level of the prewar catches.

TABLE 4.—*Reported and estimated annual skipjack catch, 1937–53*

Year [1]	Reported catch (pounds) [2]	Estimated catch (millions of pounds)
1937	12,787,261	17.0
1938	9,722,150	13.0
1939	8,604,768	11.5
1940	13,420,333	17.9
1945	3,907,302	4.6
1946	5,630,251	6.0
1947	5,591,536	6.0
1948	8,336,951	8.9
1949	9,864,009	10.5
1950	9,481,302	10.1
1951	12,874,274	13.7
1952	7,264,019	7.7
1953	12,030,537	12.8

[1] Reports assumed to be 75 percent complete for years 1937–40 (Hawaii Commissioners of Agriculture and Forestry, 1946) and 93.9 percent complete for 1945–53. No adequate data available for the war years, 1941–44.
[2] Based on weight sold, from Hawaiian Division of Fish and Game records.

Another questionable aspect of the catch records is related to the reporting of the localities in which the catches were made. In the interviews the location was given by distance and direction from some reference point on land, and in the catch reports the location was identified by an area number as shown in fisheries chart No. 2 supplied by the Hawaiian Division of Fish and Game (fig. 2). Although the method of reporting differed between the interviews and the catch reports, gross disagreements in catch localities were readily detected by comparing corresponding reports from the two sources.

With reference to the designated fishing locality, interview records and catch reports were separated into two groups: those showing agreement as to catch locality and those not showing agreement as to catch locality. The reports were considered in agreement if there was general correspondence as to location and distance of the catch from a reference point on land. In spite of rather liberal treatment, the number in agreement was only about 45 percent; in many cases the same catch was reported from opposite ends of an island or even from different islands. Thus, assuming that the true catch locality was given when the two reports were in agreement, and that a fictitious locality was given when there was disagreement between the reports, less than one-half of all reports show the true source of the catch. Hence, any short-term study (within a year) on the localities of skipjack catch should be made in terms of general rather than specific areas if results are to be of value. However, errors in the comparison of specific areas over a period of years should be less important.

Value and Weight of the Landings

The price received by fishermen for skipjack for many years before World War II was about 4 cents a pound, but it jumped to 28 cents when landings were seriously curtailed by the war. The increase in landings after the war was accompanied by a decrease in price, which in 1949 leveled off at about 14 cents a pound (table 2). This is an average of the price paid by the cannery, about 12 cents, and the higher prices received in the fresh fish market, particularly in seasons of low landings. The gross annual receipts to the fishermen were about a million dollars or more from 1945 on and reached a peak of $1.7 million in 1951.

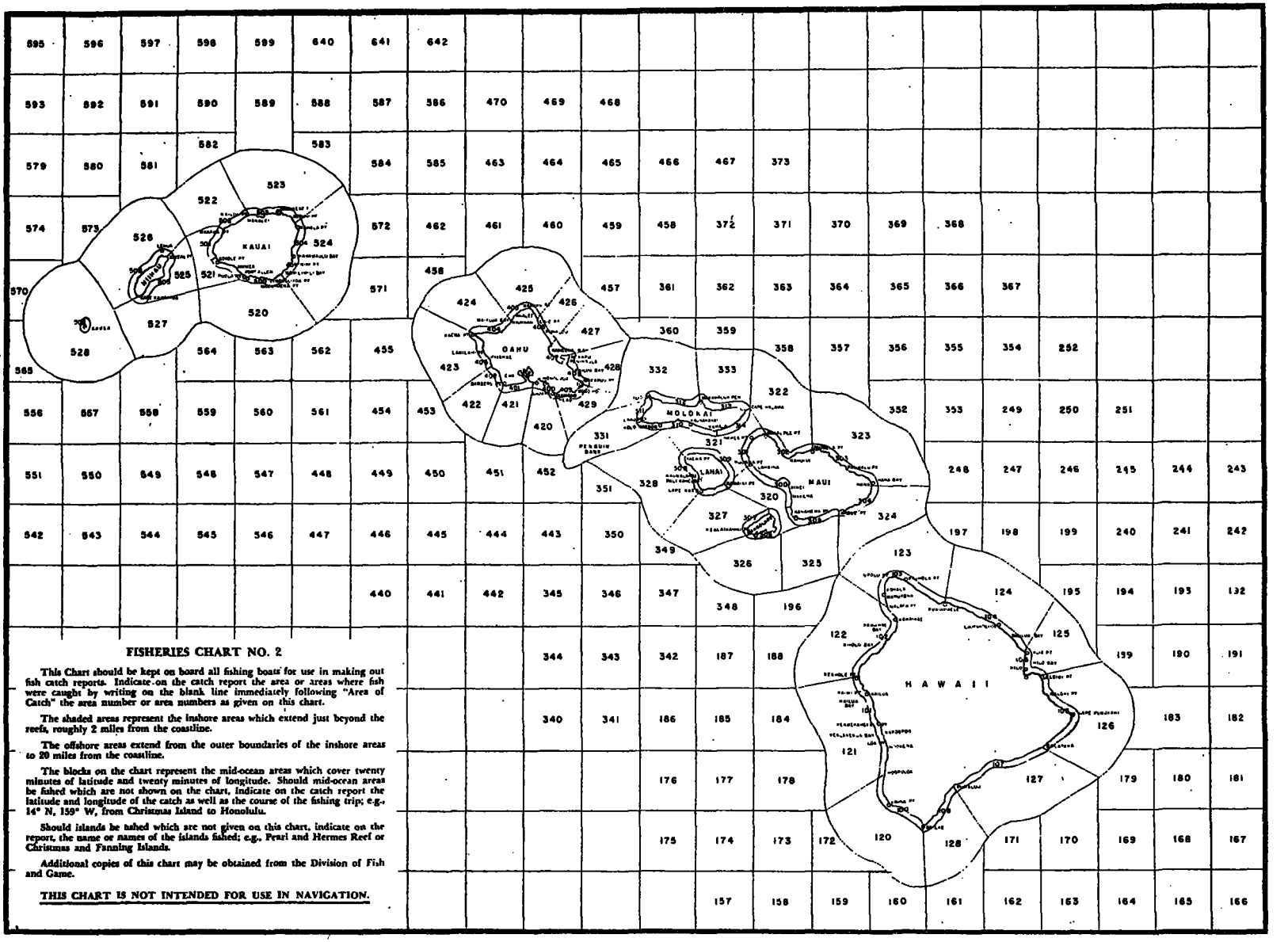

FIGURE 2.—Hawaiian Division of Fish and Game fisheries chart No. 2, showing the statistical areas established for Hawaiian waters.

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From 1928 through 1936 the catch totals were summarized only by fiscal years, but in subsequent years they are available for calendar and fiscal years. In some years the published reports do not designate whether the fish went to the market or to the cannery. In fiscal year 1936, the cannery reported its purchases for the period January through June 1936, but not for July through December 1935. The 1941 catch was low, partly because of the curtailment of fishing resulting from prewar naval maneuvers and wartime restrictions and partly because of the failure of some of the boats to operate during the first 6 months of the year owing to a controversy over the price of fish. None of these factors were serious enough to have distorted the general trend of increasing landings during the period ending in 1940.

Because of a change in the method of collecting data on the skipjack fishery, the postwar (World War II) catch statistics are much more complete than the records from 1928 through 1942. Some variations occur in the published figures, however, because from March 1944 to October 1951 the skipjack catch statistics were published in terms of weight sold, and in November 1951 this was changed to weight caught. Table 2 provides a comparison of the amount caught and the amount sold for the years 1948 to 1953 as compiled from both published and unpublished records of the Hawaiian Division of Fish and Game.

These statistics show an upward trend in the catch from 1944 to 1951, which appears to have been due partly to a changing fleet and partly to a change in relative abundance or availability of skipjack. There was a gradual increase in the number of vessels in operation from 1944 until the beginning of 1947, when about 26 vessels were engaged in full-time skipjack fishing. However, 10 of these sampans did not fish during the first 6 months of 1947 because of a disagreement over prices, and thus the first full year of fishing was 1948. The number of vessels in the fleet has remained nearly constant since the beginning of 1948.

Seasonal Variations in the Catch

The exploitation of skipjack in Hawaiian waters is highly seasonal and the bulk of the catch is landed during the months of May, June, July, August, and September (table 2). The average monthly landings reported for the years 1948 to 1953 are shown in figure 3. The reasons for this large seasonal influx of skipjack into the fishery remain obscure, but food and spawning may influence the movement into the fishery.

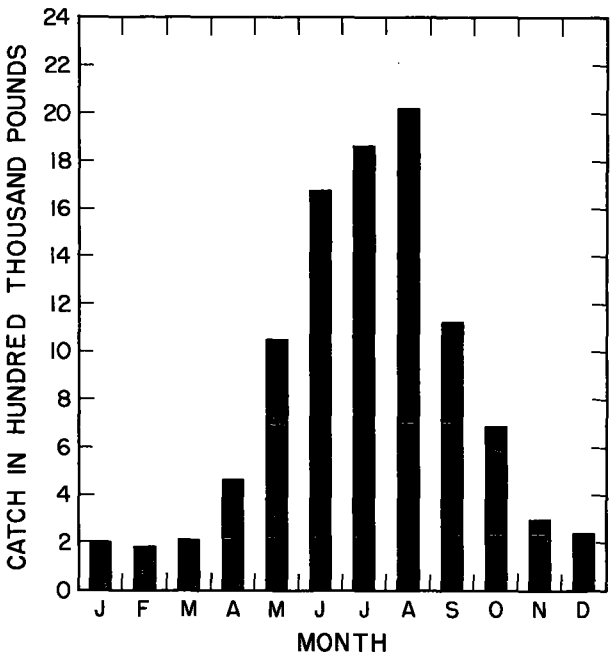

FIGURE 3.—Average monthly skipjack catch, 1948–53, based on records of the Hawaiian Division of Fish and Game.

King and Hida (1954) found that slightly more plankton, and consequently more tuna food, occurs in Hawaiian waters during the summer than in winter. It does not appear plausible, however, that a slight change in the food supply could cause such a marked seasonal fluctuation in the skipjack catch.

On the other hand, fishes are known to undertake long migrations in response to the spawning urge. From an examination of skipjack ovaries in different months of the year, Brock (1954) found indications "that the spawning period probably extended from late February, March, or April to the first part of September," coincidental with the months of high skipjack landings. He also noticed that the fully ripe or spent fish were rarely found in the catches, indicating that they may be unavailable to the fishery when in this condition, and he found evidence that individual fish spawn repeatedly during one spawning season.

POFI investigations on larval tunas (Matsumoto 1958) support Brock's conclusion that skip-

jack spawn during the summer. Matsumoto found that in plankton samples obtained in August, during a cruise in Hawaiian waters, 164 of the 326 identified tuna larvae were skipjack. The dominant size group was less than 6 mm. in length, indicating that spawning could not have been far off either in time or space.

Experiences of skipjack fishermen with spawning fish are also of interest. They have observed that "spawning schools," encountered infrequently during the height of the season, are never fished successfully and, hence, are abandoned for more readily biting schools. The schools are considered to be spawning because they are often seen in a cloud of what is thought to be milt in the water.

If the seasonal abundance of skipjack in the Hawaiian fishery is attributed to a spawning migration, the actual biological or oceanographic conditions causing this movement are not evident at the present time.

Size and Number of Fish in the Catch

The average weight and total number of skipjack caught (table 5) were computed from the catch records for each month from 1948 through 1953. A comparison of the data for those years showed that skipjack were taken in the greatest numbers and that the fish had the highest average weights during the 2 best years, 1951 and 1953 (fig. 4). The variation in number of fish landed between the fair years of 1949 and 1950 and the poor year of 1952 is relatively less than the variation in the total weight of fish landed, suggesting that skipjack may have been equally abundant during these years and that the difference in total catch was largely due to differences in the size of the fish.

The success of fishing, and with it the magnitude of the total catch in weight, is controlled, other things being equal, by a combination of two factors: the absolute numbers of fish available and the size of the fish. The good catches of 1951 and 1953 were due to the presence of large numbers of large fish, whereas the 1952 catch was poor because the skipjack were both few and small. A lesser abundance of fish may be compensated for within limits by the presence of larger fish, e. g., the third largest catch in weight, for the years under consideration, was recorded in 1949, but this year ranked last in the total number of

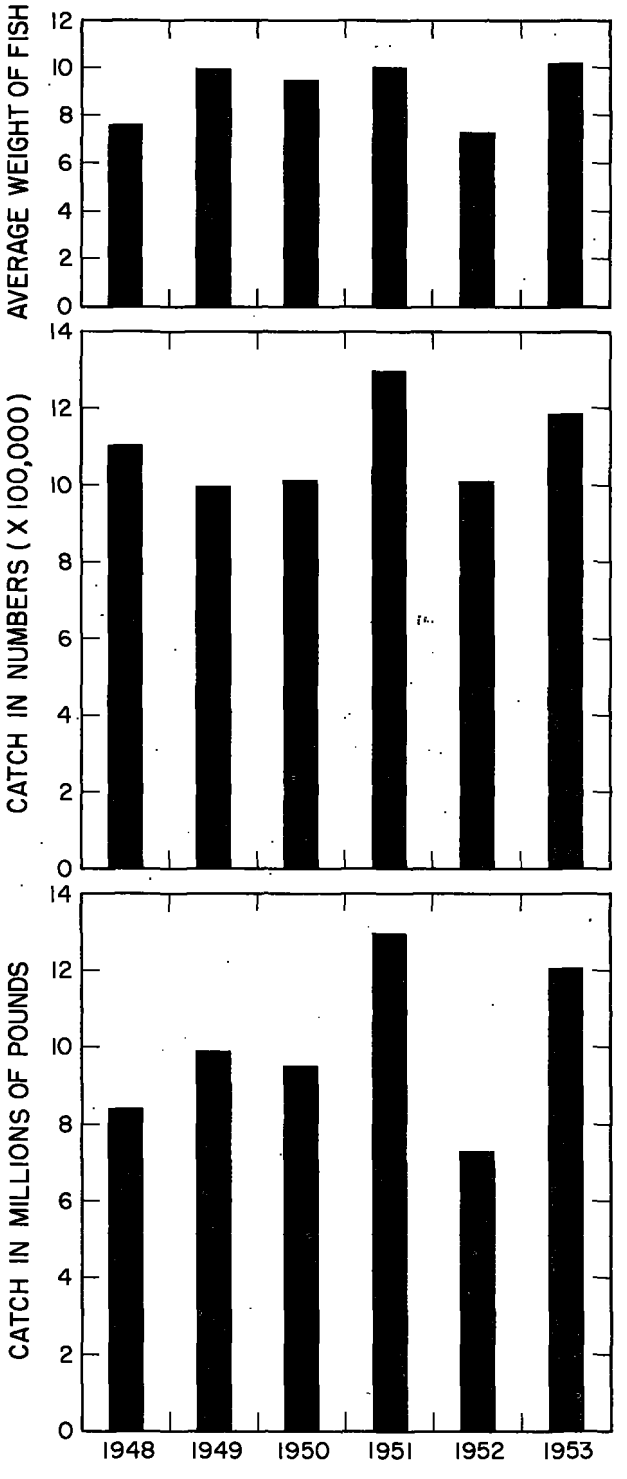

FIGURE 4.—Skipjack catch by average weight and number of fish taken and total catch, 1948–53, based on records of the Hawaiian Division of Fish and Game.

TABLE 5.—*Number and average weight of skipjack landings, by month and year, 1948–53*

[From Hawaiian Division of Fish and Game records; weight in pounds]

Month	1948		1949		1950		1951		1952		1953		Weighted average—	
	Number landed	Average weight	Number landed	Average weight	Number landed	Average weight	Number landed	Average weight	Number landed	Average weight	Number landed	Average weight	Number landed	Weight
January	[1] 66,384	10.226	10,562	6.503	27,344	5.744	11,916	7.342	4,233	6.863	14,902	13.434	24,372	9.024
February	[1] 43,851	10.128	14,121	8.259	21,115	6.722	8,680	10.090	11,527	7.804	26,142	7.809	21,341	8.645
March	[1] 56,454	4.233	15,921	7.645	39,350	4.771	15,281	6.354	7,963	7.016	55,831	10.323	31,672	6.697
April	[1] 78,705	4.422	36,446	6.486	53,179	7.540	61,879	8.555	58,782	6.586	105,278	8.204	66,174	7.014
May	[1] 84,295	6.808	93,758	10.884	80,757	7.205	160,625	14.292	82,230	7.029	128,414	9.653	112,570	9.982
June	[1] 224,583	5.113	160,897	14.048	105,912	9.304	198,916	12.994	101,230	8.084	157,238	14.255	157,348	10.580
July	199,897	10.197	136,194	12.457	117,832	16.537	360,622	6.443	224,538	7.368	190,580	7.922	183,362	9.085
August	130,029	9.972	225,793	10.747	159,610	11.309	232,177	11.557	269,325	6.528	190,823	11.226	197,458	10.028
September	128,336	6.852	137,997	7.523	191,629	6.141	129,978	10.676	113,934	8.659	137,935	9.289	137,358	8.037
October	49,038	8.639	92,231	5.334	100,996	10.125	61,848	6.655	93,412	6.162	106,384	11.272	85,595	8.185
November	30,061	7.812	46,796	5.529	59,554	11.893	32,721	7.582	14,213	7.749	22,339	9.762	35,332	8.645
December	10,922	7.231	23,246	6.819	51,543	7.667	22,411	8.492	25,560	9.728	50,247	7.633	30,590	7.912
Total number	1,102,555		993,962		1,008,821		1,297,054		1,006,947		1,186,113		1,083,172	
Weighted average weight		7.604		9.955		9.428		9.966		7.242		10.167		9.107

[1] Calculated from the adjusted total catch.

fish caught. Large catches in weight may also be obtained when large numbers of small fish are caught, however, the chances of a large catch in weight are far greater under the former condition, because the number of fish that can be caught with a given effort is somewhat independent of size for fish averaging less than 20 pounds. One report (Hawaii Commissioners of Agriculture and Forestry, 1952) states that the maximum efficiency can be realized in live-bait fishing by working skipjack schools that average between 15 to 20 pounds per fish. Fishing usually lasts 10 to 15 minutes for any one school or for a single pass at a school, hence a larger total weight can result from a "small number-larger size" combination than from a "large number-smaller size" combination.

Catch by Areas

The fishing of distant offshore grounds by the local fishery is restricted principally by the high bait mortality, the limited range of the sampans, and the lack of refrigeration for the catches. Of these three factors, live-bait mortality must be considered of primary importance. A 100-percent bait mortality even before reaching the fishing grounds is not an uncommon occurrence; consequently, much of the skipjack fishing is done close to the baiting areas.

The skipjack catch by areas, as reported by the fishermen for the years 1948 through 1953, was compiled according to the scheme of area designations used on fisheries chart No. 2 of the Hawaiian Division of Fish and Game (fig. 2). The analysis was made despite discrepancies in the reports of localities of catch, as discussed earlier, for it was felt that although there may be errors in the comparison between the small individual areas (20 square miles) within a year, the errors should be negligible over a number of years and between larger, combined areas.

The localities of capture were divided into 3 major zones: Inshore, within 2 miles of land; coastal, 2 to 20 miles; and offshore, beyond 20 miles. The major portion of the catch (about 75 percent) was caught in the coastal zone, as was shown by Royce and Otsu (1955), and the remaining 25 percent of the catch came almost entirely from the offshore zone; the inshore zone contributed an insignificant amount to the total annual catch (fig. 5).[1]

Examination of skipjack catches with respect to distance offshore shows that, except for 1952, catches from the coastal zone remained fairly constant for the years 1948 to 1953, and ranged from 5.3 million to 8 million pounds. Figure 5 suggests that a total of 8 million pounds per year may be the maximum catch that can be harvested from this zone with the present fishing intensity, as implied by the successful years of 1951 and 1953 when 7.7 million and 8.0 million pounds were caught. If this assumption is correct, any in-

[1] There are some discrepancies in the figures between the total catch and the totals of the three zones because of the rounding off of the catches into thousands of pounds and the omission of some catches from unidentified areas.

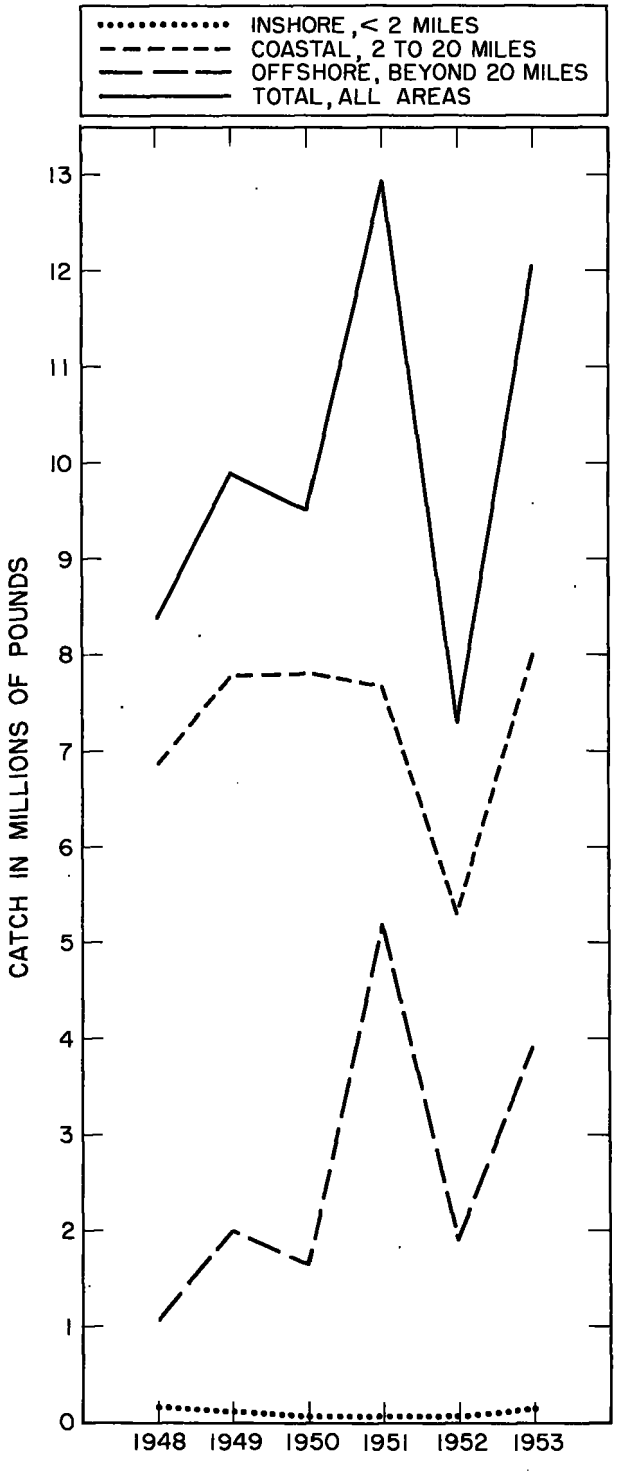

FIGURE 5.—Skipjack catch by zones and total catch from all areas.

crease in the total annual landings must come from increased catches in the offshore zone.

In general, catches from the offshore zone are closely correlated with the catches from all areas (fig. 5). In the record year of 1951, 40 percent of the total catch was taken in the more distant zone and in 1953, 32 percent, whereas during other years not more than 26 percent of the total catch was taken there.

About 90 percent of the annual catch from the offshore zone is obtained from areas between Oahu and Kauai (fig. 6, solid area) and around Oahu, Molokai, and Maui (fig. 6, hatched areas). This distribution of the catch is probably associated with the fact that the majority of the sampans in the fishing fleet are based on Oahu and Maui.

The offshore zone was subdivided into three major regions: Kauai Channel, Oahu-Molokai-Maui, and all other areas, in order to ascertain, if possible, which were the principal localities associated with the major fluctuations in annual catch (fig. 7). The total catch in the offshore zone closely parallels the catch from the region around Oahu-Molokai-Maui. Thus, it appears that the success of a fishing year depends to a large extent on the landings from this particular region.

According to the catch reports, the coastal zone around Oahu was the most productive in the Hawaiian fishery. The skipjack catch from each of the statistical areas (fig. 2, Nos. 420–429) within this zone have ranged from 99,000 to 1 million pounds per year. This apparent concentration of skipjack is probably related in part to the distribution of the fishing fleet on Oahu and in part to the location of the major baiting grounds.

An examination of all areas in the Hawaiian fishery averaging over 100,000 pounds of skipjack per year showed that (1) the best summer catches were made in areas 422 through 427, area 455 off Oahu, and area 125 off Hilo, Hawaii; (2) consistent catches without any pronounced increase during the summer months were made in areas 331, 332, 328, and 428 between Oahu and the Molokai-Lanai area, and area 122 off Kawaihae Bay, Hawaii; and (3) winter landings were relatively higher from the protected lee of the islands, especially areas 328 off Lanai, 423 off Waianae, Oahu, and 122 off Kawaihae Bay.

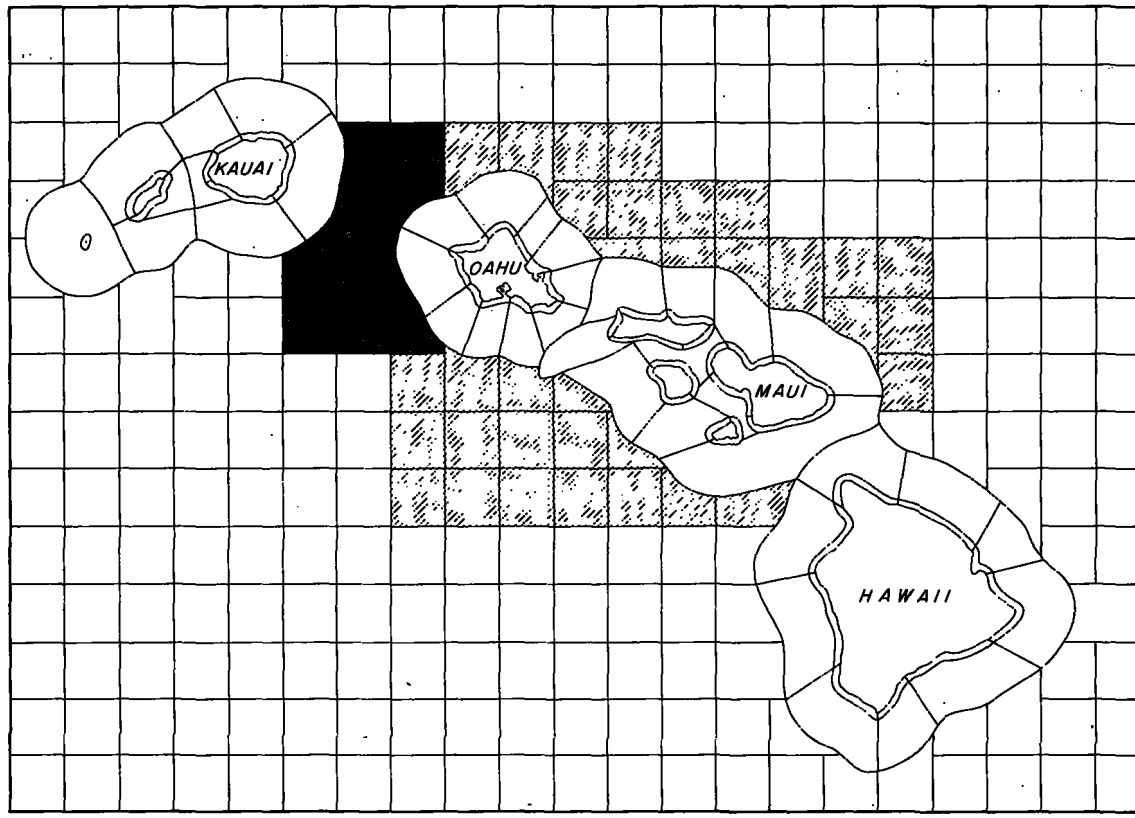

FIGURE 6.—The major offshore fishing zones between Oahu and Kauai (solid area) and around Oahu, Molokai, and Maui (hatched areas), Hawaiian Islands.

During the poor skipjack season of 1952, catches from the coastal zone showed a decline for Oahu and an increase for Kauai. The increase in the catch from Kauai, however, was insufficient to offset the drop in the catch from Oahu, resulting in a net decrease in the catch from all coastal zones. There was also a decrease in catch from the offshore zone, but the catch was still higher than the previous lows from the same zone for 1948 and 1950 when the annual landings amounted to 8.4 million and 9.5 million pounds, respectively, as compared with 7.3 million pounds for 1952. There were 3 productive areas (averaging over 400,000 pounds per year) during the poor year of 1952 that showed an increase in catch over the same areas for the best postwar year, 1951. These localities were all within 20 miles of land: area 125 off Hilo, and areas 331 and 328 southwest of Molokai and Lanai.

The region that shows the most promise of potentially greater productivity is in the offshore zone north of Oahu, Molokai, and Maui, but still within the range of the fishing fleet. The present catches are probably not indicative of the abundance of skipjack in these northern waters because of the low effort expended there, related to generally unfavorable weather conditions. The catch records over the 6-year period show good catches for 1 or 2 years, with no catch reported during other years. The areas to the south of Oahu (fig. 2, Nos. 351, 451–453) have shown evidence of increased production during the last 2 or 3 years.

With the type of vessel in use at present in the skipjack fishery, the most promising immediate prospect of increasing the catch is to exert more effort in the offshore zones, especially around Oahu, Molokai, Maui, and Lanai. The exploitation of these areas might be most feasible during the usual offseason period, when fish are not abundant in the coastal zones.

INDEX OF RELATIVE ABUNDANCE

A general measure of the catch per unit of effort in the skipjack fishery on an annual basis can best

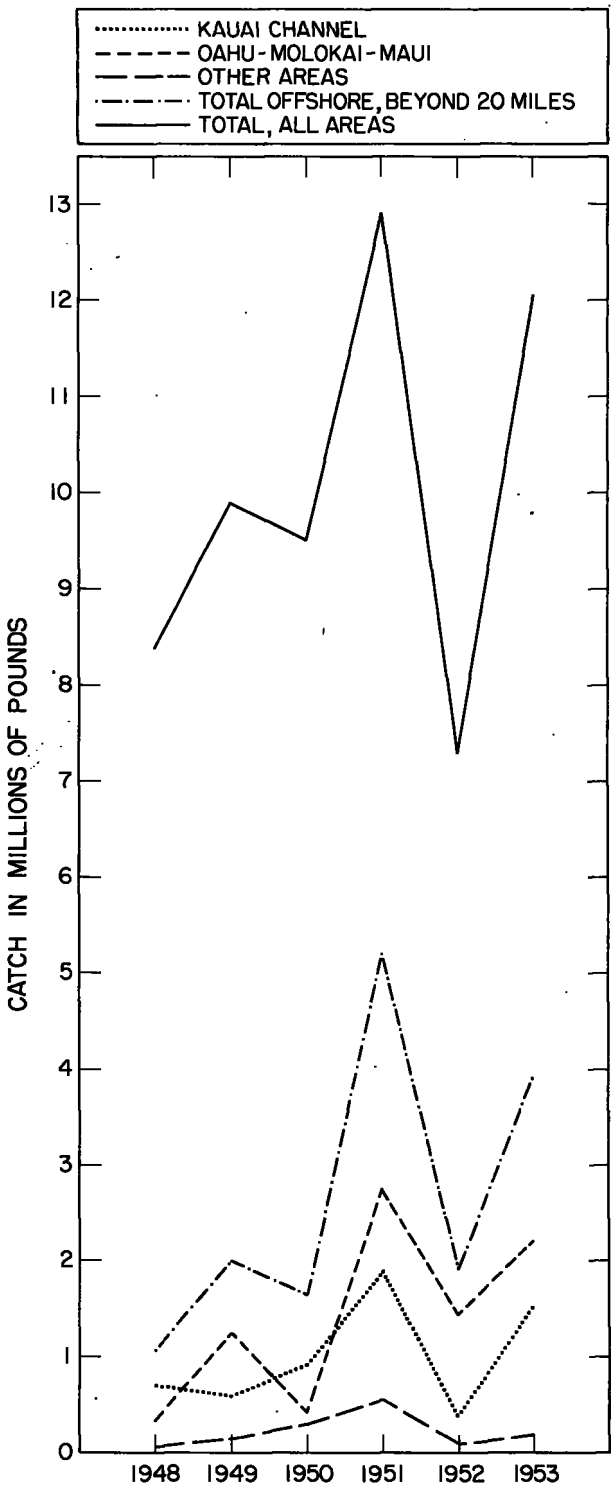

FIGURE 7.—Skipjack catch from the three major divisions of the offshore zone; from all areas beyond 20 miles; and the total catch from all areas: inshore, coastal, and offshore.

be obtained from the reports of the individual fishing trips turned in by the fishermen. A critical examination of the catch reports is necessary, however, to separate the effort expended in catching bait from the actual fishing effort.

In order to obtain some index of relative skipjack abundance, the average catch per productive fishing trip (1 day's fishing) was calculated for one sampan for a number of years and compared with the average catch for a number of other sampans for the same years. Unfortunately, as previously mentioned, the completely unproductive trips could not be accounted for in the analysis due to inadequate records.

Six sampans, A, B, C, D, E, and F, were originally selected for analysis on the basis of reliable catch reports turned in, as determined by comparison of catch and interview data. Two additional sampans, G and H, were included because their catch records showed that the number of trips reported was comparable to the number reported by the others, although their reports could not be verified for reliability, since no interview records were available. All of these vessels were based on Oahu and were representative of the local fishing fleet insofar as size of vessel was concerned.

The original catch records were examined for the years 1948 to 1953, and the average catch per trip was selected as the catch per unit of effort. The criterion used in the selection of the catches was agreement between bait-catch date and fish-landing date, both of which appear on each report sheet (appendix figs. 3 and 4, pp. 275-6). Catches used in this analysis were those in which (1) the landing date and bait-catch date were identical, (2) the landing date immediately followed a baiting date, or (3) the landing date immediately followed another landing date that was preceded by a baiting period during which bait was caught in sufficient quantities for two or three successive fishing trips.

A comparison of the skipjack catch of the selected vessels shows that, as expected, the best individual catches were made during the months of highest total catch for the fishery, and the larger vessels generally made the best catches (table 6). The relation between catches by boats and years, as shown by both the catch of individual boats and the average catch of the eight vessels (table 7), suggests a situation in the fishery different from

that indicated by the total landings. All of the selected vessels with the exception of one (G) enjoyed their most productive trips during 1951, but the catches of only four of the vessels (A, B, D, and H) showed that 1952 was an unusually poor year. Furthermore, even during the relatively good year of 1953, one of the boats (F) made its smallest catch of the period.

TABLE 6.—*Average catch of skipjack per trip of eight vessels, by season, 1948–53*

[Trip=1 day's fishing]

Vessel	Registered length (feet)	Average catch (in pounds) during—		
		Offseason [1]	Preseason and postseason [2]	Main season [3]
A	68	3,252	4,936	7,405
B	67	2,224	3,832	7,316
C	80	3,841	6,507	11,704
D	62	2,773	3,497	5,701
E	77	2,971	5,768	8,409
F	74	3,080	4,706	7,614
G	60	2,010	3,037	6,653
H	70	2,411	3,476	5,468

[1] January–March and November–December.
[2] April–May and September–October.
[3] June–August.

TABLE 7.—*Average catch of skipjack per trip of eight vessels, by years, 1948–53*

[Trip=1 day's fishing]

Vessel	Average catch (in pounds) in—						
	1948	1949	1950	1951	1952	1953	All years [1]
A	5,037	7,494	4,550	9,705	4,450	6,068	6,070
B	4,261	5,903	4,641	7,436	3,683	4,681	5,142
C	6,106	8,197	6,871	10,174	7,104	10,053	8,161
D	3,411	4,284	3,931	6,077	3,391	4,229	4,230
E	5,257	8,259	5,014	10,894	5,265	6,312	6,767
F		6,747	6,110	9,883	4,771	4,724	6,319
G	2,954	4,064	3,797	4,968	3,174	5,624	4,159
H	3,701	5,132	3,647	6,279	2,928	3,938	4,259
Average, all vessels [1]	4,393	6,235	4,878	8,348	4,440	5,788	5,696

[1] Based on total catches and corresponding number of trips.

The average skipjack catches of the eight vessels (based on a total of about 500 trips per year) were compared with the total annual landings (fig. 8), for the period 1948 to 1953. The chief difference between the two curves based on these data is the reversal in rank for the catches of 1949 and 1953. According to the catch-per-trip data, skipjack were in greater abundance in 1949 than in 1953; however, the records indicate a longer fishing season in 1953, and a corresponding larger catch that year. The total catch amounted to 12.1 million pounds in 1953, as compared with 9.9 million pounds in 1949. Since the average weight of fish taken was about the same in both years, the relative abundance of skipjack may have been greater in 1949 than in 1953.

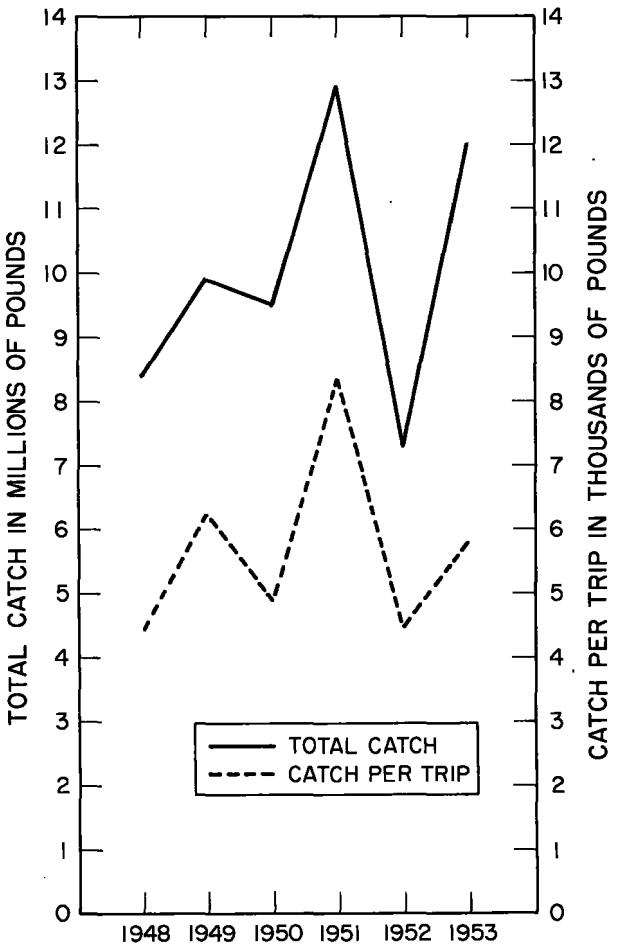

FIGURE 8.—Comparison between total annual landings and average catch per trip of eight sampans, 1948–53.

PREDICTING THE CATCH

An examination of the catch by months for the postwar years has produced some evidence of a correlation between the catch in certain early months of the year and in the main season. There is also an indication that the total catch of skipjack in any one year is associated with the size of the year-class 2 or 3 years earlier.

Employing a correlation analysis and the catch records (weight sold) for 8 years, 1946 to 1953,[2]

[2] 1946 and 1947 were not comparable with the more recent years with respect to the number of vessels in the fleet, and during 1953 a greater amount of effort was expended; nevertheless, the catch records for these years were included in this analysis to increase the number of observations.

the following comparisons were made: (1) First 3 months with remainder of the year, (2) April with May through September, (3) April with May through December, (4) April with the remaining 11 months (January to March and May to December) of the year, (5) first 6 months with last 6 months of the year, and (6) last 3 months (October to December) with the subsequent year. In all comparisons except the first, which gave a nonsignificant negative correlation, the results showed nonsignificant positive correlations. The highest correlation value ($r=0.667$, $P=$ca. 0.06) resulted from the comparison of catches for April and the remaining 11 months of the year; this apparent relation, admittedly tenuous, is worthy of closer study when more data are available.

Brock (1954, p. 95), in his analysis of skipjack length frequencies, states that,

> If it is assumed that these modal groups [40–50 cm., 68–72 cm., 79–80 cm.] represent year-classes, the following interpretation of the length frequency data may be made: At some age, perhaps 1 or 2 years, an age group or year-class is first taken in significant amounts by the fishermen during the summer fishing. By the second summer, this age group, at a length of 70 to 75 centimeters, is again taken and, as a matter of fact, is the size group most eagerly sought by the fishermen. This year-class appears again in the catch during the third summer but cannot be traced thereafter with any certainty from the available data.

The comparison between length frequencies of Hawaiian skipjack (Brock 1954, fig. 1) and the annual catch in weight indicates that larger catches are made when the greater percentage of the catch consists of the 68- to 72-cm. size group. Assuming that the seasonal abundance of skipjack in the local fishery is associated with spawning, and that the 68- to 72-cm. size fish are in their second or third year, the abundance of fish for every other year or every third year should be significantly correlated, neglecting, of course, the possibilities of catastrophic larval mortality and any oceanographic changes affecting the return of the spawning stock.

The correlation coefficient resulting from a test of the hypothesis that the annual catches of skipjack (1946–53) from every other year are positively related showed some correlation but was not statistically significant ($r=0.518$, $P>0.05$), and the comparison of the catches from every third year showed no correlation ($r=0.029$).

The possibility of making worthwhile predictions of seasonal or annual catches from preseason data seems doubtful at the present time, although it should be reexamined when a longer time series of catch data is available. The chief hope of prediction probably lies in relating fluctuations in the availability of skipjack with fluctuations in the physical, chemical, or biological properties of the environment.

THE BAIT FISHERY

The local skipjack fishery is primarily dependent on the live-bait supply, and the crew of a sampan may spend up to 50 percent of its time fishing for bait. Baiting, both day and night, may continue for 2 or 3 days before a sufficient supply can be accumulated for 1 day's fishing. Two species are of major importance in the local live-bait fishery: the anchovy or nehu, *Stolephorus purpureus* Fowler and the silverside or iao, *Pranesus insularum* (Jordan and Evermann). The nehu makes up about 92 percent of the catch; the iao most of the remainder. The postwar records show that the annual bait production has averaged about 36,000 buckets,[3] with a maximum of about 42,000 buckets caught under the present fishing intensity (table 8).

[3] A bucket is approximately equal to 7 pounds of fish.

TABLE 8.—*Bait-fish catch, by buckets, 1946–53*

[1 bucket=7 pounds of fish; data from Hawaiian Division of Fish and Game]

Locality	1946	1947	1948	1949	1950	1951	1952	1953
Anchovy (nehu):								
Oahu	16,728	21,690	23,868	27,246	22,360	18,646	14,744	21,470
Maui	6,804	5,448	10,974	7,344	[1] 10,066	[1] 9,537	[1] 6,056	[1] 8,890
Hawaii	1,410	1,470	3,708	2,664	1,671	3,292	3,103	3,718
Kauai	72	534	762	108	526	1,213	1,031	1,614
Molokai	204	150	468	288	738	582	602	76
Lanai			36					
Other			24				10	36
Total	25,218	29,292	39,840	37,650	[1] 35,361	[1] 33,270	[1] 25,546	[1] 35,804
Other bait fish (all islands)	642	1,458	2,196	1,908	[1] 4,277	[1] 7,221	[1] 4,261	[1] 1,878
Grand total	25,860	30,750	42,036	39,558	[1] 39,638	[1] 40,491	[1] 29,807	[1] 37,682

[1] Adjusted bait catch (see pp. 268 and 269).

CATCH STATISTICS

Methods of Collection

Since July 1947 the method of reporting has been based on a system whereby the fishermen turn in a combined skipjack and bait report for each successful fishing trip (but not necessarily for each baiting operation), noting the following information on bait: Date of catch, locality, amount of bait caught, and amount used. These reports are edited, coded, and transferred to punch cards which are in turn transcribed to IBM summary sheets. Unlike the commercial fish catch, the bait catches are not published for circulation; therefore the annual catches by islands must be obtained from IBM record sheets or other summarized records. The interview records have also been a source of information concerning bait catches since July 1949.

Completeness and Accuracy

In order to estimate the proportion of the bait catch reported, an analysis similar to that made on the skipjack catch was followed by comparing interview records and catch reports (table 9). The procedure was slightly modified under the assumption that the catches as reported in the interview records were reasonably accurate (1) because the optimum capacity of the bait boxes was known, and (2) because of the close proximity of the bait-catch date to the interview date.

Interview records (table 9, col. 1) were first compared with corresponding catch reports (col. 2) to determine the accuracy of the catch reports (col. 3). All bait catches as reported in interview records (col. 4) were then checked against all reported catches (col. 5) in order to compute the percentage of the catch reported (col. 6). The reported catch included all the corresponding catches (col. 2) plus the few instances in which the amount of bait caught, as reported in the catch records, was not the original amount caught, but the amount left over from a previous trip. In such instances, the original amount caught was usually not reported, and errors such as this could be detected only by the comparison of interview records and catch reports. All duplicated or partially duplicated catches that could be recognized by an examination of a sequence of catch reports were omitted from this analysis.

Comparison of columns 3 and 6 in table 9 shows that the fishermen made a fairly accurate bait-catch report when they turned in the reports, but frequently they failed to make the bait reports. Analysis showed that each individual bait report may be 91 percent complete, but that only about 75 percent of the total catch was actually accounted for.

There were other irregularities, too. Examination of the summary records showed an apparent marked increase in bait catch reported for Maui waters from 1950 to 1953. This increase coincided with the introduction of a new record form during the summer of 1950. The new forms were very similar to the old except for the changing of the unit of bait measurement from box [4] to bucket (appendix figs. 3 and 4, pp. 275–6). Many of the bait catches from Maui during this period

[4] One box is equivalent to 6 buckets of bait.

TABLE 9.—*Comparison of interview records and catch reports for the bait fishery, 1952*

[Catch, by buckets]

Month	1 Bait catches shown on selected interview records	2 Bait catches shown on catch reports corresponding to interview records in col. 1	3 Percent of bait catch reported in catch reports	4 Bait catch shown on all interview records	5 Bait catch shown on all catch reports corresponding to interview records in col. 4	6 Percent of total catch reported
May	93.5	84.0	89.8	148.5	74.0	56.6
June	509.0	467.0	91.7	585.0	473.0	80.8
July	523.0	494.0	94.4	798.0	504.0	63.2
August	757.5	694.0	91.6	800.5	713.0	89.1
September	742.0	665.0	89.6	835.0	683.0	81.8
October	632.0	567.0	89.7	858.0	599.0	69.8
November	66.0	56.0	84.8	146.0	56.0	38.4
Total	3,323.0	3,027.0		4,171.0	3,112.0	
Average			91.1			74.6

were recorded on the old form, primarily because the Maui vessels were slow to change to the new form. It is believed, however, that most of the vessels, though they used the old form, actually recorded their catches in buckets in compliance with the new regulations. For instance, entries such as 25 boxes of bait for a fishing trip on a sampan with only 6 bait boxes were numerous during this period. However, if these statistics, as recorded in the IBM summary sheets, are converted to buckets (6 buckets per box) in order to make comparisons with recent years, the totals appear unreasonable.

For this study, all the bait caught from Maui waters during the period from 1950 through 1953 was considered in terms of buckets regardless of whether or not it was reported as boxes and regardless of the form used. This could lead to an underestimation of the catch, because some of the vessels may actually have meant boxes, particularly when using the old form. There is little possibility of this adjustment affecting that portion of the bait reported from Maui by non-Maui sampans (primarily those from Oahu), because they quickly adopted the new form. Some underestimation of the catches by Maui vessels must remain, but the general level of the catches they reported was usually larger than 6 (the number of bait boxes on board), suggesting that they were complying with the new regulations although using the old form.

BAITING AREAS

The distribution of bait catch by islands (table 8) shows that Oahu and Maui are the major sources of nehu, as averages of 64 and 25 percent, respectively, of the total catch were reported from these two islands. The important baiting grounds on Oahu are Kaneohe Bay, Pearl Harbor, and Honolulu Harbor, and the bulk of the catch comes from the first two localities. The catch from Pearl Harbor varies according to the extent of the restrictions placed upon the fishery by the United States Navy and is usually less than that taken from Kaneohe Bay. On Maui, about 86 percent of the nehu catch is obtained from Maalaea Bay and the Kihei region. The islands of Hawaii, Kauai, and Molokai contribute lesser amounts to the fishery, largely because of the limited extent of the baiting grounds.

On Oahu, the island supporting the most intensive bait fishery, the annual catch has fluctuated between 15,000 and 27,000 buckets during the period 1946 to 1953. The increase in the catch in 1947 (see table 8) may have been due in part to an increase in the number of sampans operating during the latter part of the year. The slight increase during the following year (1948) was also probably related to the larger number of boats in operation throughout the year. Since the number of vessels remained fairly constant after 1947, the years 1948 to 1953 may be considered comparable insofar as fishing effort for bait is concerned. The considerable increase in the 1949 bait catch may be attributed to the partial lifting of restrictions in Pearl Harbor, making more baiting grounds available to the fishermen. The island of Kauai has shown a general increase in bait catches compared to earlier years, and so has Molokai, except for the year 1953.

The fluctuation in the bait catch on the different islands, aside from availability and abundance, may be due in part to the geographical position of the major islands. The island of Hawaii with only two principal baiting grounds (Kawaihae-Kona region and Hilo Harbor) may be considered as a separate area, whose bait resources are utilized mainly by its own sampans. The islands of Kauai, Oahu, Molokai, and Maui may be grouped together because of the practices followed by the sampans based there. Sampans from Oahu, because of their central location, may bait in Kauai, Molokai, or Maui, as well as Oahu. The sampan stationed in Kauai, on the other hand, may bait in Kauai and Oahu but probably would not exploit the baiting grounds in the more distant island of Maui to any appreciable extent. Likewise, the boats from Maui may bait in Maui, Oahu, or Molokai but will do little baiting, if any, in Kauai, and although Maui is closer to Hawaii than to Oahu, the Maui sampans will favor Oahu because the opportunities of catching bait and possibly unloading their skipjack catches are better there than in Hawaii. Hence, the bait catch from the island of Hawaii has remained constant because of the more or less isolated nature of its fishery, whereas the catches from Kauai and Molokai may have been affected by the amount of effort directed to these islands, depending on the abundance of bait in the major baiting grounds of Oahu and Maui.

SIGNIFICANCE OF BAIT PRODUCTION

On the basis of the foregoing information on bait statistics and the analysis of the completeness of the reported catch, the maximum annual yield of bait may be reestimated to be closer to 50,000 or 60,000 buckets (table 10) than to the reported catch of 42,000. Since it has been found from previous studies that there is about 30 percent mortality of bait associated with the initial period of capture (Hawaii Commissioners of Agriculture and Forestry, 1952) and the reported amount of bait caught may be only 75 percent complete, the total annual bait catch as reported may be roughly comparable to the amount actually utilized in the fishery.

TABLE 10.—*Reported and estimated annual bait catch, 1946–53*

[Reports assumed to be 74.6 percent complete; in thousands of buckets]

Year	Reported catch	Estimated catch
1946	25.9	34.7
1947	30.8	41.3
1948	42.0	56.3
1949	39.6	53.1
1950	39.6	53.1
1951	40.5	54.3
1952	29.8	39.9
1953	37.7	50.5

TABLE 11.—*Relation between live-bait and skipjack catches, 1946–53*

[1 bucket=7 pounds of fish]

Year	Bait catch (buckets)	Skipjack (pounds)	
		Sold	Catch per bucket
1946	25,860	5,630,251	217.7
1947	30,750	5,591,536	181.8
1948	42,036	8,336,951	198.3
1949	39,558	9,864,009	249.4
1950	39,638	9,481,302	239.2
1951	40,491	12,874,274	318.0
1952	29,807	7,264,019	243.7
1953	37,682	12,030,537	319.3

The availability of bait may, in certain years, be a limiting factor in the skipjack fishery. A comparison of the annual bait and skipjack catches (table 11) shows that the catch of skipjack per bucket of bait was higher for 1951 and 1953 than for any of the other years. Apparently, these 2 years represented periods of maximum efficiency with respect to utilization of bait; furthermore, the interviews with fishermen indicated that bait was a limiting factor during these years. During 1947 and 1948, when bait efficiency was low, the amount of bait probably had little effect on production.

An evaluation of the effect of variations in the bait supply is difficult, however, because of numerous other factors affecting the annual skipjack landings. The fish may be equally abundant in different years, but their vulnerability due to biting readiness (slow or fast biting) may differ; thus, more bait may be needed to catch an equal amount of fish in one year than in another. Also, the fish may differ in size between years; thus, the predominance of smaller fish in the fishery would require the use of more bait to catch an equal weight of fish. But, regardless of the efficiency in the utilization of bait, the possibilities of obtaining larger skipjack catches at the present time are more favorable when more live bait is available. Brock [5] has discussed the monthly variations in the weight of skipjack caught per bucket of bait used, and showed that larger catches are obtained during the summer months, when the bulk of the annual catch is landed.

SUMMARY

1. All existing catch records of the Hawaiian skipjack fishery for the period 1900 to 1953 have been brought together in this report. The annual skipjack catch for the more recent years, 1948 to 1953, ranged from 7 million to 13 million pounds, and accounted for 50 to 70 percent by weight of all fish landed in the local commercial fishery.

2. Comparison of interview and catch records indicated that the 1945–53 skipjack catch statistics were approximately 94 percent complete.

3. Because of the variation in size composition of the catch, the apparent relative abundance of skipjack depends on whether the total weight or the total number of fish in the catch is used. In order of decreasing catch by weight, the years may be arranged as follows: 1951, 1953, 1949, 1950, 1948, and 1952. In terms of catch by number of fish, the order becomes 1951, 1953, 1948, 1950, 1952, and 1949.

4. Because of the convenience to the sampans of fishing close to home ports and to baiting grounds, about 75 percent of the skipjack catch

[5] Mimeographed statement "Explanation of tables and figures concerned with use of bait for the years 1950 to 1954," Hawaii Commissioners of Agriculture and Forestry, Division of Fish and Game, Honolulu.

during 1948 to 1953 was taken within 20 miles of land. The catch within this coastal zone has remained relatively constant from year to year (with the exception of 1952); large increases in the annual catch have been the result of increased catches from the offshore zone.

5. The average skipjack catch in weight per trip was used as a possible index of relative abundance and the catch in decreasing order may be arranged as follows: 1951, 1949, 1953, 1950, 1952, and 1948.

6. Attempted predictions of the yearly skipjack catch based on past catch statistics alone are of little value, partly because of the relative shortness of the period under observation. More reliable predictions may be possible in the future when the relation between fish stocks and environment can be ascertained.

7. The expansion of the Hawaiian skipjack fishery has been restricted primarily by the shortage of bait. The principal bait used is nehu (*Stolephorus purpureus*), an anchovy, and the main sources of supply are the inshore waters of Oahu and Maui.

8. An examination of interview records and catch reports indicated that only 75 percent of the total bait catch was reported. In view of the high bait mortality (about 30 percent), the reported bait catch, averaging about 36,000 buckets (252,000 pounds) a year, may be a close approximation of the amount actually used in fishing.

9. The skipjack catch per bucket of bait (7 pounds) ranged from a low of 182 pounds in 1947 to a high of 319 pounds in 1953.

10. Specifications of each full-time skipjack sampan in the Territory of Hawaii for 1953 are presented in the appendix to aid in evaluating future changes in catch that may be related to changes in vessel design.

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APPENDIX

In respect to information listed in the following table, the basic specifications of the full-time Hawaiian skipjack sampans fishing in 1953 were taken primarily from the files of the United States Customs, Marine Division, unless otherwise stated. The various registered measurements, as defined in Merchant Vessels of the United States (United States Treasury, 1952) are as follows:

Registered length "is the length measured on the top of the tonnage deck from the fore part of the outer planking or plating at the bow to the after part of the sternpost of screw steamers and to the after part of the rudderpost of other vessels. The registered length is not usually the same as the overall length nor the load-water-line length."

Registered breadth "is the breadth at its widest part measured from the outer side of the planking or plating on one side to the corresponding point on the opposite side."

Registered depth "is the depth measured from the inner side of the tonnage deck, amidships, to the bottom of the hold. The depth is not the draft of a vessel."

APPENDIX TABLE 1.—*Basic specifications of the full-time Hawaiian skipjack boats (sampans) fishing in 1953*

[All boats with single screw, diesel engine(s)]

Name of boat	Official number	Island	Tonnage		Registered dimensions			Type of hull	Date built	Number in crew	Engine	Horsepower	Bait boxes [1]		
			Gross	Net	Length (ft.)	Breadth (ft.)	Depth (ft.)						Number	Average effective volume (gal.)	Type of circulation
Amberjack	252808	Maui	61	41	70.0	16.0	7.3	Steel	1947	15	General Motors	330	6	1,085	Forced.
America Maru	231965	Oahu	54	33	71.5	14.8	8.8	Wood	1930	10	Gray Marine	330	6	685	Open flow.
Bluefin	238180	do	31	19	66.1	13.1	5.9	do	1927	10	do	225	6	558	Do.
Bonito	239892	do	37	19	67.7	13.8	6.7	do	1940	10	Atlas Imperial [2]	155	6	580	Do.
Broadbill	238206	do	36	11	66.8	12.8	6.0	do	1926	10	General Motors	300	6	614	Do.
Buccaneer	253735	do	68	40	69.4	16.9	7.8	Steel	1947	12	do	330	6	1,232	Forced.
Constance C	238251	do	44	21	60.5	13.2	7.2	Wood	1930	9	Gray Marine [2]	230	6	736	Open flow.
Corsair	257593	Hawaii	51	34	65.0	15.2	7.2	do	1949	12	Atlas Imperial	160	6	1,000	Do.
Darling Dot	254011	Oahu	77	52	80.5	16.9	6.8	do	1947	14	do	250	6	1,297	Do.
Dolphin	239501	Maui	33	17	66.8	12.7	7.3	do	1928	8	Gray Marine [2]	110	6	688	Do.
Electa	237448	Oahu	47	23	72.1	13.5	7.7	do	1938	11	Union	150	6	854	Do.
Helena II [3]	239190	Maui	29	13	65.8	12.3	6.2	do	1928	11	Gray Marine	225	6	575	Do.
Kiyo Maru [4]	238307	Oahu	27	18	58.3	11.8	5.6	do	1937	7	Union	150	6	600	Do.
Marlin	238043	do	44	18	70.0	13.5	5.9	do	1935	11	Caterpillar [2]	275	6	670	Do.
Maui Maru [5]	239364	Maui	29	14	67.3	13.0	5.7	do	1929	9	Gray Marine	165	6	577	Do.
Momi	238185	Oahu	31	15	61.9	12.5	5.5	do	1934	8	Caterpillar	115	6	574	Do.
Neptune	237230	do	46	20	71.5	13.6	6.6	do	1938	10	Atlas Imperial	250	6	839	Do.
Olympic	252822	Maui	38	25	66.8	14.5	6.0	do	1947	10	Gray Marine	450	6	708	Do.
Orion	251045	Oahu	51	23	76.6	16.2	6.7	do	1946	12	Caterpillar [3]	400	6	1,064	Do.
Sailfish	230892	do	51	35	74.4	15.1	6.5	do	1931	10	Atlas Imperial	160	6	1,135	Do.
Skipjack	238265	Hawaii	39	19	71.9	13.9	6.3	do	1928	11	Caterpillar [2]	165	6	785	Do.
Sooty Tern	253367	Maui	45	31	72.8	14.9	6.2	do	1947	13	Gray Marine [2]	330	6	1,127	Do.
S. T. Uruma [6]	252940	Oahu	47	32	72.3	15.7	5.1	do	1947	13	Atlas Imperial	250	6	891	Do.
Sunfish	238284	do	32	15	69.8	12.6	5.8	do	1926	10	Gray Marine [2]	225	6	664	Do.
Tradewind	260364	Kauai	54	34	72.6	15.5	7.3	do	1950	11	Atlas Imperial	200	6	873	Do.
Yellowfin	238314	Oahu	33	17	59.3	12.6	5.9	do	1928	10	Gray Marine	225	6	576	Do.

[1] From unpublished report "Measurements of bait tanks on Territory of Hawaii aku boats" by A. L. Tester, 1949.
[2] From files of the Hawaiian Division of Fish and Game.
[3] Changed to *Ooji* in 1954.
[4] Changed to *Holokahana II* in 1954.
[5] Changed to *Helena II* in 1955.
[6] Changed to *Kilohana* in 1954.

TERRITORY OF HAWAII
BOARD OF COMMISSIONERS OF AGRICULTURE AND FORESTRY

MONTHLY STATEMENT OF FISH CATCH

(One copy must be filed for each boat operated)

Report for month of..... .....194.....Name of Operator.....

Commercial ☐ Address .....

Sport - - - ☐ .....

License No..... Approx. No. of Hours Boat was Operated:.....

Boat F. G. No..... Gallons of Gasoline Used in Boats:.....

Gallons of Gasoline Used in Motor Vehicles:.....

DESCRIPTION OF BOAT

Type	Motor		Horse Power	Length	Beam	Draft
	Inboard	Outboard				

DISTRICT WHERE FISH CAUGHT:.....

Variety	Weight Caught	No. Lbs. Sold	Price Per Lb.	Total Money Rec'd	Variety	Weight Caught	No. Lbs. Sold	Price Per Lb.	Total Money Rec'd
Ahi					Ulua				
Aku					Weke				
Akule or Hahalalu					Lobster				
A'u					Crabs				
Mahimahi					Opihi				
Moi					Squid				
Sea Mullet					Turtle				
Pond Mullet					Others (List Below) –				
Opakapaka									
Opelu									
TOTAL					TOTAL				

The above statement is true and correct to the best of my knowledge.

Date:..... .....

.....
(Signature)

Witness: .....
(Game Warden)

District: .....

APPENDIX FIGURE 1.—Fish-catch report form; introduced in March 1944 as standard form for reporting all types of fishing.

DIVISION OF FISH AND GAME

FISH CATCH REPORT

Sheet No..... Date.....19.....

Name of Licensee..... Lic. No.....

Name of Boat..... F. and G. No.....

Area of Catch..... Fishing Gear.....

(SEE ZONE MAP)

	SPECIES CAUGHT	NO. CAUGHT	LBS. CAUGHT	LBS. SOLD	VALUE	
TUNAS	Aku					
	Ahi					
	Ahipalaha					
	Bluefin					
	Big Eye					
	Kawakawa					
A'U	Striped					
	Black					
	Broadbill					
	Au Lepe					
	Mahimahi					
	Ono					
	Hapuupuu					
	Kahala					
	Kalekale					
	Omilu					
	Opakapaka					
	Uku					
	Ulaula					
	Ulua					
	Weke-ula					
	Awa					
	Akule					
	Hahalalu					
	Amaama (Sea)					
	Kala					
	Kumu					
	Moi					
	Oio					
	Papai					
	Ula					
	Weke					
	Opelu					
	Iheihe					

BAIT FISH	NEHU	IAO	OTHERS	OPELU (KAAU)
No. of Boxes.....				
Area Taken.....				

The above statement is true and correct to the best of my knowledge.

Signature..... District:.....

THIS COPY FOR DIVISION OF FISH AND GAME

APPENDIX FIGURE 2.—Fish-catch report form; introduced in July 1945 as standard form for reporting all types of fishing.

TERRITORY OF HAWAII
BOARD OF COMMISSIONERS OF AGRICULTURE AND FORESTRY
DIVISION OF FISH AND GAME

FISH CATCH REPORT

Name of Licensee..... License No.....

Name of Boat..... FG No.....

Type of Fishing..... ☐ Fishing Gear..... ☐

FORM C-1 S-B B1645-200 BKS-3-49

Area of Catch..... ☐ Date of Landing..... ..... 19.....
(See Fisheries Chart No. 2) Mo. Day

	SPECIES CAUGHT		No. CAUGHT	LBS. CAUGHT	LBS. SOLD	VALUE*	
TUNAS 001	Aku (Skipjack)	002					
	Ahi (Yellowfin) (Shibi)	003					
	Ahipalaha (Albacore) (Tombo-shibi)	004					
	Bluefin	005					
	Big-eyed (Menpachi-shibi)	006					
	Kawakawa	007					
SWORD-FISHES (A'U) 008	Striped Marlin	009					
	Black Marlin	010					
	Broadbill Swordfish	011					
	Au lepe (Sailfish)	012					
Mahimahi		013					
Ono		014					

BAIT REPORT

BAIT FISH		DATE TAKEN	LOCALITY TAKEN	QUANTITY TAKEN	QUANTITY USED
Nehu	01			boxes†	boxes†
Iao	02			boxes†	boxes†
Opelu	20			fish	fish
Sardines	07				pounds

* Value represents the amount of money received by the fisherman for total pounds of fish sold. Do not record price per pound.
† One box of livebait is approximately equivalent to 6 buckets of livebait.

The above reports are true, correct, and complete to the best of my knowledge and belief.

Signature..... Port of Landing..... ☐
Licensee or Authorized Agent

Island.....

THIS COPY FOR DIVISION OF FISH AND GAME

APPENDIX FIGURE 3.—Fish-catch report form; introduced in July 1947 as standard form for reporting live-bait (skipjack) and flagline (longline) fishing.

TERRITORY OF HAWAII
BOARD OF COMMISSIONERS OF AGRICULTURE AND FORESTRY
DIVISION OF FISH AND GAME

FISH CATCH REPORT

Name of Permittee..... Boat Permit No.....

Name of Boat..... FG No.....

Type of Fishing..... ☐ Fishing Gear..... ☐

FORM C-1 S-B 93859 10M SETS-7-51

Area of Catch..... ☐ Date of Landing..... ..... 19.....
(See Fisheries Chart No. 2) Mo. Day

	SPECIES CAUGHT		No. CAUGHT	LBS. CAUGHT	LBS. SOLD	VALUE*
TUNAS 001	Aku (Skipjack)	002				
	Ahi (Yellowfin) (Shibi)	003				
	Ahipalaha (Albacore) (Tombo-shibi)	004				
	Japanese Bluefin (Black Tuna) (Maguro)	005				
	Big-eye (Menpachi-shibi) ("Bluefin")	006				
	Kawakawa	007				
SWORDFISHES (A'U) 008	Striped Marlin	009				
	Black Marlin	010				
	Short-nose Marlin	107				
	Silver Marlin	108				
	Broadbill Swordfish	011				
	Au lepe (Sailfish)	012				
Mahimahi		013				
Ono		014				

BAIT REPORT

BAIT FISH		DATE TAKEN	TIME TAKEN† DAY	TIME TAKEN† NIGHT	LOCALITY TAKEN	QUANTITY TAKEN	QUANTITY USED
Nehu	41					buckets	buckets
Iao	42					buckets	buckets
Opelu	20					fish	fish
Sardines	07						pounds

* Value represents the amount of money received by the fisherman for total pounds of fish sold. Do not record price per pound.
† Check one to indicate whether baiting was done at day or at night. Applies to livebaiting only.

The above reports are true, correct, and complete to the best of my knowledge and belief.

Signature..... Port of Landing..... ☐
Permittee or Authorized Agent

Island.....

THIS COPY FOR DIVISION OF FISH AND GAME

APPENDIX FIGURE 4.—Fish-catch report form; introduced in July 1950 as standard form for reporting live-bait (skipjack) and flagline (longline) fishing.

BOARD OF COMMISSIONERS OF AGRICULTURE AND FORESTRY

AKU CATCH REPORT

DIVISION OF FISH AND GAME TERRITORY OF HAWAII

C-4

Name of Permittee..... Boat Permit No..... Month..... 19.....

Name of Boat..... F.G. No. ..... Type Fishing.....

Day of Landing	Area of Catch	Port of Landing	AKU (Skipjack) 002		AHI (Yellowfin) 003			MAHIMAHI 013			KAWAKAWA 007			OTHERS				OTHERS			
			Lbs. Caught	Value*	No. Caught	Lbs. Caught	Value*	No. Caught	Lbs. Caught	Value*	No. Caught	Lbs. Caught	Value*	Species Caught	No	Lbs. Caught	Value*	Species Caught	No.	Lbs. Caught	Value*

BAIT REPORT

Date Taken	Locality Taken		Time Taken † Day	Time Taken † Night	SPECIES TAKEN Nehu 41	SPECIES TAKEN Iao 42	SPECIES TAKEN Other (Give Name) ✓	Quantity Taken in Buckets	Quantity Dead in Buckets	Quantity Used in Buckets	Quantity Left Over in Buckets

The reports contained hereon are true, correct, and complete to the best of my knowledge and belief.

Signature .....
Permittee or Authorized Agent

* "Value" represents monies received.

† Check one to indicate whether baiting was done day or night.

✓ Check either nehu or iao—write out name of bait fish if other than nehu or iao.

APPENDIX FIGURE 5.—Presently used fish-catch report form; introduced in July 1954 as standard form for reporting live-bait (skipjack) fishing only.

DIVISION OF FISH AND GAME
Board of Agriculture and Forestry
Territory of Hawaii

AKU BOAT INTERVIEW SHEET

(Confidential)

Interview Date..... (MONTH DAY YEAR)

Catch Date..... (MONTH DAY YEAR) Boat..... Captain.....

Time Began to Scout for Fish.....

First School Fished: From.....to..... Total Wt.....Av. Wt.....
Catch Locality ..... Am't. of Bait Used.....

Second School Fished: From.....to..... Total Wt.....Av. Wt.....
Catch Locality ..... Am't. of Bait Used.....

Third School Fished: From.....to..... Total Wt.....Av. Wt.....
Catch Locality ..... Am't. of Bait Used.....

Fourth School Fished: From.....to..... Total Wt.....Av. Wt.....
Catch Locality ..... Am't. of Bait Used.....

Fifth School Fished: From.....to..... Total Wt.....Av. Wt.....
Catch Locality ..... Am't. of Bait Used.....

Sixth School Fished: From.....to..... Total Wt.....Av. Wt.....
Catch Locality ..... Am't. of Bait Used.....

Schools Sighted Not Fished

TIME	LOCALITY	ESTIMATED SIZE OF SCHOOL	ESTIMATED AV. WT. OF FISH

Finished for Day ..... Number of Fishermen on Boat.....

BAIT FISHING

	DATE	SPECIES	%	AMOUNT CAUGHT IN BUCKETS	CATCH LOCALITY	TIME SPENT TO CATCH BAIT
Day Bait.....						
Night Bait.....						

Amount of Bait Died.....
(IF POSSIBLE GIVE SPECIES AND AMOUNT BY PERCENT)

Amount of Bait Left.....
(IF POSSIBLE GIVE SPECIES AND AMOUNT BY PERCENT)

Remarks (Sufficient bait for day's fishing, schools fished for but no fish caught, etc.):.....

.....

.....

CONFIDENTIAL

APPENDIX FIGURE 6.—Skipjack interview record form.

U. S. GOVERNMENT PRINTING OFFICE: 1958 O—456773