APPENDIX A

BAIT PROBLEMS IN THE HAWAIIAN SKIPJACK TUNA FISHERY

The Hawaiian skipjack tuna pole-and-line fishery is primarily dependent on the supply of live bait. Essentially, any small fish will serve as bait and the effectiveness varies from species to species. Hawaiian skipjack tuna fishermen, by far, prefer nehu, Stolephorus purpureus, a small (40-60 mm), fragile anchovy that school in bays and harbors of the Hawaiian Islands. It possesses most of the qualities of a good baitfish, but there are some major problems in capturing and using nehu. Among them are the limited supply, the high initial mortality after capture despite careful handling, and the short time (usually 2-3 days) that it survives in the baitwells. Nehu accounts for 93% of the bait caught in Hawaiian waters; almost all the remainder of the bait catch is made up of silverside or iao, Pranesus insularum.

The generalized block diagram in Figure 1 shows the sequence of events that leads to a catch of skipjack tuna (Uchida and Sumida, 1971). Basically, it starts with either day or night baiting. Day baiting starts at dawn and ends when sufficient bait has been captured. If little or no day bait is caught, the vessel may attempt night baiting. If that proves unsuccessful, day baiting is repeated.

DAY BAITING

Day baiting frequently lasts for about 3 hours. The following description of day baiting operations is from Uchida and Sumida (1971):

> "The fishermen use an outboard skiff loaded with a surround net to scout for baitfish that school in shallow waters of bays and harbors or near river mouths. Having located a school, the fishermen surround it and then partially 'dry up' the net to form a bag to hold the school. To avoid killing the bait, the fishermen 'swim' the net-enclosed baitfish back to the vessel and transfer them into baitwells. Several sets may be required to obtain enough bait to justify fishing."

NIGHT BAITING

Night baiting does not require an active scouting for schools of baitfish. Uchida and Sumida (1971) described night baiting operations as follows:

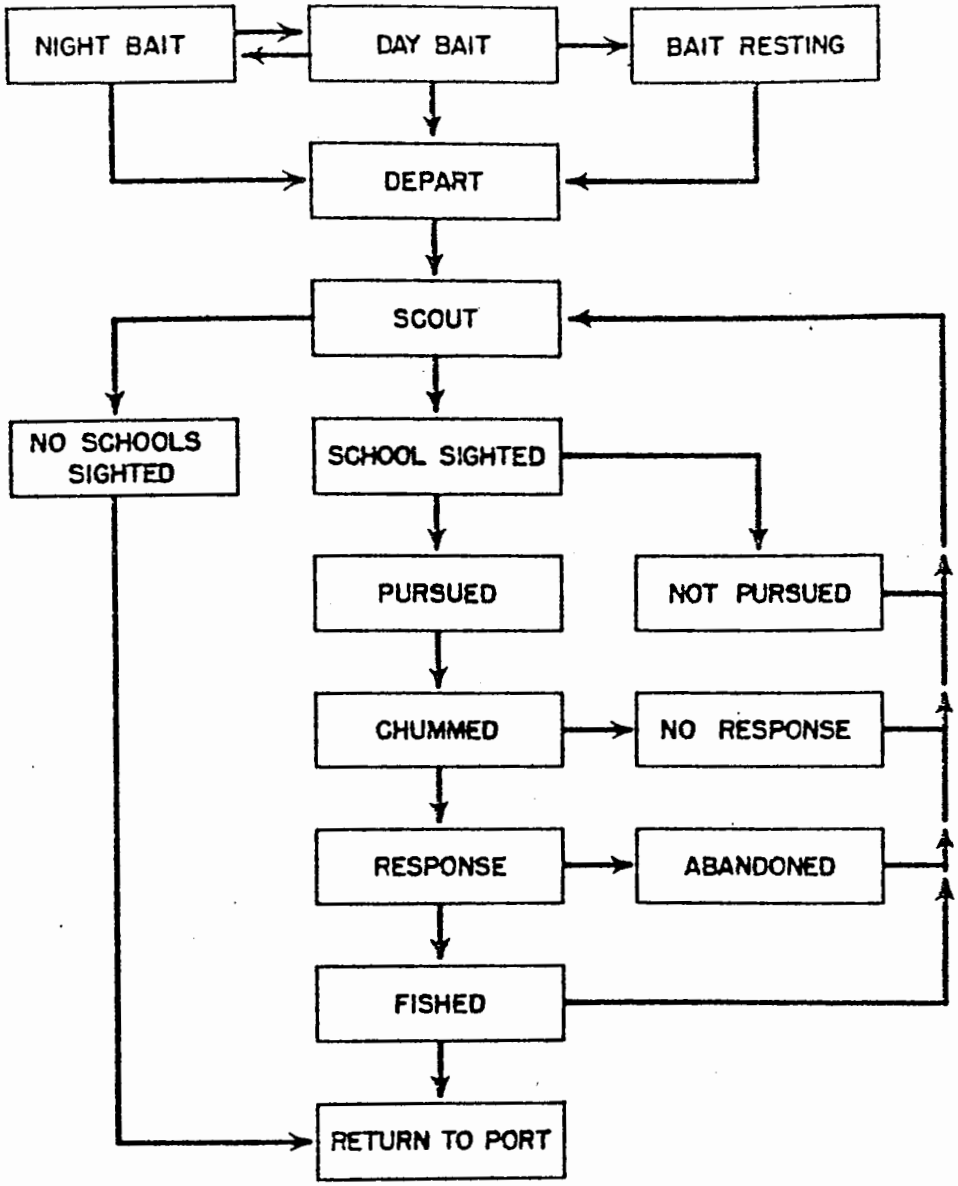

Figure 1.--Block diagram of baiting and fishing operation. From Uchida and Sumida (1971).

> "...a submerged light attracts the baitfish to the anchored or moored vessel. Usually just before daybreak, the fishermen set the net around the school and transfer the bait into the bait-wells. So that they may have enough sleep, the fishermen rarely set the net more than once during the night. Night baiting frequently started at 1901-0100 and in 90 percent of the operations ended at 0501-0600; it usually lasted about 8 hours."

CATCH

In 1965-72, the annual catch of nehu fluctuated between 29,879 buckets and 41,462 buckets and averaged 34,648 buckets (Table 1). The seasonality of nehu catches is shown in Figure 2. Catches were usually low from January to April, then rose markedly in May and June and remained relatively high through August after which they declined progressively to the end of the year. The variations in the monthly catches reflected not only the relatively high abundance of nehu during the summer, but also the higher fishing intensity to which nehu were subjected to when peak fishing for skipjack tuna occurred during the same period.

The proportion of bait caught by day and by night baiting also varied widely over the years and since 1965 the trend has been toward larger catches from day-baiting operations. For example, in 1965-72, the proportion of the annual catch resulting from day-baiting operations was only 58% in 1965 but rose markedly to 94% in 1972 (Table 2). Day-baiting effort has also undergone considerable changes. Whereas in 1965 only 37% of all baiting effort was expended in day baiting, by 1972, 85% of the baiting effort was expended during the day (Table 2). The result of this shift in emphasis from night to day baiting was a reduction in the time available for skipjack tuna fishing, either in terms of the number of days fished or number of hours fished per day. (Actually, although some vessels catch bait in the morning and remain in port to "rest" the bait, others will head straight out to sea after baiting and attempt to fish skipjack tuna.) Table 3 shows the number of days spent day baiting and fishing. It is obvious that the proportion of time spent fishing to the time spent day baiting in 1965-72 has gradually decreased from 2.9 days of fishing per day of baiting in 1965 to 1.5 days in 1971. Therefore, reducing day-baiting effort would result in an increase in skipjack tuna fishing effort.

MORTALITIES AND BAIT USED

The single most objectionable feature of nehu as live bait is that they are notoriously vulnerable to mortality from handling. The fish suffers scale losses and other injuries during netting and

Table 1.--The amount of bait caught, used, and the percentage of the bait used in fishing in the Hawaiian skipjack tuna fishery, 1965-72.

Year	Amount of bait		Percent used
	Caught	Used	
	Buckets	Buckets	
1965	35,535	27,566	78
1966	31,418	23,279	74
1967	31,633	21,149	67
1968	35,155	23,726	76
1969	29,879	19,126	64
1970	33,098	20,462	62
1971	41,562	28,857	69
1972[1]	38,900	22,940	59
Average 1965-72	34,648	23,388	68

[1]Preliminary figures.

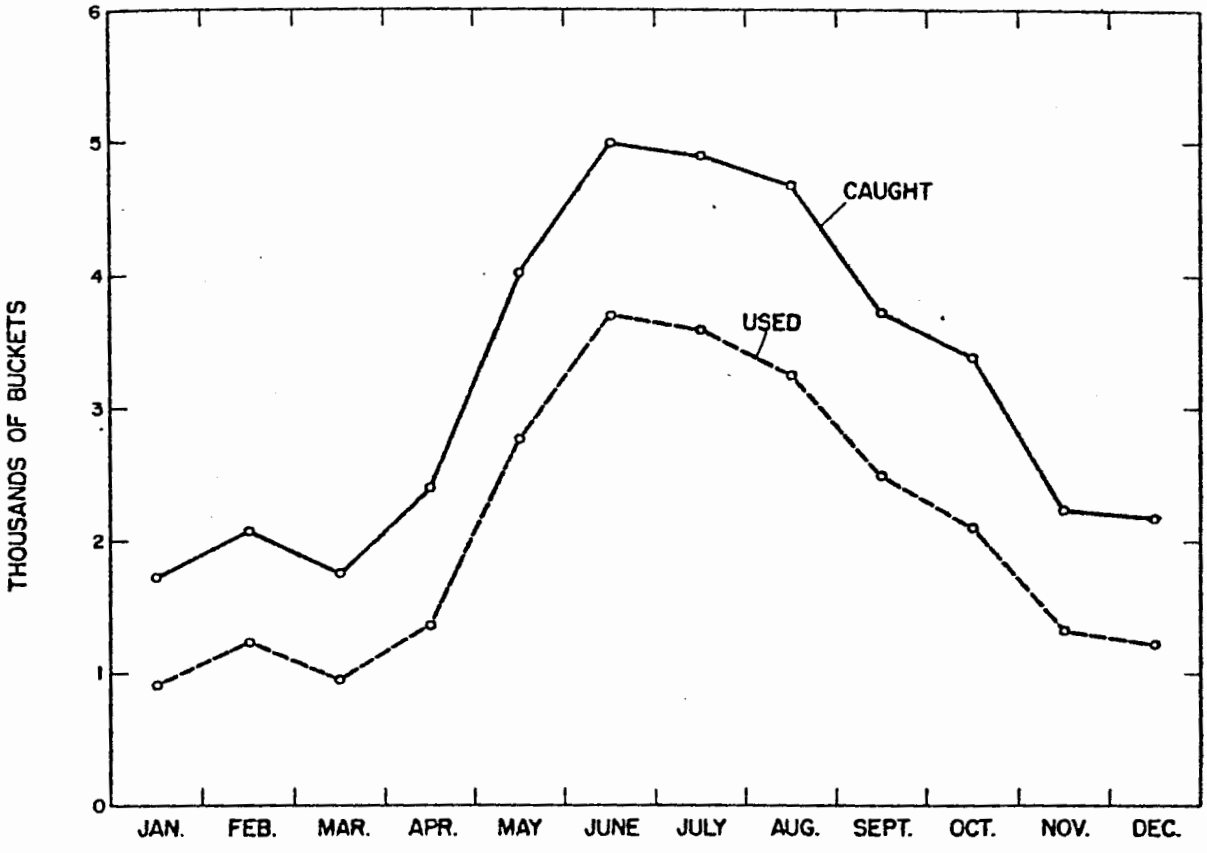

Figure 2.--The average number of buckets of baitfish caught and amount used for fishing by the Hawaiian skipjack tuna fishing vessels, 1970-72. (A bucket estimated at 3.2 kg of baitfish.)

Table 2.--Catch, baiting effort, and catch per effort in the fishery for nehu in Hawaiian waters, 1965-72. Percentages of the catch and the effort expended, by day and night baiting operations, are given in parenthesis. (Note: The total catch from both day- and night-baiting operations for each year is not the same as that shown in Table 1 because some catch reports failed to designate when the catches were made.)

Year	Catch		Baiting effort		Catch per effort	
	Day	Night	Day	Night	Day	Night
	Buckets	Buckets	Days	Nights	Buckets	Buckets
1965	19,972 (58)	14,251 (42)	838 (37)	1,424 (63)	23.8	10.0
1966	20,696 (67)	10,242 (33)	781 (44)	1,011 (56)	26.5	10.1
1967	22,336 (71)	9,187 (29)	736 (45)	913 (55)	30.4	10.1
1968	30,148 (86)	4,911 (14)	1,055 (66)	544 (34)	28.6	9.0
1969	25,535 (86)	4,164 (14)	864 (70)	374 (30)	29.6	11.1
1970	30,332 (92)	2,724 (8)	1,017 (78)	290 (22)	29.8	9.4
1971	38,786 (93)	2,776 (7)	1,334 (82)	288 (18)	29.1	9.6
1972	36,713 (94)	2,187 (6)	1,187 (85)	206 (15)	30.9	10.6

Table 3.--The total number of days spent day baiting and skipjack tuna fishing and the number of days fished per day of baiting, 1965-72.

Year	Effort (in days)		Number of days fished per day of baiting
	Day baiting	Skipjack tuna fishing	
1965	838	2,400	2.86
1966	781	2,086	2.67
1967	736	2,010	2.73
1968	1,055	2,177	2.06
1969	864	1,743	2.02
1970	1,017	1,894	1.86
1971	1,334	2,013	1.51
1972	1,187	1,882	1.58

when they are being transferred to the baitwells of the vessels. Brock and Takata (1955) determined that mortalities resulted primarily from loss of body fluids from osmosis through injuries and wounds. They found that by placing nehu in brackish water after capture to reduce osmotic pressure at the sites of injuries and wounds, mortalities could be substantially reduced.

About a third of the nehu caught in Hawaiian waters usually do not survive long enough to be used as bait for fishing. Table 1 shows that in 1965-72, between 62% and 78% of the bait caught survived sufficiently long to be used in fishing. Most of the remainder died immediately after capture. A very small fraction of the bait taken to sea is eventually discarded in order to clear the baitwells for fish storage or for holding a new supply of bait. The proportion of the bait used to the bait caught appears to be relatively constant throughout the year (Figure 2).

NEED FOR ADDITIONAL BAIT

Bait availability significantly affects the operation of the Hawaiian skipjack tuna fleet. Every day spent in baiting reduces the effective fishing effort for skipjack tuna. Some of the vessels spend as much as half of the time fishing for bait.

Table 3 showed that in recent years, the time spent in day baiting was about 40% of the total daytime activity of the fleet. Obviously, a reduction in time spent catching bait by day would provide more time for fishing. However , bait would have to be provided by other means. By increasing fishing effort for skipjack tuna, the yield and its value to the fishermen should increase proportionately.

As an example, the Hawaiian skipjack tuna catches for 1965-72 have been projected by increasing fishing effort and decreasing day-baiting effort. Table 4 shows that catches would have increased from 9% to 17% if time spent day baiting was reduced by 25%. In 1965, for example, a reduction of 25% in day-baiting effort would have made available 210 additional days for fishing, thus raising the present fleet's skipjack tuna fishing effort from 2,400 days to 2,610 days. The dollar increase in the value of the catch would have ranged between $112,000 and $464,000 (Figure 3). A 50% reduction in day baiting with a proportionate increase in fishing effort would have increased the annual catches by 17% to 33% and the value by $262,000 to $929,000. Further reduction in day baiting by 75% would have given the fishermen additional fishing days to increase the catch from 26% to as much as 50%. This increased catch would have been worth from $394,000 to $1,393,000. And finally, if all day baiting were eliminated and the savings in time channeled into skipjack tuna fishing effort, the catch would have increased from 35% to as much

Table 4.--The actual and projected catch and value of skipjack tuna derived by reducing day-baiting effort by 25%, 50%, 75%, and 100%, 1965-72.

Year	Actual day-baiting effort	Actual days fished	Skipjack catch	Value	Catch per day fished	Price per ton	Reduction in day baiting	Reduction in day-baiting effort	Projected days fished	Projected skipjack catch	Projected value	Increase in catch	Increase in value
	No. of days	No. of days	Metric ton	Dollar	Metric ton	Dollar	Percent	No. of days	No. of days	Metric ton	Dollar	Percent	Dollar
1965	838	2,400	7,328.96	$2,013,861	3.05	$274.78	25	210	2,610	7,960.50	$2,187,386	9	$ 175,525
1966	781	2,086	4,256.82	1,403,623	2.04	329.74	25	195	2,281	4,653.24	1,534,359	9	130,736
1967	736	2,010	3,646.80	1,263,116	1.81	346.36	25	184	2,194	3,971.14	1,375,444	9	112,328
1968	1,055	2,177	4,227.41	1,539,617	1.94	364.20	25	264	2,441	4,735.54	1,724,684	12	185,067
1969	864	1,743	2,704.94	1,245,204	1.55	460.34	25	216	1,959	3,036.45	1,397,799	12	152,595
1970	1,017	1,894	3,334.46	1,496,919	1.76	448.92	25	254	2,148	3,780.48	1,697,133	13	200,214
1971	1,334	2,013	6,051.39	2,752,710	3.01	454.89	25	334	2,347	7,064.47	3,213,557	17	460,847
1972	1,187	1,882	4,952.12	2,949,372	2.63	595.58	25	297	2,179	5,730.77	3,413,132	16	463,760
1965	838	2,400	7,328.96	2,013,861	3.05	274.78	50	419	2,819	8,597.95	2,362,545	17	348,684
1966	781	2,086	4,256.82	1,403,623	2.04	329.74	50	390	2,476	5,051.04	1,665,530	19	261,907
1967	736	2,010	3,646.80	1,263,116	1.81	346.36	50	368	2,378	4,304.18	1,490,796	18	227,680
1968	1,055	2,177	4,227.41	1,539,617	1.94	364.20	50	528	2,705	5,247.70	1,911,212	24	371,595
1969	864	1,743	2,704.94	1,245,204	1.55	460.34	50	432	2,175	3,371.25	1,551,921	25	306,717
1970	1,017	1,894	3,334.46	1,496,919	1.76	448.92	50	508	2,402	4,227.52	1,897,818	27	400,899
1971	1,334	2,013	6,051.39	2,752,710	3.01	454.89	50	667	2,680	8,066.80	3,669,507	33	916,797
1972	1,187	1,882	4,952.12	2,949,372	2.63	595.58	50	594	2,476	6,511.88	3,878,345	31	928,973
1965	838	2,400	7,328.96	2,013,861	3.05	274.78	75	628	3,028	9,235.40	2,537,703	26	523,842
1966	781	2,086	4,256.82	1,403,623	2.04	329.74	75	586	2,672	5,450.88	1,797,373	28	393,750
1967	736	2,010	3,646.80	1,263,116	1.81	346.36	75	552	2,562	4,637.22	1,688,876	27	425,760
1968	1,055	2,177	4,227.41	1,539,617	1.94	364.20	75	791	2,967	5,755.98	2,096,328	36	556,711
1969	864	1,743	2,704.94	1,245,204	1.55	460.34	75	648	2,391	3,706.05	1,706,043	37	460,839
1970	1,017	1,894	3,334.46	1,496,919	1.76	448.92	75	763	2,657	4,676.32	2,099,294	40	602,375
1971	1,334	2,013	6,051.39	2,752,710	3.01	454.89	75	1,000	3,013	9,069.13	4,125,456	50	1,372,746
1972	1,187	1,882	4,952.12	2,949,372	2.63	595.58	75	890	2,772	7,290.36	4,341,993	47	1,392,621
1965	838	2,400	7,328.96	2,013,861	3.05	274.78	100	838	3,238	9,875.90	2,713,700	35	699,839
1966	781	2,086	4,256.82	1,403,623	2.04	329.74	100	781	2,867	5,848.68	1,928,544	37	524,921
1967	736	2,010	3,646.80	1,263,116	1.81	346.36	100	736	2,746	4,970.26	1,721,499	36	458,383
1968	1,055	2,177	4,227.41	1,539,617	1.94	364.20	100	1,055	3,232	6,270.08	2,283,563	48	743,946
1969	864	1,743	2,704.94	1,245,204	1.55	460.34	100	864	2,607	4,040.85	1,860,165	49	614,961
1970	1,017	1,894	3,334.46	1,496,919	1.76	448.92	100	1,017	2,911	5,123.36	2,299,979	54	803,060
1971	1,334	2,013	6,051.39	2,752,710	3.01	454.89	100	1,334	3,347	10,074.47	4,582,776	66	1,830,066
1972	1,187	1,882	4,952.12	2,949,372	2.63	595.58	100	1,187	3,069	8,071.47	4,807,206	63	1,857,834

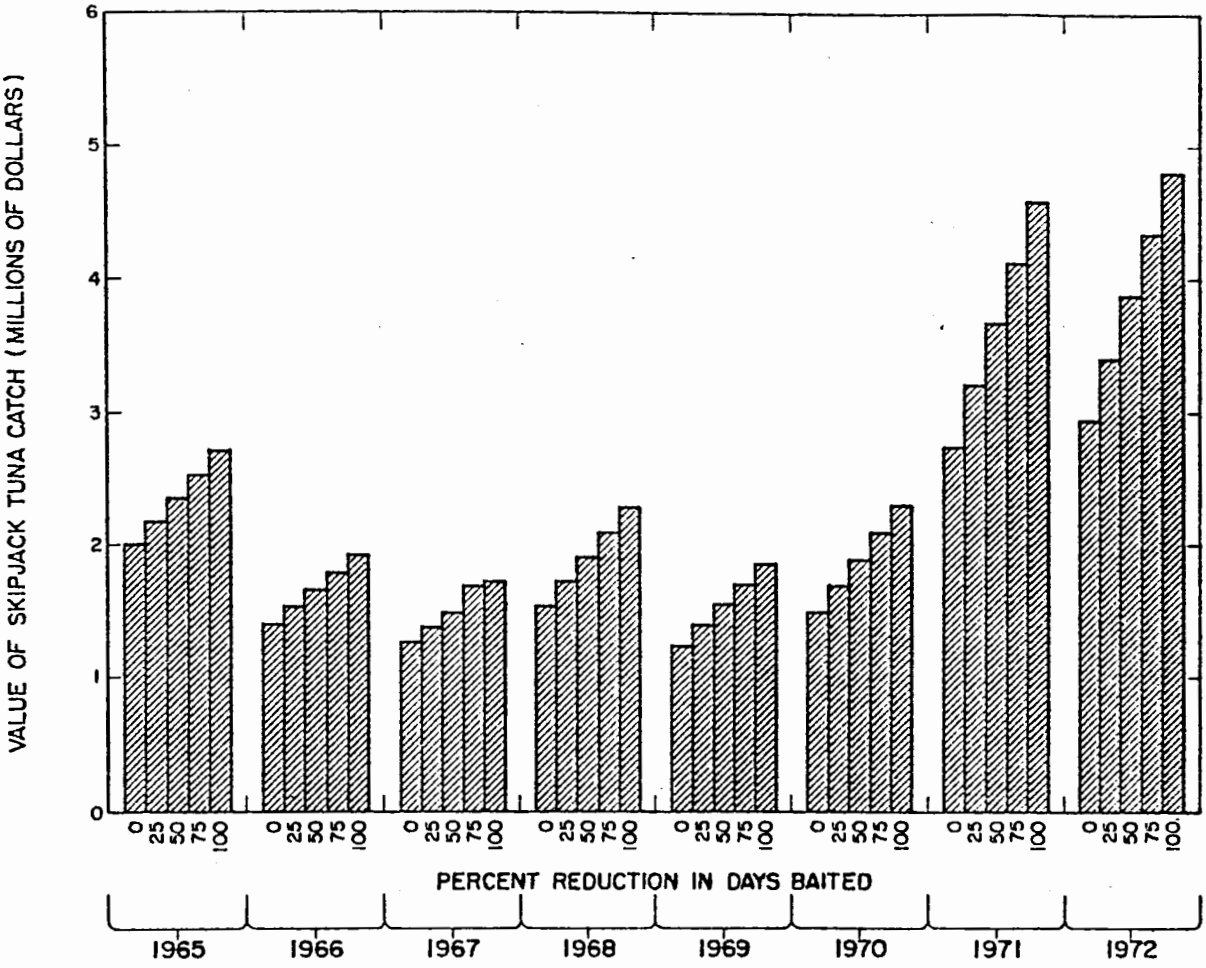

Figure 3.--The increase in value of the Hawaiian skipjack tuna catch resulting from a projected decrease of 25%, 50%, 75%, and 100% in day baiting effort and a concurrent increase in skipjack tuna fishing effort, 1965-72.

as 66% and the value of this increase would have been worth from $458,000 to $1,858,000.

The reasons for the wide variations in the projected catches and values are due to (1) changes in the proportion of day-baiting effort to fishing effort and (2) changes in the ex-vessel price of skipjack tuna. The first has already been discussed. Concerning changes in skipjack tuna prices, Figure 4 shows that the price paid per metric ton of skipjack tuna in Hawaii from 1965 to 1968 increased moderately but remained below $365 per ton. In 1969, however, the price rose markedly and reached $460 per ton. Prices stabilized in 1970-71 but increased sharply again in 1972 to slightly under $600 per ton.

The value of the skipjack tuna catch in Hawaii is determined not only by the price paid for skipjack tuna by the cannery but also by the price paid by the wholesalers in the fresh-fish trade. At present prices, the fishermen can improve their economic base considerably by further increases in fishing effort, and hence, in landings. One approach to increasing fishing effort is to separate bait catching from skipjack tuna fishing. The net value of the increased catch of skipjack tuna, however, should exceed the cost of maintaining a separate bait fishery. This separate fishery could be based on baitfish that are (1) cultured locally, or (2) transported from California to Hawaii on a regular basis.

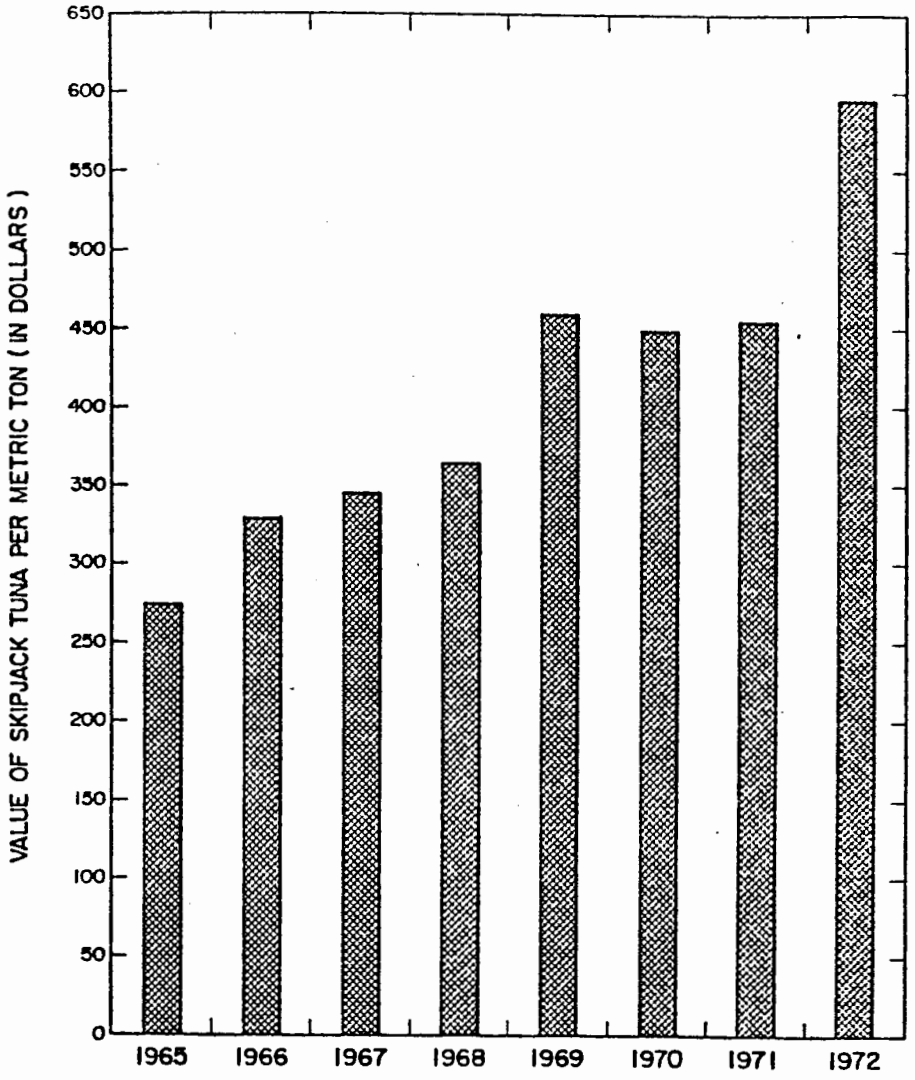

Figure 4.--Price per ton received by the fishermen for skipjack tuna caught in Hawaiian waters, 1965-72.