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PREFACE

This report was prepared during a summer's fellowship at the Southwest Fisheries Center Honolulu Laboratory. The purpose of these fellowships is to bring university scholars into an applied research setting. Academic freedom is preserved. Because the report was prepared by an independent faculty fellow, its statements, findings, conclusions, and recommendations are those of Dr. Hudgins and do not necessarily reflect the view of the National Marine Fisheries Service.

Samuel G. Pooley
Industry Economist

INTRODUCTION

The size of a product is often a quality variable and an important determinant of demand. In many markets particular size fish command a price premium or price discount. In economic terms, size of fish plays the same role as other determinants of demand such as income, tastes, and the price of substitute commodities.[1] Since the size composition of the catch affects prices, the income of fishermen is affected by any change in this composition. The composition of the catch is potentially under the control of the fishermen themselves in many fisheries.[2] Fishermen can change the level of their landings or target different schools of fish in attempts to raise the value of their total catch.

Skipjack tuna, Katsuwonus pelamis, fishermen in Honolulu, Hawaii contend that "large" tuna are recently less plentiful than in previous years. If this is true, then they have lost a major portion of their ability to target particular fish and raise their incomes. The purpose of this research is to report the results of statistical analysis which tests the fishermen's contention. In addition, it is argued that the causes of this changing size composition may be economic in origin. The conclusion is that a decline in Hawaii skipjack tuna fishermen incomes of over $2 million annually is the consequence of economic activity elsewhere in the Pacific Ocean and the increase in fuel costs since 1973. The paper is arranged as follows: Part I gives a brief description of the fishery, part II is a discussion of the statistical results testing whether annual composition and seasonal composition of catch have changed and in what direction, part III is an examination of the various economic factors, endogenous and exogenous to the fishery, which have been proposed as causes for the size change, and part IV describes the consequences for Hawaii fishermen incomes when size composition changes.

I. DESCRIPTION OF THE FISHERY

Historically there were 12 to 15 vessels based in Hawaii fishing for skipjack tuna with pole and line. Fishermen chum with nehu, Stolephorus purpureus, an anchovy type fish caught in Pearl Harbor and Kaneohe Bay. The tuna are sold in a fresh fish market and until January 1985 in a processor market (cannery). In January 1985, the cannery closed. By April 1986, there were nine vessels actively fishing.

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[1]See Gates (1974) for discussion of theoretical issues of fish size in demand curves.

[2]According to Garrod and Chong (1978:14) approximately 85-90% of fresh skipjack in Hawaii is sold at retail level as fillets, steaks, and sashimi style. The price premium is related to the fact that "large" have a relatively higher yield per fish and require lower labor costs per pound to fillet.

The fish are sold by size category, and "large" skipjack tuna (>15 lb (7 kg)) command the highest price. The price vector reflects the eatable yield of the various sizes. Large fish, for example, yield about 50% eatable meat, and medium, small, and extra small fish yield approximately 43, 40, and 30%, respectively.[3] Variation in actual eatable yield also depends on the skill of the person filleting the fish.

The usual season for skipjack tuna is considered to be from April to October when "large" fish are plentiful. The years 1972 and 1973 were the peak for "large" size catches. Total catches by year are given in Table 1. The fishermen's assertions of a changing size composition of catch are based on their observation of falling total annual catches in weight and a smaller number of "large" fish landed, as well as an apparent shortening of the season. Before 1973, the catch of "large" skipjack tuna was highly correlated with the total catch, but not correlated thereafter.

Table 1.--Total catches of skipjack tuna in Hawaii by year, 1964-82.

Year	Pounds caught
1964	6,326,683
1965	12,632,433
1966	7,481,410
1967	6,400,685
1968	7,699,314
1969	4,947,898
1970	5,883,975
1971	10,947,019
1972	9,426,269
1973	9,094,412
1974	5,767,900
1975	3,762,362
1976	7,483,274
1977	6,135,889
1978	5,106,805
1979	5,938,848
1980	3,250,894
1981	4,093,432
1982	2,948,801
1982 in metric tons	1,340

[3]Large are considered >15 lbs in weight; medium are 8-14 lbs; small are 4-7 lbs, and extra small are <4 lbs.

Mendelssohn (1981:896) argues that "since 1973...there has been a definite change in the size composition of the catch." This is in contrast to the estimates of availability for skipjack tuna done for the western and eastern Pacific which show continuing levels of abundance (Inter-American Tropical Tuna Commission (IATTC) 1982; Kearney 1983).

The annual data for Hawaii show a downward trend and large year-to-year fluctuations between 1964 and 1982. Until 1973 over 64% of the total catch comprised "large" tuna. From 1974 to 1982 that fell to 36%. This difference is statistically significant.

Skipjack tuna are highly mobile and there is no a priori reason to believe the catch would be equally distributed across the sizes. There is an economic incentive through the pricing structure for fishermen to target "large" fish if available, which is reflected in the relatively greater proportion of "large" fish caught. The actual distribution of catch across sizes by year is given in Table 2. Results of additional analysis of this catch composition are presented in the next section.

Table 2.--Percentage size composition of total Hawaiian skipjack tuna catches by year, 1964-82.

Year	Percent large	Percent medium	Percent small	Percent extra small
1964	0.6954	0.1059	0.1612	0.0373
1965	0.6496	0.2618	0.0759	0.0124
1966	0.6981	0.2253	0.0709	0.0055
1967	0.5712	0.1615	0.2043	0.0628
1968	0.5260	0.3240	0.1229	0.0270
1969	0.5692	0.0673	0.2219	0.1414
1970	0.4558	0.0881	0.3576	0.0984
1971	0.5563	0.2182	0.2233	0.0020
1972	0.8859	0.0607	0.0406	0.0126
1973	0.8025	0.0994	0.0799	0.0180
1974	0.4012	0.2021	0.2313	0.1652
1975	0.3137	0.1493	0.2674	0.2695
1976	0.2091	0.1800	0.5453	0.0654
1977	0.2439	0.2739	0.4452	0.0368
1978	0.4210	0.2215	0.2337	0.1236
1979	0.4544	0.3596	0.1397	0.0462
1980	0.2827	0.3751	0.2369	0.1050
1981	0.4570	0.1716	0.2283	0.1429
1982	0.4856	0.1578	0.2264	0.1300

II. COMPOSITION OF ANNUAL CATCHES AND SEASONAL DISTRIBUTION

Annual Analysis 1964-82

Annual catches fell from the expected long term trend after 1973. The mean monthly total catch in the 1964-73 period was 305 metric tons (MT) (673,667 lb). This mean fell to 190 MT (411,926 lb) for 1974-82. Absolute and relative catches of "large" skipjack tuna fell after 1973. The mean monthly catch of "large" fell from 200 MT (439,790 lb) to 65 MT (144,704 lb) in 1964-73 and 1974-82, respectively. In relative terms, catches of "large" fish fell from 64.1% of total annual catch in 1964-73 to 36.3% in 1974-82. The fisherman observation that "large" fish are less plentiful is supported by statistical analysis. The decline in total catches is not, however, completely explained by the decline in "large" fish caught.

To examine relative changes among sizes, simple correlation coefficients between size categories were calculated for the period 1964-82 (Table 3). Several correlations were significant: weight of "large" is positively correlated with total weight and with percentage "large" in total catches; weight of "large" is negatively correlated with small and extra small weights.

Table 3.--Simple correlation coefficients among sizes 1964-82 (pounds).

Weight	Large	Medium	Small	Extra small	Total
Large	1.0	0.3646*	-0.1910*	-0.6357*	0.8729*
Medium	--	1.0	0.1335*	-0.5044*	0.6494*
Small	--	--	1.0	0.0773	0.1363*
Extra small	--	--	--	1.0	0.6135*
Percent of total weight					
Large (%)	0.8642*	-0.0118	-0.5760*	-0.5171*	0.5383*
Medium (%)	-0.2430*	0.6982	0.0122	-0.2309*	-0.0254*
Small (%)	-0.6891*	-0.1919*	-0.8635*	0.3995*	-0.3507*
Extra small (%)	-0.6836*	-0.5494*	0.0781	0.9325	-0.7353*

Percent of total weight	Large (%)	Medium (%)	Small (%)	Extra small (%)
Large (%)	1.0	-0.4506*	-0.8231*	-0.5188*
Medium (%)	--	1.0	0.0105	-0.1722*
Small (%)	--	--	1.0	0.3217
Extra small (%)	--	--	--	1.0

Correlations among sizes, although statistically significant, give no evidence as to when the relative proportions may have changed. It may be that although "large" sizes were no longer available, other sizes became relatively or absolutely more abundant. The effect on fisherman incomes of the decline in "large" fish may have been offset by increases in other sizes.

The mean monthly catches of medium, small, and extra small fish varied widely over the period. The results of mean t-tests indicate that medium size catches fell significantly from prior years in 1980. The mean monthly catch of medium fish in 1964-79 was 50 MT (114,244 lb) while that in 1980-82 was 30 MT (66,319 lb). The mean monthly catch of small fish in 1964-77 was 55 MT (123,068 lb) while that in 1978-82 was 35 MT (73,274 lb). The mean catches of extra small fish rose significantly in 1975 relative to prior years. The mean monthly catch of extra small fish 1964-74 was 12 MT (27,154 lb) while that in 1975-82 was 20 MT (41,114 lb).

The change in total annual catches observed by the fishermen then results from absolute declines in "large" (in 1974), medium (in 1980), small (in 1978), and only slightly offset by an absolute increase in extra small fish (in 1976). Similar tests were done to examine relative shifts in proportion of total catch by size. The proportion of "large" fish decreased in the same year (1973) that absolute catches of "large" fish declined. Only the proportion of "large" fish showed any statistically significant change. This implies that proportionally, none of the other sizes, medium, small, or extra small, has increased or decreased outside the expected range. As "large" fish declined there was no offsetting increase in other size fish except for extra small which brings the lowest price (total and per pound).

The same conclusions are apparent when catch per landing is calculated (Table 4). Although there is some variation in number of 1-day trips taken per year this variation does not explain the decline in "large" fish caught since 1974. The total catch per trip has declined slightly. Given the changed composition of the catch, each landing in 1982 has a lower value in revenue relative to prior years.

The decline in abundance of "large" skipjack tuna around the Hawaiian Islands began in 1974 and had not reversed as of 1982. The fall in total weight caught is also attributable to the decline in small and medium size catches. Although there continues to be wide variation in annual catches, the downward trend is clearly apparent. This contrasts with findings of Skillman and Riggs (1978) who found no definable trend in this same fishery. The fishermen also contend that the season is shorter since "large" season fish seem to come later in the year and be abundant for fewer months. This contention is examined in the next section.

Table 4.--Catch (weight) per landing per year, 1964-82.

Year	Large	Medium	Small	Extra small	Total
1964	3,209	489	744	172	4,615
1965	4,679	1,886	547	90	7,202
1966	3,210	1,036	326	25	4,598
1967	2,354	666	842	259	4,121
1968	2,293	1,413	536	118	4,360
1969	2,144	254	836	533	3,766
1970	1,743	337	1,367	376	3,823
1971	3,776	1,481	1,516	14	6,787
1972	5,272	362	242	75	5,951
1973	4,544	563	453	102	5,663
1974	1,347	679	777	555	3,357
1975	754	359	643	648	2,404
1976	890	766	2,320	278	4,254
1977	994	1,116	1,814	150	4,074
1978	1,501	789	833	441	3,564
1979	2,043	1,617	628	208	4,496
1980	928	1,231	777	345	3,280
1981	1,659	623	829	519	3,629
1982	1,354	440	631	362	2,787
1982 in kilograms	615	200	287	165	1,267

Seasonal Analysis

Although there have been dramatic declines in the absolute weight caught annually in the various size categories, no evidence was found that either seasonal distribution of skipjack tuna catches or seasonal levels of landings have changed over the period. A chi-square test was applied to data disaggregated by month. The expected distribution of catches by size and level of landings is given in Table 5. The only year in which any actual distribution differed from the expected was 1982. This difference is attributable to the fact that significantly fewer "large" fish were caught in June 1982.

This seasonal analysis suggests that the month-to-month behavior of the skipjack tuna and the skipjack tuna fishermen in Hawaii has not changed across the years. There is a simple decline in the number of fish available. Some event clearly affected the availability of "large" skipjack tuna in 1974 and continues to influence the fishery. Although there has been no change in fishing method, other economic activity has occurred which may explain the changed size distribution. These economic causes are examined in the next section.

Table 5.--Expected seasonal distribution of catches by sizes and of landings, 1964-82.

Month	Total	Percentage catches by size				Percent of total landings
		Large	Medium	Small	Extra small	
Jan.	3.63	1.95	8.68	4.14	0.93	6.41
Feb.	2.51	1.11	4.93	3.92	2.61	6.08
Mar.	3.13	1.76	5.12	3.83	6.82	5.94
Apr.	5.15	3.17	6.93	7.16	10.74	7.36
May	12.40	11.25	12.05	12.92	18.81	10.67
June	16.88	19.31	10.57	17.12	14.28	12.09
July	19.10	25.01	12.80	11.34	11.60	12.77
Aug.	15.06	19.09	6.51	12.84	13.49	11.14
Sept.	7.61	6.66	5.25	11.15	12.11	8.31
Oct.	6.01	5.06	7.20	7.29	6.58	7.09
Nov.	4.62	3.13	10.46	4.04	1.14	6.01
Dec.	3.84	2.42	9.45	3.19	0.83	6.08

III. INFLUENCE OF ECONOMIC FACTORS

Measures of biological abundance of skipjack tuna for the Pacific Ocean indicate that the resource is in no danger of being overfished. Given this, the decline in catches around Hawaii appears to be a regional issue in that the decline is not occurring elsewhere. This implies that economic activity is influencing the Hawaii fishery. This economic activity can be categorized as: that which occurred in Hawaii and is endogenous to the fishermen, that which occurred in Hawaii and is exogenous to the fishermen, and that which occurred elsewhere in the Pacific Ocean. Each category is examined below.

The most obvious economic event which might affect catches would be a change in the fishing behavior of the Hawaii fishermen themselves. Measures of economic factors, over which the fishermen might be expected to have some degree of control, are given by year in Table 6. There was a decline over 1964-82 of the number of vessels fishing, the average catch per vessel, and the average catch per landing. To examine the relative effects of these variables on total catches, the following model was tested against the annual data:

$$C = C(V, L, S, dC) \qquad (1.1)$$

where:

C = total catch in pounds
V = number of vessels
L = number of landings
S = size composition of catch measured as percent "large"
dC = yearly change in total catch.

Table 6.--Measures of economic activity in Hawaii skipjack tuna fishery by year, 1964-82.

Year	Number of vessels	Average catch per vessel	Average catch per trip
		Pounds	Pounds
1964	18	351,482	7,706
1985	19	664,864	6,392
1966	16	467,588	4,245
1967	15	426,712	3,758
1968	14	549,951	4,060
1969	12	412,324	3,469
1970	13	452,613	4,348
1971	13	842,078	6,143
1972	13	725,097	5,528
1973	14	649,600	5,416
1974	13	443,684	3,215
1975	15	250,824	2,350
1976	13	575,636	4,152
1977	15	409,059	4,401
1978	13	392,831	3,563
1979	17	349,344	4,495
1980	13	250,068	3,280
1981	14	292,388	3,628
1982	14	210,628	2,795
1982 in metric tons		95.5	1.27

The model was run with two sets of independent variables to correct for expected collinearity among the determinants of catch. The results are:

$$C = -62325 + \underset{(243323)}{245816\ V} + \underset{(2245330)}{7{,}209{,}330\ S^*} + \underset{(100730)}{3404880\ dC^*} \qquad (1.2)$$

$N = 19$; $R^2 = 0.66$.

$$C = -2533760 + \underset{(1133)}{4502\ L^*} + \underset{(1700320)}{5020920\ S^*} + \underset{(748160)}{255860\ dC^*} \qquad (1.3)$$

$N = 19$; $R^2 = 0.83$.

(standard errors are in parentheses).

The * indicates the estimated parameter differs from zero at a 95% confidence level.

Estimate (1.2) says that the size composition of catch (measured as percent "large" of the total) and the change in catches from last year are statistically significant determinants of total catches. The number of vessels is not. Estimate (1.3) has similar results except that number of

landings rather than absolute number of vessels is a significant determinant of total catches. The average catch per landing between 1964 and 1973 was 5,106 lb and between 1974 and 1982 was 3,188 lb. In 15 years out of the 19-year period, the direction of change in number of landings is the same as that for catches, implying that fishermen are responding to fish availability rather than causing the catches to change (Table 7). In addition there is no reason to believe that levels of landings should affect the levels of average catch per landing. The fishermen presumably would be catching as much as possible. As shown in part II, there has also been no change in distribution of landings across the season. The economic variables over which the fishermen in Hawaii have some degree of control do not explain the changed size composition of catch or fall in total catches since 1974.

There are three economic events which occurred in Hawaii during the 1964-82 exogenous to the fishery itself. These events may have affected the total catches of the skipjack tuna fishermen in Hawaii: availability of bait, placement of fish aggregating devices (FAD's) offshore, and increasing fuel costs. Fishermen harvest nehu with which they chum skipjack tuna schools. Since 1981, bait in Pearl Harbor and Kaneohe Bay is less plentiful apparently because of environmental regulations about the

Table 7.--Percentage change in mean monthly landings and percentage change in total annual catch.

Year	Percent annual change in mean monthly landings	Percent annual change in total catch
1964	--	--
1965	+46.0	+99.6
1966	-11.0	-40.7
1967	-3.0	-14.4
1968	+11.0	+20.2
1969	-25.0	-35.7
1970	+7.7	+18.9
1971	+16.0	+86.0
1972	-4.0	-13.8
1973	-1.5	-3.5
1974	+6.8	-36.5
1975	-10.0	-34.7
1976	+12.9	+98.8
1977	-22.5	-18.0
1978	+2.0	-16.7
1979	-7.5	+1.6
1980	-25.0	-45.2
1981	+14.6	+25.9
1982	-6.3	-27.9

type of refuse the U.S. Navy can dump into harbors and bays. Bait availability does not explain the changed composition of catches which began in 1974, although the problem probably exacerbates the decline in total catches. The placement of FAD's also does not explain the size composition of catch with respect to "large", medium, or small fish. The FAD's were in place for the full 1980 fishing season. Sproul (1984) says that fishermen use the FAD's primarily to compensate for low-catch or zero-catch trips. The best evidence indicates that FAD's attract smaller fish. The statistical analysis presented above indicated that small fish declined in 1978 and extra small fish increased in 1976, neither of which coincides with the placement of the FAD's. The analysis did show that medium size fish declined in 1980. If the FAD's had an influence, we would expect the opposite effect, catches of smaller fish which could be defined to include medium fish should have increased rather than decreased.

Fuel costs are a major determinant of the decision to take a trip and the length of a trip. Fuel costs have increased in Hawaii steadily since 1973. This increase may have led to a subtle change in fisherman behavior in that they no longer go as far out to sea or search as long as in previous years. Recent estimates (Hudgins 1980:64) indicate that for each $0.10 increase in the real price of fuel, total monthly catch will decline by about 5,900 kg (13,000 lb). Gasoline prices have increased over 1964-82 about 359%. This increase implies a 780 MT (1,716,000 lb) decrease in annual catches in response to rising fuel costs. It is certainly possible that a slight change in fish migratory patterns farther offshore combined with shorter distances traveled by fishermen in response to increased fuel costs would explain part of the decrease in total catch since 1974.

Aside from fuel costs then, there is nothing which occurred in Hawaii during the period which explains the decline in catches or the change in size composition. Economic activity in the skipjack tuna fishery elsewhere in the Pacific does offer some explanation. There are two major issues to explore: behavior of the canneries which buy and pack tuna and the general expansion of the skipjack tuna fishery in the Pacific. In 1973 canneries on the west coast of the United States, because of the mercury scare, were required to buy more skipjack tuna to mix with other tuna to bring down the mercury content of a can of tuna. Vessels responded by increasing their catches of skipjack tuna in the eastern Pacific relative to other species of tuna. At the same time, some evidence indicates that yellowfin tuna, *Thunnus albacares*, were beginning to show signs of declining abundance (IATTC 1982). The data in Table 8 show these increasing catches of skipjack tuna. Further analysis would be necessary to determine how much of this increase is attributable to cannery demand for skipjack tuna and how much was vessel response to increasing relative availability of skipjack tuna. It is obvious though that skipjack tuna catches in the eastern and western Pacific increased in the same year that skipjack tuna catches in Hawaii began to show declines in "large" fish.

The skipjack tuna fishery elsewhere in the Pacific continued to expand, and between 1965 and 1982, catches of skipjack tuna in the Pacific increased 157% (Hudgins and Greeman 1985). Catches in the Pacific jumped from <50,000 MT in 1965 to >300,000 MT in 1973 and 572,000 MT in 1982.

Table 8.--Skipjack catches in eastern and western Pacific by year (metric tons). Source: FAO Yearbook of Fishery Statistics, various annual editions.

Year	Eastern Pacific	Western Pacific
1970	59.0	67.8
1971	83.2	102.5
1972	55.7	117.1
1973	52.0	173.0
1974	75.3	302.7
1975	96.9	265.2
1976	129.6	252.4
1977	91.7	271.5
1978	130.9	364.0
1979	119.3	298.2
1980	130.5	303.1
1981	147.5	299.8
1982	92.5	217.8

United States vessels caught about 20,000 MT in the Pacific in 1973 and over 100,000 MT by 1979. The migratory patterns of skipjack tuna across the Pacific from east to west are well defined (Matsumoto et al. 1984) so it seems that the fish may have been caught before ever getting to Hawaii. The migratory patterns of skipjack tuna across the Pacific from west to east are undetermined although there is some evidence from tagging experiments that skipjack tuna have migrated from the western Pacific to the area around Hawaii. The biological interaction of the various fisheries within the Pacific deserves further attention. The economic interaction of the various fisheries within the Pacific seems clear. The fish lost to Hawaii fishermen have been captured by vessels elsewhere. These economic events elsewhere in the Pacific offer the most reasonable explanation of the changed size distribution of catches around Hawaii. The consequences of these changes on Hawaii fisherman incomes are examined in the next section.

IV. CONSEQUENCES FOR HAWAII SKIPJACK TUNA FISHERMAN INCOMES

Since 1974 the abundance of "large" skipjack tuna caught by the Hawaii-based pole-and-line fleet has significantly declined. Although the subsequent decreases in medium (in 1980) and small fish (in 1978) are also important for fisherman income, "large" fish comprised the major portion of the catch. The shifts in distribution by size are given in Table 9.

Table 9.--Annual size distribution: 1964-73, 1974-82, 1964-82.

Period	Percent "large"	Percent medium	Percent small	Percent extra small
1964-73	64.1	16.1	15.5	4.1
1974-82	36.3	23.2	28.3	12.0
1964-82	50.9	19.4	21.6	7.9

The average annual catch fell between the periods by 1,425 MT (3,140,892 lb). This decrease in total catches occurred across all sizes. If we use the expected 1974-82 distribution on the actual 1964-73 catches, it is obvious that not only has size distribution changed but absolute weight in each size category has decreased.

Expected and actual annual catches if size distribution changed but total pounds caught did not change.

	Large	Medium	Small	Extra small
Expected 1974-82	2,934,493	1,875,488	2,287,773	970,080
Actual 1974-82	1,794,349	1,146,801	1,398,900	593,173
Difference	-1,140,147	-728,687	-888,873	-376,907
Attributable to fuel cost increases	-615,679	-393,487	-479,991	-203,529
Attributable to absolute decline in catches due to less abundance	-524,467	-335,200	-408,881	-173,377

Fuel cost increases may explain as much as half of the total decrease which should affect the total catch across all sizes. The residual is attributable to the exogenous decline in absolute weight caught in each size category. The decreases attributable to changed size composition are much larger. For example if size composition had not changed but total quantity caught had changed, the expected and actual catches by size would be (in pounds):

	Large	Medium	Small	Extra small
Expected 1974-82 with no change in size distribution	3,168,534	795,841	766,182	202,667
Actual 1974-82 catch	1,794,349	1,146,801	1,398,900	593,173
Difference	-1,374,185	+350,906	+632,718	+390,506

Two effects must then be considered when evaluating the impact of exogenous changes on prices and incomes. The first is the effect on price as absolute catches fall. This quantity effect would have an inverse relationship with prices. Elasticity of demand for this market has been estimated to be -1.82 (Hudgins 1980:67). The absolute decline during 1974-82 in annual catches of 1,425 MT (3,140,892) would result in an increase in prices of about 20%.[4] The second is the effect on price as average size of catch changes. This effect would be positively related to prices, with prices and size moving in the same direction. This effect is easily seen using the 1982 price vector and calculating the total values of the various catches under the different size distribution assumptions:

1982 skipjack wholesale price vector:

P_{large} = 0.90/lb
P_{medium} = 0.81/lb
P_{small} = 0.63/lb
$P_{extra\ small}$ = 0.49/lb
P_0 = average weighted price

1964-73 Catch Value (1982 prices)

1964-73 size distribution	$6,725,160	P_0	= 0.83
1974-82 size distribution	$6,076,826	P_0	= 0.75

1974-82 Catch Value (1982 prices)

1964-73 size distribution	$4,078,312	P_0	= 0.83
1974-82 size distribution	$3,715,784	P_0	= 0.75

[4]The change in quantity over the period was about 38%. The 20% increase in price is calculated at the mean value assuming all other determinants of demand, including size are held constant, over the period. Pooley and Hudgins (unpublished data) found no significant change in total skipjack demand between the 1970-78 and 1979-83 periods.

The price and total value of the catch declined about 10% under the changed size distribution. For each 2.8% decrease (increase) in "large" fish, as a proportion of total catch, there is about a 1% decrease (increase) in price. Similar calculations were done to evaluate the loss attributable to fuel cost increases and absolute declines in catches. The loss in Hawaii fisherman incomes from the various causes are (all valued in 1982 prices):

Fuel cost increases	- $1,274,958[a]
Absolute decline in fish abundance	- $1,086,084[b]
Change in size distribution	- $362,529[c]
Total decline in Hawaii fisherman income	- $2,723,571

[a]Decline in total quantity caught in 1974-82 not attributable to decline in fish abundance or changing size distribution.

[b]Decline in total quantity caught in 1974-82 not attributable to fuel cost increases or changed size distribution.

[c]Decline in total quantity caught in 1974-82 solely attributable to changed size distribution. Includes decrease in "large," relative increase in medium, small, extra small fish.

The conclusion is that when evaluated in relative terms (at 1982 wholesale prices), the value of the total catch has declined by almost $3 million. Over $1 million is attributable to the absolute decline in fish abundance caused by fishing activity elsewhere in the Pacific. Fuel cost increases may have led to less search time or decreased numbers of landings resulting in the loss of over $1 million value. The changed size distribution attributable to increased fishing elsewhere in the Pacific led to a loss of $350,000. This loss is relatively less, simply because of the mitigating influence of the relatively increased catches of medium, small, and extra small fish. If "large" fish had declined without the absolute increases in the other sizes the loss attributable to the decline in "large" fish alone is valued at $1,236,766. The Hawaii skipjack tuna fisherman incomes are definitely being affected by economic events beyond their control.

V. CONCLUSIONS

Skipjack tuna fishermen in Hawaii had complained that "large" tuna were less abundant on an annual basis and that the skipjack tuna season had apparently been shortened. The statistical analysis supports the first complaint but not the second. There has been a statistically significant decline in "large" fish (in 1974), in medium fish (in 1980), in small fish (in 1978), and an increase in extra small fish (in 1976). There is no evidence that seasonal distribution of sizes or landings has changed over the period 1964-82.

Several causes of this absolute decline in "large" fish and total catches were examined. Only increased fuel costs and increased fishing

effort elsewhere in the Pacific offer explanations for the declining catches. It appears most likely that the stock is being truncated before it ever reaches Hawaii waters.

Hawaii fisherman incomes have been strongly affected by declining total catches and changing size distribution. The decline in total catches has the most important impacts on total value. Although the decrease in total catches would lead to an increase in average price of about 20%, the decline in quantity caught and sold (38%) dominated and led to dramatic decreases in total value of the catch. The change in size distribution, especially the decline in "large" fish as a proportion of total catch, would have led to about a 10% decline in average price. This combination of market factors and exogenous events indicates that it will be increasingly difficult for the skipjack tuna industry in Hawaii to expand without some change in technology or expansion of markets.

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