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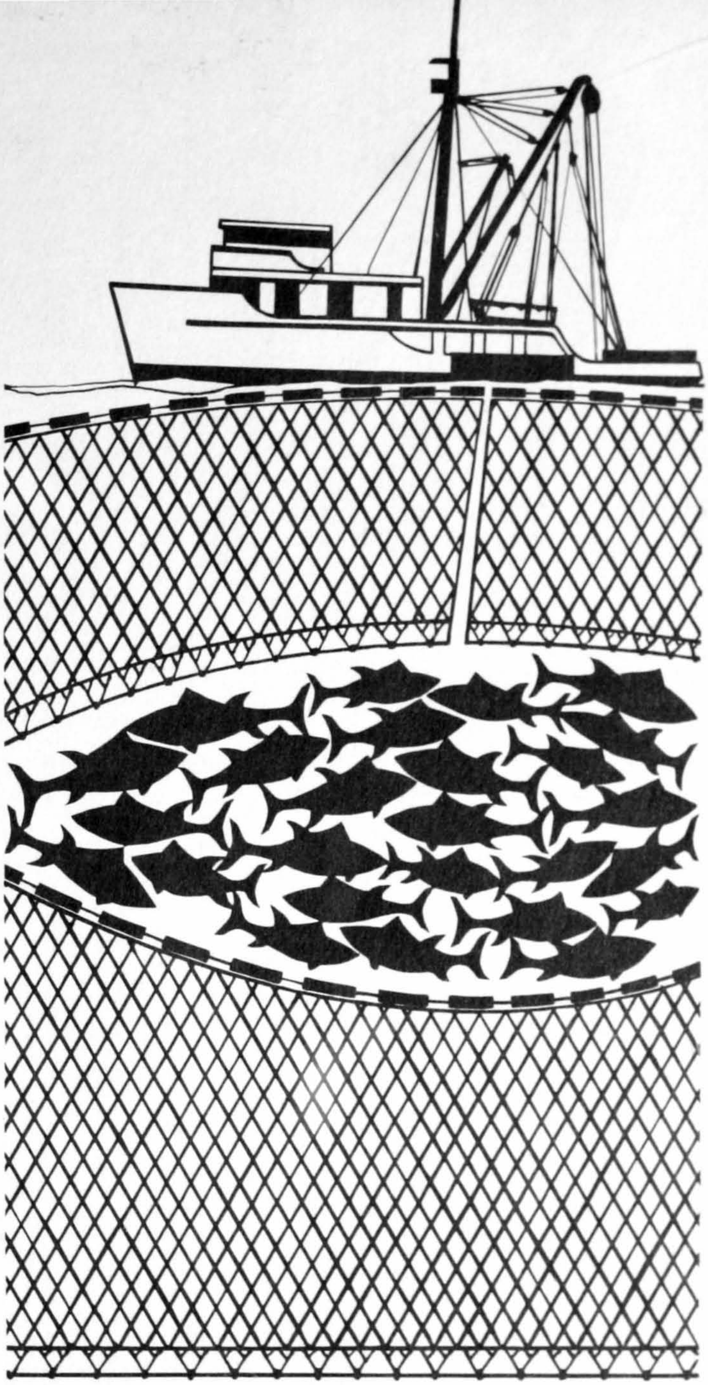

FISHERY INDUSTRIAL RESEARCH

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FEASIBILITY OF USING TENNESSEE RIVER FISH FOR FISHERY PRODUCTS

by

Richard A. Krzeczkowski

ABSTRACT

Populations of reservoir fishes are dominated by species that are of no interest to sport fisherman and that are of low market value. Yet a useful outlet is needed for them. Would they perhaps be suitable for the production of fish meal?

In partial answer to this complex question, the present study investigated the nutritional aspects of some of the principal species of fishes growing abundantly in reservoirs. In this connection, carp, freshwater drum, gizzard shad, and threadfin shad from the Tennessee River (specifically, Kentucky Lake) were harvested commercially and were rendered into press cake and fish meal. The seasonal variations in proximate analyses, the composition of extracted fish oil, the presence or absence of thiaminase in the materials, the concentration of DDT and DDE, and the comparative value of the fish meal in broiler rations were determined.

The study indicated that these species of fishes are nutritionally and physically suitable for the production of fish press cake, meal, and oil.

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Author: Richard A. Krzeczkowski, *Chemist*, Bureau of Commercial Fisheries Technological Laboratory, Ann Arbor, Michigan. Present address: Bureau of Commercial Fisheries Technological Laboratory, 622 Mission Street, Ketchikan, Alaska 99901.
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INTRODUCTION

During the past 30 years, many large reservoirs have been built within the United States, primarily for flood control, irrigation, navigation, and the production of electric power. A byproduct of these reservoirs has been the creation of fisheries and recreational resources that, in some areas, have gained an importance equal to that of the original purpose. In these areas, game fishes have been utilized to a great extent by sport fishermen. Those species, however, that are of no interest to sport fishermen and particularly those species that have a relatively low market value as commercial fish are not being utilized. Yet, these fishes of low value commonly dominate the populations of reservoir fishes. The Bureau of Commercial Fisheries Exploratory Fishing and Gear Research staff at Ann Arbor, Michigan, (1969) has estimated that the potential harvest for nongame fish in the Mississippi River drainage system is 450 million pounds annually. Less than 20 percent (70 to 90 million pounds) of these fish are harvested each year.

Where commercial fisheries have been established, the production is usually limited to species with a good market value--the production of catfish and buffalo fish is a good example. Rarely are fishes of low value--such as carp (*Cyprinus carpio*), freshwater drum (*Aplodinotus grunniens*), gizzard shad (*Dorosoma cepedianum*), and threadfin shad (*D. pentenense*)--taken in the quantities that are commensurate with their abundance. If the use of reservoir aquatic resources is to be maximized and if regulatory agencies are to use commercial fisheries as a tool to effect the management of fishes in reservoirs, practical means of utilizing the abundant but low-value fishes is highly desirable.

The only commercial potential now appears to be in the industrial processing of the low-value fishes for pet food, fur-animal food, fish meal, or related nutritional uses. The criteria of economics that are imposed on an industrial fishery are stringent and have prevented the establishment of significant reservoir fisheries of this kind. The species of fishes that are used most commonly for the production of meal are marine members of the herring family, which are harvested cheaply in vast quantities and which have proved to be nutritionally valuable for poultry.

If we bypass the economics of fish processing and the problems attending the sale of the product at a competitive price, we are still faced with the fundamental problem of the nutritional value of the products. Therefore, the possibility of using fresh-water species for the production of fish meal requires that the suitability of these species as the ingredients of a meal used in animal rations be established. The overall purpose of this study accordingly was to explore the nutritional feasibility of utilizing low-value species from a typical reservoir, such as Kentucky Lake in the Tennessee River, for processing into fish press cake, meal, and oil.

The species chosen for study were carp, freshwater drum, gizzard shad, and threadfin shad, all of which are abundant. Fishery biologists from Tennessee Game and Fish Commission and Tennessee Valley Authority estimate that a reservoir such as Kentucky Lake could yield from 15 to 30 million pounds of carp, freshwater drum, and shads annually.

The specific purposes of the study were to determine (1) the seasonal variation in the concentration of protein, oil, ash, and moisture in the raw fish, press cake, and fish meal; (2) the composition of the extracted fish oil; (3) the presence or absence of thiaminase (a vitamin B_1 antimetabolite) in the products; (4) the seasonal variation in the concentration of certain pesticides in the raw fish and in the products; and (5) the nutritional value of the fresh-water fish meal as compared with that of menhaden (*Brevoortia tyrannus*) meal when included in broiler rations.

I. SEASONAL VARIATION IN THE PROXIMATE COMPOSITION OF THE RAW FISH, THE PRESS CAKE, AND THE FISH MEAL

A. MATERIALS AND METHODS

The following sections describe (1) the raw materials used and preparation of the products from them and (2) the analytical procedures used.

1. Raw Materials and Preparation of Products

a. Raw materials.—The samples of fish were collected by the use of commercial trawl and gill nets. All the samples were collected in Kentucky Lake, Tennessee, in the area of Johnsonville, Tennessee. The fish were harvested during August and November 1966, and January, February, March, April, and June 1967 for seasonal variation. They were segregated by species, packed in ice as soon as they were caught, and frozen within 24 hours. The frozen fish were stored at about 0° F. until they were transported frozen to the laboratory at Ann Arbor. Upon arrival at the laboratory, they were stored at −30° F. until they were processed.

The carp were 16.4 to 22 inches long and weighed 0.5 pounds to 5 pounds.

The freshwater drum were 8 to 19 inches long and weighed 0.33 pounds to 1.5 pounds.

The catch of shad was composed of 80 percent threadfin and 20 percent gizzard shad by number. This ratio represented the commercial catch (net-run) of shad, so no attempt was made to separate the two species because commercially such a separation would not be practical. The average length of these fish varied from 2.7 to 8.3 inches; the weight varied from 100 fish per pound to 11 fish per pound. In all samplings and measurements, the ratio of 80 percent threadfin shad to 20 percent gizzard shad by number was maintained.

The condition and quality of all fishes were excellent.

b. Preparation of products. — The fishes were conventionally wet rendered to produce press cake and oil; and fish meal was made from the press cake.

(1) Press cake and oil.—The temperature of 100 pounds of whole fish of each species was allowed to rise to about 0° F., and the frozen fish were then ground once through a meat chopper having a plate with holes ¼-inch in diameter.

The ground fish was cooked to 203° F. in 100-pound batches by use of a steam-jacketed kettle and the direct injection of steam.

While the resulting cooked material was still hot, it was pressed in a 4-foot, 3-stage screw press. The yield of press cake was 50 to 65 percent.

Portions of the raw, ground fish and press cake were sampled, and the samples were stored at −30° F. for chemical analysis.

Oil was decanted from the press water, and a sample of it was also taken for analysis.

(2) Fish meal.—The press cake to be processed into fish meal was dried in a vacuum, steam-jacketed dryer at 15 inches of mercury vacuum and 5 pounds per square inch steam. The material was dried until the percentage of water was less than 10. The dried material was then pulverized in a hammer mill, which

had a screen with 0.05-inch openings. The resulting fish meal was sampled for analysis, and the sample was stored at −30° F. The yield of fish meal was 17 to 23 percent of the amount of raw fish used.

2. Analytical Procedures

The following sections describe (a) the methods used in the preparation of the samples for proximate analysis and (b) the methods of proximate analysis used.

a. Sample preparation.—Frozen samples of raw fish and of press cake were ground twice through a meat chopper having a plate with holes 1/8-inch in diameter and were blended by stirring before being sampled. The samples of fish meal were weighed directly from the milled, frozen stock.

b. Proximate analysis.— All samples were analyzed in duplicate for the percentages of protein, oil, ash, and water by the procedures of the Association of Official Agricultural Chemists (Horwitz, 1960).

B. RESULTS

Differences in proximate composition as influenced by species and season were investigated for (1) the raw fish, (2) the press cake, and (3) the fish meal.

1. Raw Fish

Table 1 indicates a wide variation in the concentrations of protein, oil, ash, and water among the three species as well as among the individual specimens within a given species.

The percentage of protein ranged from 14.17 to 18.46, except for two samplings. The shad harvested on August 27, 1966, had 13.19 percent protein, and the carp harvested on December 9, 1966, had 20.50 percent protein. The average percentages of protein in each species was as follows: carp, 17.18; freshwater drum, 15.28; and shad, 14.38. The data do not reveal any significant seasonal variation in the percentage of protein.

The range in the percentage of oil was large in the shad and freshwater drum and appeared to be seasonally dependent. The percentage of oil for carp was lowest in the spring (4.0 percent) and ranged higher during the rest of the year (6.8 to 9.6 percent). The percentage of oil for freshwater drum was, likewise, low during the spring--2 percent--and was higher during the rest of the year--7.3 percent to 10.7 percent. The percentage of oil for shad ranged from a low of 2.9 during the spring and summer to a high of 8.8 in the winter.

The average percentage of ash in the fishes ranged from 3.29 to 5.78. The percentage of ash was lowest in shad and highest in freshwater drum. The percentage of ash in shad and freshwater drum was lowest during the winter, and this low percentage for ash corresponded to a high percentage for oil.

The percentage of water ranged from a low of 65.91 to a high of 79.26, with an average of 72.97 for all the fishes. Shad had a high percentage of water; whereas, carp and freshwater drum had lower values.

As would be expected, the percentage of oil and of water varied inversely with one another. The percentage of oil plus water in all the fishes ranged between 77 and 83.

2. Press Cake

The percentage of protein showed no seasonal dependency and ranged between 20.20 and 26.30 except for carp press cake (dated February 2, 1967), which had a percentage of 28.28.

The percentage of ash ranged between 6.11 and 15.89. The percentage of ash in freshwater drum and shad press cake appears to be dependent on the percentage of oil in the raw sample. A lower percentage of oil in the raw fish corresponds to a higher percentage of ash in the press cake. The percentage of ash in carp press cake varied directly with the percentage of oil in the raw carp.

The percentage of water ranged from 55.54 to 65.92 for all press cakes. The percentage of oil ranged from 2.90 to 8.74. In all samples, the percentage of oil plus water ranged between 61.3 to 71.2. All but freshwater drum press cake (dated April 1967) with a value of 58.4 percent was within this range.

Table 1.—Seasonal variation in length, weight, and composition of Tennessee River fish

Species and state	Average length[1]	Average weight[1]	Time of year	Protein	Oil	Ash	Water	Concentration of pesticides p,p'-DDE & p,p'-DDT		Thiaminase activity
	Inches	*Pounds*	*Month*	*Percent*	*Percent*	*Percent*	*Percent*	*P.p.m.*	*Percent of original*[2]	*Present or absent*
Shad:										
Raw fish . . .	2.7	.01	Aug.	13.19	3.39	4.62	79.26	0.35	100	+
Press cake . .			1966	24.33	4.52	12.43	57.84	0.72	100	—
Fish meal . .				53.98	9.32	26.95	10.00	1.50	85	—
Raw fish . . .	4.1	.2	Nov.	14.70	8.8	3.29	73.20	0.90	100	+
Press cake . .			1966	21.58	5.18	7.64	65.90	0.45	40	—
Fish meal . .				57.39	14.11	18.67	10.00	2.10	36	—
Raw fish . . .	4	.2	Jan.	14.17	8.18	3.38	73.75	1.04	100	+
Press cake . .			1967	21.62	5.09	6.11	65.72	0.63	41	—
Fish meal . .				61.85	11.49	16.90	10.00	1.85	36	—
Raw fish . . .	6.1	.1	Mar.	14.28	3.17	4.37	78.18	0.93	100	+
Press cake . .			1967	25.23	4.98	8.02	61.77	1.32	70	—
Fish meal . .				59.43	10.97	19.76	10.00	3.05	66	—
Raw fish . . .	8.3	.8	June	15.55	2.86	5.28	76.31	0.80	100	+
Press cake . .			1967	26.30	3.36	10.76	59.58	0.61	40	—
Fish meal . .				61.29	5.58	23.39	10.00	1.53	37	—
Carp:										
Raw fish . . .	18.3	4.9	Aug.	17.50	9.64	4.76	68.81	1.50	100	+
Press cake . .			1966	21.32	4.70	8.64	65.54	0.96	32	—
Fish meal . .				59.32	10.62	19.42	10.00	1.65	22	—
Raw fish . . .	16.4	3.5	Nov.	20.50	8.95	4.55	65.91	2.48	100	+
Press cake . .			1966	24.53	4.27	7.89	62.40	3.60	72	—
Fish meal . .				60.65	10.91	17.52	10.00	5.46	44	—
Raw fish . . .	17	5	Jan.	16.46	6.81	3.64	72.05	3.06	100	+
Press cake . .			1967	23.66	6.35	6.54	60.62	3.00	48	—
Fish meal . .				57.89	15.99	15.79	10.00	7.38	48	—
Raw fish . . .	20.25	5.5	Feb.	18.46	7.89	4.72	68.93	2.52	100	+
Press cake . .			1967	28.20	7.69	7.99	56.12	2.25	45	—
Fish meal . .				58.22	15.02	16.86	10.00	7.37	43	—
Raw fish . . .	22	5	Apr. 1967	18.47	4.13	5.55	71.85	--	—	+
Raw fish . . .	18	8	June	15.40	7.91	4.09	72.60	1.10	100	+
Press cake . .			1967	20.20	6.94	10.78	62.08	.90	41	—
Fish meal . .				55.97	9.29	24.95	10.00	2.02	37	—
Freshwater drum:										
Raw fish . . .	13	1.4	Aug.	15.57	7.29	5.57	71.51	2.11	100	—
Press cake . .			1966	25.76	4.22	10.64	58.69	0.97	28	—
Fish meal . .				56.78	6.45	25.68	10.00	1.50	15	—
Raw fish . . .	19	1.9	Nov.	16.74	10.72	4.18	69.10	3.60	100	—
Press cake . .			1966	24.22	5.59	8.58	61.62	0.90	15	—
Fish meal . .				57.68	13.12	18.64	10.00	2.05	11	—
Raw fish . . .	9	12	Mar.	15.24	1.95	5.36	77.45	1.26	100	—
Press cake . .			1967	23.83	3.26	14.54	58.37	1.29	60	—
Fish meal . .				54.23	5.70	30.29	10.00	1.89	30	—
Raw fish . . .	8	1.75	Apr.	14.63	2.14	5.78	77.45	1.22	100	—
Press cake . .			1967	25.67	2.90	15.89	55.54	1.70	84	—
Fish meal . .				52.28	5.65	32.29	10.00	3.50	57	—
Raw fish . . .	9.5	3.25	June	14.21	9.11	5.41	71.27	1.74	100	—
Press cake . .			1967	20.60	8.74	8.20	62.46	1.30	45	—
Fish meal . .				52.98	15.91	21.35	10.00	3.54	41	—

[1] The average length and weight were calculated for whole fish from 100-pound batches.
[2] The percent of the original concentration of pesticide is accurate to ±5 percent.

Most of the values shown were directly dependent on pressing efficiency and on the physical consistency of the cooked material. Cooked carp was difficult to press, inasmuch as this material slipped in the screw press. This unfavorable pressing characteristic was probably due to a high content of eggs in most of the carp used. The percentage of water plus oil for all samples of press cake appears to be directly influenced by the percentage of oil in the raw fishes.

3. Fish Meal

The proximate composition of all the meals is reported on the basis of 10 percent of water. Where the actual concentration of water in a meal was less than 10 percent, the data were adjusted to the 10-percent basis to facilitate the comparison of data.

The percentage of oil in freshwater drum and shad meal varied directly with the percentage oil in the raw fish and ranged from 5.58 to 15.91. Oddly, most of the oil values for carp meal varied inversely with the oil values for the raw fish. This inverse relation is believed to be due to pressing difficulties caused by a high content of eggs when the percentage of oil was low. One lot of carp (dated April 6, 1967), which was lowest in oil content but highest in egg content, would not compress; hence, no data are given for its corresponding press cake and meal.

The percentage of ash in all the meals varied from 16.8 to 32.29 and appears to be inversely related to the percentage of oil in the meal. In the carp and shad meals, the ash varied from 16.80 to 26.95. The percentage of ash was highest in the freshwater drum meal (18.64 to 32.29) probably because of the characteristic large bony structure in these fish.

II. ANALYSES OF THE EXTRACTED FISH OIL

Reported here are the analyses of (A) the gross properties of the oil as revealed by the iodine value, saponification value, and color of the oil, and (B) the fatty acid composition of the oil.

Table 2.—Gross properties of oils from the press liquor of carp, freshwater drum, and shad

Species	Wijs iodine value	Saponification value	Gardner color value
Carp	121	189	11 to 13
Freshwater drum .	123	190	6 to 10
Shad	125	192	10 to 12

A. GROSS PROPERTIES

1. Materials and Methods

The oil samples, which were decanted from the press water (fish caught in November 1966) as was described in Section I, were analyzed for iodine value (Wijs) and saponification value by the official methods of the American Oil Chemists Society (Mehlenbacher, Hopper, and Sallee, 1955). Color values were obtained by means of a Gardner color comparator.

2. Results

The gross properties of the oil were closely similar for the three species. The iodine values found for the rendered carp, freshwater drum, and shad oil ranged from 121 to 123, and the saponification values ranged from 189 to 192 (Table 2). All the oils were light in color and ranged from 6 to 13 Gardner.

B. FATTY ACID COMPOSITION

1. Materials and Methods

Oils obtained from the various fishes as was described in the preceding section were saponified and converted to the methyl esters of the constituent fatty acids for subsequent gas-liquid chromatography.

The methyl esters were prepared by a semimicro methanolysis adapted to the method of Metcalfe, Schmitz, and Perla (1966). The methyl esters were analyzed with a Perkin-Elmer 810 gas chromatograph[1] equipped with a dual flame ionization detector. The columns used were each composed of stainless-steel tubing 0.210 inch in inside diameter and 8 feet in length. The column contained 4.0 percent (by weight) of diethylene glycol succinate polyester supported on 80-mesh to 100-mesh

[1] The use of trade names is merely to simplify descriptions; no endorsement is implied.

chromosorb G. The following operating conditions were used: flesh heat temperature 280° C., column temperature 170° C., detector temperature 200° C., and 50 milliliters per minute nitrogen carrier gas flow.

The gas-liquid chromatographic peaks of the samples were identified by comparison with standard peaks obtained from pure methyl esters. Equivalent chain-length values were determined according to the method of Miwa (1963) and were compared with values reported by Hofstetter, Sen, and Holman (1965) for identifying peaks for which no pure methyl ester was available. The area of each chromatographic peak representing a fatty acid present was obtained by multiplying the height of each peak by the width at half-weight. The area of each peak was then related to the total peak area to obtain the percentage of each specific fatty acid.

The analyses were performed in duplicate from fish caught in November 1967. The large components (Table 3) are estimated to be accurate to about ±6 percent; the medium-size components, to ±10 percent; and the small components, to ±60 percent. The data are reported to two places simply to reveal the relative amounts of the small components.

Table 3.—Comparison of the total fatty acid distribution in oils from press liquor of carp, freshwater drum, and shad

Fatty acids	Fatty acid distribution in oil from:		
	Carp	Freshwater drum	Shad
Ratio C atoms to double bonds	*Weight percent*	*Weight percent*	*Weight percent*
Saturated acids			
12:0	0.11	0.13	0.20
14:0	2.84	2.70	3.93
15:0[1]	0.78	1.96	2.66
16:0	18.08	19.53	22.10
17:0	0.79	1.15	1.74
18:0	2.06	2.32	3.41
19:0[2]	0.42	Trace	0.50
20:0	0.26	Trace	Trace
Monoenoic acids			
15:1	0.30	0.46	--
16:1	25.54	26.42	10.32
17:1[3]	1.26	2.95	1.81
18:1	34.31	27.97	32.32
19:1 ?	0.42	0.51	--
20:1	1.45	1.65	1.31
22:1	0.21	Trace	Trace
Dienoic acids			
18:2	1.62	3.32	4.12
20:2 ?	0.29	0.32	1.01
Trienoic acids			
16:3ω4 ?	0.27	0.41	0.53
18:3	1.04	0.90	5.41
20:3	0.22	0.16	0.37
22:3	0.28	0.37	0.58
Tetraenoic acids			
18:4	0.56	0.56	0.83
20:4ω3	1.14	1.45	1.75
20:4ω6	0.32	0.32	0.62
22:4	0.20	0.23	0.72
Pentaenoic acid			
21:5ω2 ?	0.21	0.13	--
20:5	3.38	2.08	1.98
22:5	0.59	0.93	0.84
Hexaenoic acid			
22:6	1.04	0.99	1.65

[1] Includes iso 15:0.
[2] Combined pair of 19:0 and 16:4ω1.
[3] Combined pair of 17:1 and 16:2.

2. Results

The percentage of total saturated fatty acids ranged between 25 and 35 for all the oils (Table 3). Fatty acid 16:0 was the dominating saturated fatty acid accounting for 18 to 22 percent of the total fatty acid distribution. The distribution of saturated fatty acids is similar in carp and freshwater drum; shad oil, however, contained about 3 percent more fatty acid 16:0 and 2 percent more fatty acid 14:0.

Fatty acids 16:1 and 18:1 dominate the monoenoic distribution, which accounts for 46 to 64 percent of the total fatty acid distribution. Fatty acid 18:1 was found to be the major acid in carp with 34 percent, freshwater drum with 28 percent, and shad with 32 percent. Shad contained only 10 percent of fatty acid 16:1 as compared with 26 percent in carp and freshwater drum.

The polyunsaturated fatty acid distribution for oil of carp and freshwater drum is similar and accounts for about 12 percent of the total fatty acid distribution. Shad oil, however, contained about 20 percent polyunsaturates. This difference was mainly due to more dienoic acids 18:2 and 20:2 and trienoic acid 18:3.

Values shown in Table 3 are similar to values found by Ackman (1967) in four North American fresh-water fishes, except that Ackman found slightly higher values for pentaenoic acid 20:5 and hexaenoic acid 22:6.

III. THIAMINASE ACTIVITY IN THE PRODUCTS

The enzymatic activity of thiaminase was determined chemically by use of the method described by Gnaedinger (1965) in which thiamine is oxidized to thiochrome, a fluorescent compound.

All raw samples except those of freshwater drum showed thiaminase activity; however, all resulting rendered products were determined to be thiaminase inactive. [Fortunately, thiaminase is readily inactivated by heat (Gnaedinger and Krzeczkowski, 1966)].

IV. SEASONAL VARIATION IN THE CONCENTRATION OF PESTICIDES

A. METHODS AND MATERIALS

DDT (Dichlorodiphenyltrichloroethane) and DDE (the minus-HCL derivative of DDT) were determined by a rapid procedure developed at the Bureau of Commercial Fisheries Technological Laboratory, Ann Arbor, Michigan, which has proved convenient where a large number of samples are analyzed. Briefly, the procedure consists of:

a. Saponifying the sample with KOH.

b. Extracting the saponified material with hexane.

c. Analyzing the hexane extract by gas-liquid chromatography.

An Aerograph gas chromatograph equipped with a 9-foot glass column having an inside diameter of 3.5 millimeters was used. The front 60 percent of the column was packed with 5 percent QF-1 on Gas-chrom Q 100 to 120 mesh; the rear 40 percent was packed with 5 percent DC-11 on Gas-chrom Q 100 to 120 mesh. With this instrumental setup and procedure, p,p'-DDE and p,p'-DDT came off as one peak.

B. RESULTS

The analysis of DDT and DDE indicates a possible seasonal variation in whole raw carp and freshwater drum (Table 1). The concentration of the pesticides in carp ranged from 1.10 to 1.50 parts per million in the summer and from 2.48 to 3.06 parts per million during the rest of the year. The June and August samples shown are 1 year apart, indicating that the pesticide concentration gained in the fall and winter, but decreased in the summer.

The concentration of pesticides in freshwater drum appears lowest in the spring with 1.2 to 1.26 parts per million. August and June samples, which are 1 year apart, show higher values of 1.74 to 2.11 parts per million. The November sample has a high reading of 3.6 parts per million indicating that pesticide values in freshwater drum were highest in the fall and lowest in the spring.

Shad samples do not show a strong seasonal association. All values were between 0.80 and 1.04 parts per million except the August sample, which had a low of 0.35 parts per million.

Although the concentration of pesticide increased in the press cake and the fish meal, the amount of pesticide decreased greatly. Table 1 shows that 15 to 84 percent of the original amount of pesticide remained in the press cake and that 11 to 66 percent remained in the fish meal. Only the percentages for the shad collected in August rose above this range.

The pesticide appears to be associated with fish oil; thus, the reduction in the amount of pesticide in the press cake and the fish meal was directly related to the amount of oil rendered out of the raw fish.

V. RELATIVE NUTRITIONAL QUALITY FOR BROILERS

The fifth specific purpose of the work reported here was to provide a quantity of carp and shad fish meal to the University of Tennessee for broiler-feeding trials. Freshwater drum was not included because of limited facilities. The purpose of these feeding trials was to determine whether the fresh-water fish meals differ significantly in nutritional value from that of menhaden meal when included in broiler rations. Menhaden meal, which is of marine origin, is the fish meal produced in largest quantity in the United States and is used extensively in rations for broilers.

For the broiler-feeding study by the University of Tennessee, 945 pounds of carp and 921 pounds of shad were taken from the Tennessee River in January 1967 and were rendered in the Bureau of Commercial Fisheries pilot plant at Ann Arbor into 156 pounds of shad fish meal and 213 pounds of carp fish meal. The Bureau of Commercial Fisheries Technological Laboratory at College Park, Maryland, provided the University of Tennessee with 400 pounds of menhaden fish meal, which was used as the control meal.

Table 4 shows the proximate analyses of the meals prepared experimentally at Ann Arbor and the menhaden meal.

Table 4.—Proximate analyses of carp and shad prepared experimentally and menhaden meal prepared commercially

Fish meal	Protein	Oil	Ash	Water
	Percent	*Percent*	*Percent*	*Percent*
Carp	59.96	16.64	16.43	6.03
Shad	62.79	11.67	17.16	8.50
Menhaden	61.52	12.08	18.20	8.20

Bletner and Goan (1968) have reported on the results of the feeding trials. They concluded that the fish meals prepared from carp and shad were equal to menhaden fish meal for growth and feed efficiency.

SUMMARY AND CONCLUSIONS

As part of an effort to find a use for reservoir fish of little interest to sport fishermen and of low commercial value, the composition of carp, freshwater drum, and shad from Kentucky Lake on the Tennessee River was investigated.

In the raw fish, the percentage of protein ranged mostly from about 14 to 18. The data revealed no significant seasonal variation in the percentage of protein. The percentage of oil ranged from about 3 to 10. The percentage appeared to be seasonally dependent and tended to be lowest during the spring. The percentage of ash ranged from about 3 to 6. It tended to be low when the percentage of oil was high.

In the fish cake, the percentage of protein ranged mostly from about 20 to 26, the percentage of oil ranged from about 3 to 9, and the percentage of ash ranged from about 6 to 16. A high percentage either of oil or of eggs in the raw material reduced pressing efficiency.

The gross properties of the oil were closely similar for all three species. The iodine value ranged from 121 to 123, the saponificat value ranged from 189 to 192, and the were all light in color.

The percentage of saturated fatty acid the rendered oils ranged between 25 and 35, the percentage of the monoenoic acids 16:1 and 18:1 ranged between 42 and 59, and the percentage of the polyunsaturated acids was 11 to 20, with fatty acids 20:5 and 22:6 being lower than that usually found in fresh-water fishes and varying from about 3 to 4 percent. These oils are high in fatty acids 16:1 and 18:1 and should be of industrial value.

All samples of raw fish except those of freshwater drum showed thiaminase activity; however, all the rendered products were thiaminase inactive.

In the raw fish, the concentration of DDE and DDT ranged from about 1.1 to 3.1 parts per million for carp, from about 1.2 to 3.6 parts per million for freshwater drum, and from about 0.35 to 1.0 parts per million for shad.

The concentration of pesticides showed a seasonal change that varied somewhat from one species to another. Owing to the association of the pesticide with fish oil and to the greater relative removal of water than of oil from the press cake and fish meal, the concentration of pesticide increased in the press cake and fish meal, although the total amount of pesticide present was greatly reduced. The decrease in the total amount of pesticide in the press cake and fish meal was accounted for by the amount partitioned into the rendered oil.

The composition of commercially made fish meals vary considerably because of the variety of raw material used and the use of several different processing techniques. The composition of menhaden meals produced by Atlantic processors in 1960 is as follows: protein 53.6 to 66.5 percent, oil 3.7 to 13.7 percent, ash 14.7 to 27.0 percent, and moisture 5.2 to 15.4 percent. The composition of menhaden meals from Gulf of Mexico processors in 1960 shows yet a different range in analysis as follows: protein, 56.5 to 66.7 percent; oil, 9.0 to 15.2 percent; ash, 17.8 to 21.9 percent; and moisture, 6.1 to 8.7 percent.[2]

Five fish meals each of carp, freshwater drum, and shad were prepared in this study from samples harvested in the winter, spring, summer, and fall seasons. In these fish meals, the protein ranged from about 52 to 62 percent; oil, 6 to 16 percent; ash, 7 to 32 percent; and moisture, 5 to 10 percent. All these values are reasonably close to those of commercially produced menhaden meals. But the quality of protein, oil, and ash rather than the content determines the nutritive value. This quality is best determined in actual feeding studies.

Work at the University of Tennessee showed that, with broilers, carp meal and shad meal were each equal to menhaden meal for growth and feed efficiency.

The overall conclusions from the work is that the products from carp, freshwater drum, and shad are closely similar and that these species of fishes are nutritionally and physically suitable for the production of fish press cake, fish meal, and fish oil.

ACKNOWLEDGMENT

John Conder of the Tennessee Game and Fish Commission collected the samples, and Robert Reinert of the Bureau of Commercial Fisheries analyzed the samples for pesticides.

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MS. #2024

ECONOMIC STUDY OF THE SAN PEDRO WETFISH BOATS

by

William F. Perrin and Bruno G. Noetzel

ABSTRACT

The San Pedro wetfish fleet is shrinking in size and is not yielding good wages for fishermen or good returns to investors. A study was made to determine if improvement of the economic state of the antiquated fleet might be accomplished by the construction of new, efficient vessels, both for replacements and for expansion of the fleet to harvest underused stocks of jack mackerel and anchovies in the region of the California Current. The investigation yielded two conclusions: (1) the construction of new vessels--even if subsidized--is not economically feasible at present rates of catch and prices of fish and (2) the expansion of the fleet through acquisition of surplus vessels from other fisheries at relatively favorable cost is feasible, given sufficient demand for wetfish at present prices.

CONTENTS

Authors: William F. Perrin, *Fishery Biologist*, Bureau of Commercial Fisheries Fishery-Oceanography Center, P.O. Box 271, La Jolla, California 92037, and Bruno G. Noetzel, *Industry Economist*, Bureau of Commercial Fisheries Division of Economic Research, 7338 Baltimore Avenue, College Park, Maryland 20740.
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INTRODUCTION

San Pedro is the major seaport for Los Angeles, California. San Pedro wetfish[1] boats (Figure 1) fish currently for mackerel, bonito, anchovies, and tuna in local waters and land them in a fresh unfrozen condition. When Pacific sardines, used for canning and reduction purposes, were available, these boats harvested most of the production of this species. In recent years with changed resource and economic conditions, vessel operators in this fleet have been financially hard-pressed because of rising costs coupled with static fish prices. At the same time, large underused populations of mackerel and anchovies are reported to exist in the California Current region (Ahlstrom, 1968) within the range of the fleet. If these resources are to be harvested by U.S. fishermen, the wetfish fleet would seem to be the most feasible fleet to expand, either through recruitment of available vessels from other fisheries or through the construction of new vessels. Motivated by these considerations, the Bureau of Commercial Fisheries in 1968 began an investigation of the present financial condition of the fleet and the economics of the operations of wetfish boats. This report presents the results of the study. The introduction presents background material on the makeup, history, landings, and operations of the San Pedro fleet, states the precise aims of the study, and describes the data base used.

The San Pedro wetfish-boat fleet is part of the roundhaul fleet, which is made up of

[1] Wetfish are here defined to include jack mackerel *(Trachurus symmetricus)*, Pacific mackerel *(Scomber japonicus)*, Pacific sardine *(Sardinops caerulea)*, and bonito *(Sarda chiliensis)* for canning and also for the fresh-fish market; and northern anchovy *(Engraulis mordax)* for reduction.

Figure 1.–The *North Pacific*, a typical San Pedro wetfish boat.

four types of vessels: (1) tunaboats, (2) combination boats, (3) wetfish boats, and (4) miscellaneous small roundhaul boats.

(1) Tunaboats. Tunaboats are large, long-range purse seiners that vary in fish capacity from 100 to 800 short tons and that fish almost solely for tuna--yellowfin tuna (*Thunnus albacares*) and skipjack tuna (*Katsuwonus pelamis*) off Mexico, Central America, South America, and Africa; and bluefin tuna (*Thunnus thynnus*) and albacore tuna (*T. alalunga*) off California and Mexico. McNeely (1961) has described the purse-seining gear used and the methods of fishing. Green and Broadhead (1965) have described and analyzed the costs and earnings of tropical tunaboats.

(2) Combination boats. Combination boats are purse seiners that vary in fish capacity from 140 to 160 tons and are medium-range vessels that fish primarily for tuna off California and Mexico and for wetfish mostly off California, with tuna making up the major part of the catch. In 1967, eight combination boats were in the San Pedro fleet.

(3) Wetfish boats. Wetfish boats are relatively small purse seiners that vary in fish capacity from 25 to 160 tons and that are 40 to 86 feet long overall. They operate within 100 miles of San Pedro. Individual trips last from 1 to 10 days; the average trip is between 1 and 2 days. Scofield (1951) has described the vessels, gear, and fishing methods. Recent technological developments in the fleet, including the adoption of nylon nets and hydraulic net-hauling blocks, have paralleled those described by McNeely (1961) for the tunaboat fleet. These boats fish primarily for wetfish. A significant proportion of their catch, however, in terms of value is made up of bluefin tuna and albacore tuna (see the wetfish fleet landings below). The number of San Pedro wetfish boats decreased from 47 in 1958 to 25 in 1968 (Figure 2); the greatest reduction was in boats in the size range of 25 to 50 tons.

(4) Miscellaneous small roundhaul boats. Small roundhaul boats include very small purse seiners that vary in fish capacity from 5 to 25 tons and "lampara" boats that vary in fish capacity from 5 to 40 tons and that fish for wetfish, squid (*Loligo opalescens*), anchovies--for use as bait in sport fishing--and a wide variety of other species landed primarily for the fresh-fish markets.

Of these four types of vessels in the San Pedro roundhaul fleet, wetfish boats (Category 3 above) were the subject of this study.

Wetfish boats have had a history of coping with adversity. The decline of the California sardine fishery (Figure 3) left a sizable fleet of small purse seiners on the West Coast in need of profitable employment. Some turned to seining of salmon or tropical tunas, some converted to trawling, and many became the property of foreign fishing companies and left U.S. waters; but some boats, especially those at Monterey and San Pedro, expanded their activities on jack mackerel, Pacific mackerel,

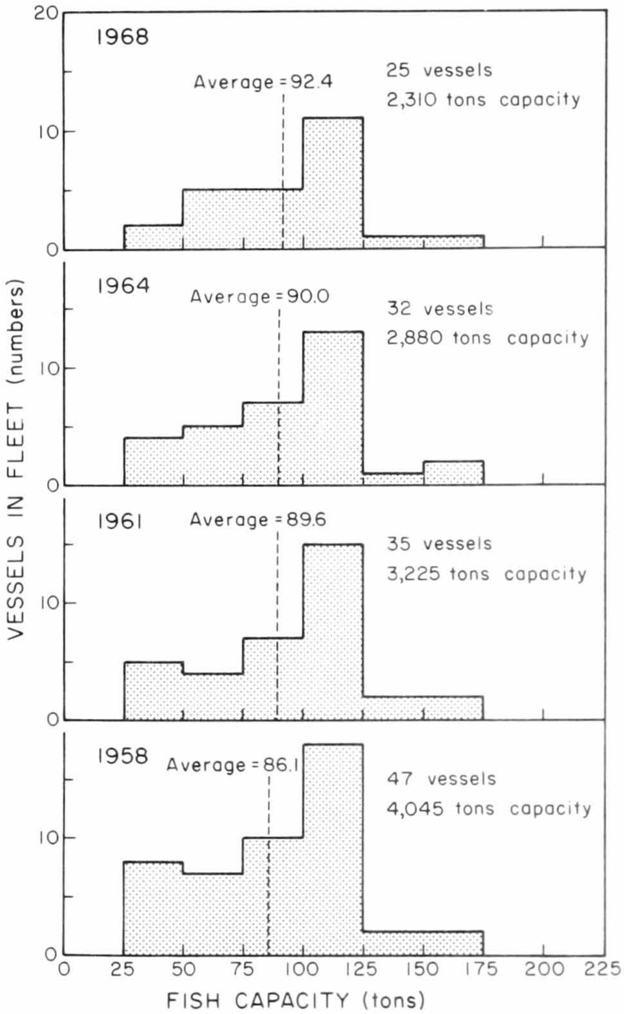

Figure 2.—San Pedro wetfish-boat fleet, 1958-68. (Fishermen's Cooperative Association of San Pedro furnished these data.)

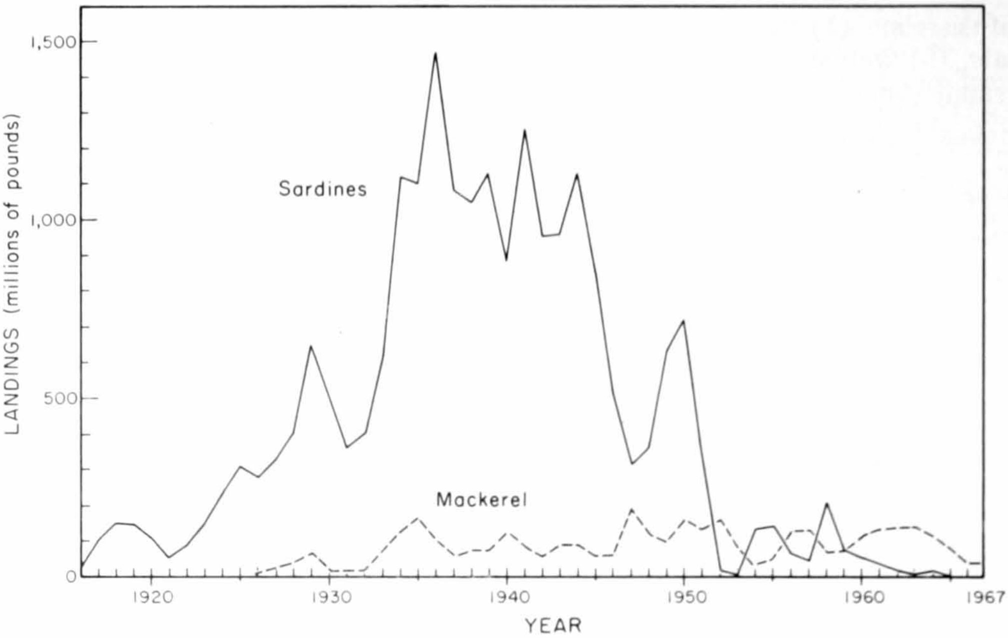

Figure 3.—Sardine and mackerel landings in California, 1916-67. The data are from the California Division of Fish and Game, Staff, Bureau of Marine Fisheries, 1949; California Department of Fish and Game, Staff, Marine Fisheries Branch, 1954, 1956; California Department of Fish and Game, Staff, Marine Resources Operation, 1958; California Department of Fish and Game, Biostatistical Section, Marine Resources Operation, 1960a, 1960b, 1961, 1963, 1964, 1965; Greenhood and Mackett, 1965, 1967; and Heimann and Frey, 1968a, 1968b.

albacore, bluefin and skipjack tuna, and bonito, which they had fished less intensively while sardines were abundant. The main emphasis was on mackerel (both species). They joined a declining fleet of various types of less efficient vessels already fishing primarily for Pacific mackerel (Croker, 1938; Roedel, 1952). When sardines in some years became temporarily more abundant, the vessels fished that species for short periods, so that landings of sardines and mackerel showed an inverse relation between 1952 and 1962 (Figure 3). Because landings of sardines have been negligible since 1962, the fleet has depended primarily on mackerel. Thus, the wetfish-boat fleet is essentially what is left of the sardine fleet. The newest boat in the fleet was built in 1947 (Table 1).

Table 1.—Year of construction of 24 boats that were in the San Pedro wetfish-boat fleet in 1968

Year of construction	Vessels
	Number
1935	4
1937	5
1939	3
1940	1
1944	8
1945	1
1946	1
1947	1
Total	24

Source: U.S. Bureau of Customs (1965) and information provided by the Fishermen's Cooperative Association of San Pedro.

Table 2 shows the landings of the wetfish boats at San Pedro during 1963 through 1967. It also shows the percentage of the total landings in California for each species making up the San Pedro wetfish-boat landings.[2] During this period, landings for the fleet closely paralleled the total landings for California (Figure 4). Because the species landed vary widely in exvessel price (Table 3), figures for landings alone do not illustrate the species base of the fleet in value terms. Figure 5 shows the make-up of the landings in terms of the percentage of total value accounted for by each species during 1963 to 1967.[3] The year-to-year varia-

[2] From unpublished data furnished by the California Department of Fish and Game.
[3] From unpublished landings data furnished by the California Department of Fish and Game and from price data gathered in the present study.

Table 2.—Landings of the San Pedro wetfish-boat fleet, 1963-67[1] (with percent of total California landings in parentheses[2])

Species	Landings in:				
	1963	1964	1965	1966	1967
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Jack mackerel	68,783,000 (72.1)	60,325,000 (69.6)	47,523,000 (71.1)	31,044,000 (76.0)	29,447,000 (77.1)
Pacific mackerel	29,595,000 (73.5)	21,539,000 (80.3)	4,566,000 (64.8)	2,612,000 (56.4)	632,000 (54.2)
Sardine	3,538,000 (49.6)	8,270,000 (63.0)	1,110,000 (57.6)	406,000 (46.2)	40,000 (26.8)
Bluefin tuna	3,295,000 (10.9)	2,938,000 (12.7)	2,220,000 (13.9)	1,727,000 (5.0)	1,585,000 (11.5)
Albacore tuna	375,000 (0.8)	21,000 (0.1)	694,000 (3.0)	87,000 (4.8)	1,000 (<0.1)
Bonito	2,606,000 (64.8)	1,674,000 (64.1)	4,019,000 (71.3)	13,412,000 (70.0)	12,314,000 (58.0)
Anchovy	1,000 (<0.1)	170,000 (3.4)	212,000 (3.7)	30,122,000 (48.4)	37,342,000 (53.6)
Other[3]	83,000	369,000	351,000	299,000	236,000
Total	108,966,000 (21.4)	95,602,000 (19.4)	62,062,000 (13.7)	80,523,000 (17.6)	81,777,000 (16.2)

[1] The data on landings of the San Pedro wetfish-boat fleet are from unpublished data furnished by the California Department of Fish and Game.
[2] The total California landings from which the percentages were calculated are from the California Department of Fish and Game, Biostatistical Section, Marine Resources Operations, 1965; Greenhood and Mackett, 1965, 1967; Heimann and Frey, 1968a, 1968b.
[3] The other species include: skipjack tuna, "bullet mackerel" *(Auxis thazard)*, Pacific pompano *(Peprilus simillimus)*, blacksmith *(Chromis punctipinnis)*, "smelt" (Atherinidae), halfmoon *(Medialuna californiensis)*, "perch" *(Embiotocidae)*, white croaker *(Genyonemus lineatus)*, white seabass *(Cynoscion nobilis)*, "shark," squid *(Loligo opalescens)*, and small quantities (less than 2,000 pounds) of several other species.

tions in the composition of the catch reflect the following changing conditions in the fishery:

1. The decreasing population of Pacific mackerel, due to overfishing (Ahlstrom, 1968).
2. Yearly fluctuations in the abundance of the migratory bluefin tuna and albacore, probably due to varying local oceanographic conditions within the range of the wetfish fleet.
3. Yearly fluctuations in the demand for bonito by the processors.
4. A legal moratorium on sardine fishing (as of 1967), following a drastic decline in abundance.
5. The legalization by the California State legislature of the taking of anchovies for reduction to fish meal (as of November 1965).

Although these data and observations indicate that the San Pedro wetfish industry is not in a strong position economically, they do

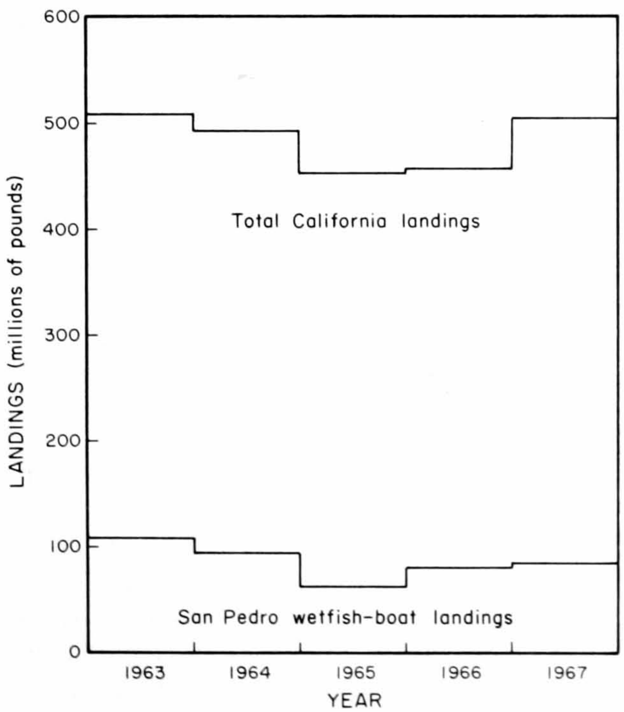

Figure 4.—San Pedro wetfish-boat landings and total California landings, 1963-67. The total-landing data are from the California Department of Fish and Game, Biostatistical Section, Marine Resources Operation, 1965; Greenhood and Mackett, 1965, 1967; Heimann and Frey, 1968a, 1968b. The wetfish-boat landings are from unpublished data furnished by the California Department of Fish and Game.

Table 3.–Average prices paid for fish taken by San Pedro wetfish boats, 1963-68

Species	Prices in:											
	1963		1964		1965		1966		1967		1968[1]	
	Cents per pound	*Dollars per short ton*	*Cents per pound*	*Dollars per short ton*	*Cents per pound*	*Dollars per short ton*	*Cents per pound*	*Dollars per short ton*	*Cents per pound*	*Dollars per short ton*	*Cents per pound*	*Dollars per short ton*
Mackerel (both spp.)[2]	2.103	42.06	2.294	45.88	2.713	54.26	3.430	68.60	3.625	72.50	3.771	65.42
Sardine[2]	3.307	66.14	3.261	65.22	3.234	64.68	18.649	[3]372.98	20.000	[3]400.00	--	--[4]
Bluefin tuna[2]	10.212	204.24	11.114	228.28	13.135	262.68	14.484	289.68	12.396	247.92	--	--[4]
Albacore tuna[2]	16.190	323.80	15.944	318.62	16.081	321.62	24.738	494.76	19.500	390.00	--	--[4]
Skipjack tuna[2]	9.976	199.52	--	--[5]	10.240	204.80	--	--[5]	--	--[5]	--	--[4]
Bonito[2]	2.870	57.40	2.629	52.58	2.780	55.60	4.067	81.34	4.146	82.92	4.248	84.96
Anchovy	1.698	[5]33.96	1.649	[6]32.66	1.723	[6]34.66	0.941	18.82	1.000	[2]20.00	--	--[4]
Average for all species	2.465		2.665		3.300		2.948		2.679		--	

[1] First quarter of 1968.
[2] Based on settlement data gathered in the present study (see section on data base, page 112).
[3] Sold mostly to fresh-fish markets.
[4] No fish were landed in the first quarter of 1968.
[5] Negligible quantities of skipjack were caught in these years by the wetfish fleet.
[6] Based on landings and value data; California Department of Fish and Game, Biostatistical Section, Marine Resources Operations, 1965; Greenwood and Mackett, 1965, 1967.

not supply sufficient information for a complete analysis. The purpose of the work reported here therefore was to gain a complete view by means of a detailed economic study. The main specific aims of this study were:

1. To determine the condition of the wetfish-boat fleet at San Pedro (as of March 1968) with respect to (a) productivity, revenue, and profits of the fleet, (b) capital structure and return on investment, (c) crew earnings, and (d) employment.

2. To present a model with which prospective wetfish-boat operators may predict costs and earnings under varying conditions of such factors as composition of the catch, characteristics of the vessel, value of the vessel, and size of the crew.

3. Then, using the model developed and examining other pertinent economic data, to determine the economic feasibility of constructing new wetfish boats and of expanding the fleet.

An understanding of the data in this report and of the discussion of the data requires an understanding of share-out procedures--that is, of the way in which the proceeds of the catch are divided between owner and crew. A discussion of these procedures therefore follows.

A share-out, or "settlement," is made by the boat owner when enough fish have been sold to more than cover expenses, usually once a month at the end of the "dark" (of the moon). Because the lunar month is 29½ days, sometimes more than one settlement occurs in a calendar month. A settlement usually is not made, however, when insufficient fish are caught to cover operating expenses during the lunar month. In this event, income and expenses are held over until the next or a later period. Occasionally, a settlement may be made even when expenses are not met, and negative "shares" are computed and deducted from the shares in the following settlement.

The settlement is computed on a "settlement sheet" having a standard format. Copies of the settlement sheet are retained by the boat owner and his accountant, and a copy is forwarded to the labor union representing the crew. Computing the settlement involves four steps as follows:

1. Operating costs or "trip expenses" are deducted from the gross revenue. By union agreement, only certain items of expense may be deducted from the gross. These deductible items include fuel; lubricating oil; salt; ice; foreign fishing licenses; explosives and rifle ammuni-

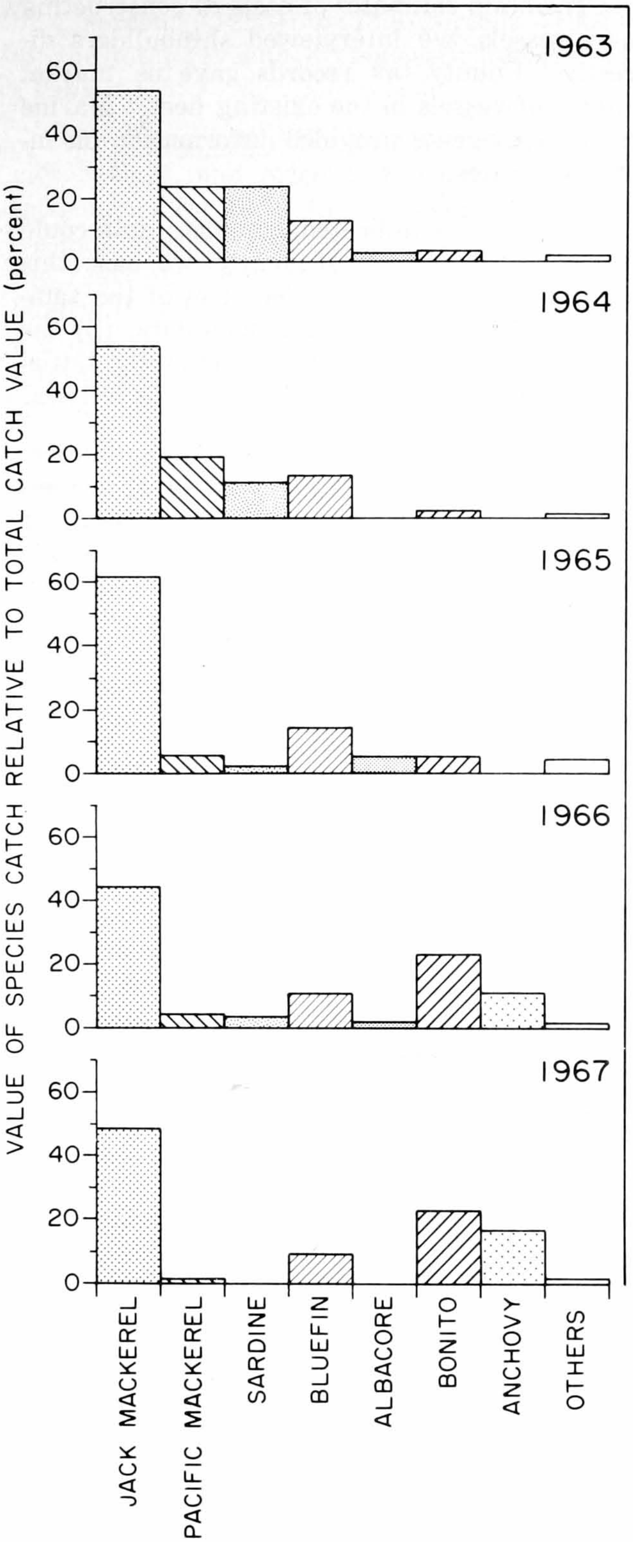

Figure 5.—Species makeup by value of catch of San Pedro wetfish-boat fleet, 1963-67. The figures are based on unpublished landings data furnished by the California Department of Fish and Game.

tion for control of seals and sharks; airplane spotting services; and contributions to the welfare fund, the pension fund, and the patrol agency.

The patrol agency is maintained by the union members. Its duties are to police the collective bargaining agreement and to check weights and payments.

Other expense items formerly deducted from the gross but not allowable under present agreements included: lobbying, attorneys' fees, donations, appliances, and rental and repairs of electronic equipment. Only the last item appeared frequently on settlement sheets included in the sample used in the present study.

The gross revenue as construed here excludes the value of rejected fish, overlimits (fish not authorized to be delivered to plants but delivered nevertheless), and fish transferred to other vessels, but it does include the value of fish transferred from other vessels.

2. The net proceeds (gross income minus trip expenses) are divided into the boat share and the gross crew share. The division is made according to a schedule established by agreement with the labor unions (Table 4). When refrigeration equipment is used, the vessel receives an additional 3 percent of the net proceeds.

Table 4.—Share-out schedule for San Pedro wetfish boats

Boat's hatch capacity	Boat's share	Crew's share	Members in crew including skipper
Tons	*Percent*	*Percent*	*Number*
1- 25	34¾	65¼	5- 6
26- 50	36½	63½	6- 7
51- 75	37½	62½	9-10
76-100	39	61	10-11
101-125	39½	60½	10-11
126-150	41½	58½	11-12
151 and up	42½	57½	11-12

Source: Fishermen's Cooperative Association of San Pedro.

3. The crew's gross share is split equally among the members of the crew, including any owners who serve as crew mem-

bers. If a crewman was not on the boat for the entire fishing period, his share is prorated accordingly. This prorating is done by making a "split"--that is, by computing separate settlements for the segments of the period in which the size of the crew was different. For example, if 10 men worked for 14 days and 11 men worked for an additional 12 days, a separate settlement is computed for 14 days with 10 shares and for 12 days with 11 shares. Fuel, welfare, pension, electronics, and most "other trip expenses" are prorated to the segments. Patrol and airplane spotting costs are deducted from the gross for the segment in which these costs occurred. Likewise, catch income belongs to the segment during which the fish were caught. For this report, we use the average size of crew to the nearest whole man during the month.

4. The cost of provisions and of galley supplies such as crockery and cooking utensils is split equally among the members of the crew and is deducted from their shares.

Data for this report were obtained primarily from records maintained by bookkeeping and accounting firms for the vessel owners. These records include: (1) copies of the settlement sheets together with copies of receipts for fish sold to wholesalers or processors during the period covered by each settlement and (2) balance sheets, profit-and-loss statements, tax forms, and other documents pertaining to the finances of the corporation or partnership operating the vessel.

Access was not gained to the company records of some vessels. For these vessels, we obtained settlement information from the copies of settlement sheets retained by the unions, but we could get neither catch nor corporation financial data.

Marine Resources Operations of the California Department of Fish and Game furnished data on total landings by the wetfish-boat fleet.

To obtain estimates of costs of constructing new vessels, we interviewed shipbuilders directly. County tax records gave us market values of vessels in the existing fleet. Marine insurance agents provided information on insurance rates.

As was just indicated, complete data could not be obtained. Consequently, we base this report on sample data. The sizes of the samples for (1) the annual financial data, (2) the costs and earnings data for monthly settlements, and (3) the catch data were as follows:

(1) Annual financial data. The sample included annual data on finances for 12 vessels from 1963 to 1965 inclusive, for 14 vessels for 1966, and for 15 vessels for 1967. These data represented about 44 percent of the total vessel years for the fleet during the period. The data were not strictly comparable on a time axis because the fiscal year used varied from company to company.

(2) Revenue and costs data for monthly settlements. We obtained access to monthly settlement sheets for 22 vessels. The sample included data on revenue, itemized trip expenses, and crew size from 940 settlements from January 1963 to March 1968, inclusive (Table 5). Three vessels entered the sample in 1965 and one in 1966; the other 18 vessels were covered for the entire period. Each vessel was not represented by a settlement for each month during the sample period, because of tieups due to repairs, modifications, and labor disputes and because catches in some months were too small to justify settlement. The settlements in the sample represent from

Table 5.—Sample size of revenue and costs data for monthly settlements, 1963-68

Year	Settlements in sample	Vessels in sample	Revenue in sample	Revenue relative to total revenue for fleet
	Number	*Number*	*Dollars*	*Percent*
1963	169	18	1,413,000	52.4
1964	163	18	1,394,000	54.7
1965	174	21	1,499,000	73.2
1966	194	22	1,796,000	75.6
1967	188	22	1,726,000	78.8
1968[1]	52	22	346,000	--

Note: The data on total revenue and estimates are based on unpublished landings data furnished by the California Department of Fish and Game and on price data from the present study.
[1] Data for only the first quarter of the year.

52.4 percent (1963) to 78.8 percent (1967) of the total revenue of the wetfish-boat fleet (Table 5).

(3) Catch data. We gathered data on species, weight, and price of the catch for 826 settlements for 18 of the 22 vessels for which we had obtained cost and revenue data. For the remaining four vessels, catch data correlated with settlements were not available. Table 6 shows the percentage in the sample of the total wetfish-boat fleet landings for each major species. Pacific mackerel and jack mackerel were combined into a single category, "mackerel," because many of the cannery receipts used as the sources of data in this study did not specify the species of mackerel. The sample is skewed toward tuna and away from sardines, anchovies, and bonito for most of the years. This bias for the higher priced species is also reflected in a comparison of the elements of the last column of Table 5 with those of the last row of Table 6. For example, the sample for 1963 includes 38.2 percent of the total fleet landings but it includes 52.4 percent of the value of the landings. This skewness must be taken into account when an empirical costs-prediction model is constructed on the basis of the present sample.

Table 6.—San Pedro wetfish-boat landings included in sample by species, 1963-67

Species	Landings included in the sample relative to the total wetfish landings in:				
	1963	1964	1965	1966	1967
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Mackerels	44.4	46.9	58.0	62.4	71.2
Sardine	20.2	42.9	22.3	10.0	5.5
Bluefin tuna	68.0	63.0	73.0	74.1	60.1
Albacore	67.1	--	57.3	71.4	--
Bonito	30.0	30.9	19.2	55.5	60.7
Anchovy	--	0.0	0.0	41.1	65.1
Average	38.2	38.9	38.3	52.4	54.8

Note: Where no data are given, the landings of the given species were negligible (see Table 7).

A portion of the catch in the sample for each year was classified as "other or unidentified (single price paid for a mixed catch, or itemized cannery receipt not available)." Table 7 shows the percentage of the value of the landings in the sample classified in this category for each year. We do not know the proportion of this value that should pertain to each species. We therefore were not provided with a basis for increasing the percentage by weight listed as included in the sample (Table 6). A decreasing percentage for sardines in Table 6, however, is almost certainly due in part to the fact that a greater percentage of the total landings of sardines in southern California are from mixed catches of mackerel and sardines (Greenhood, 1965). The composition of these mixed catches was estimated in the landings data furnished by the California Department of Fish and Game but not on the cannery receipts that were the sources of catch data for this study.

Table 7.—Relative value of landings classified as "other or unidentified," 1963-68

Sample year	Relative value of landings classified as "other or unidentified"
	Percent
1963	2.4
1964	10.1
1965	8.3
1966	4.0
1967	6.9
1968[1]	1.1

[1] First quarter.

I. FINANCIAL CONDITION OF THE FLEET

In our evaluation of the financial condition of the fleet, we consider the following factors: (A) productivity, revenue, and profits, (B) capital structure and return on investment, (C) crew earnings, and (D) employment.

A. PRODUCTIVITY, REVENUE, AND PROFITS

Productivity per vessel in terms of tons of fish landed showed no net gain from 1963 to 1967 (Table 8). Landings per vessel in 1967

Table 8.—Productivity of San Pedro wetfish-boat fleet, 1963-67

Year	Average landings per vessel	Average revenue per vessel	Total revenue of fleet
	Tons	*Dollars*	*Dollars*
1963	1,473	73,000	2,697,000
1964	1,366	73,000	2,549,000
1965	872	57,000	2,048,000
1966	1,184	70,000	2,375,000
1967	1,461	78,000	2,191,000

Note: These figures are based on unpublished data on landings furnished by the California Department of Fish and Game and on the price data in Table 3.

ranged from 535 to 2,570 tons (Figure 6). The average vessel revenue showed a net increase, but the total fleet revenue decreased owing to the decrease in the number of vessels. The vessel average annual revenue for the period ranged from $45,145 to $119,610 with the grand average being $77,557 (Figure 7).

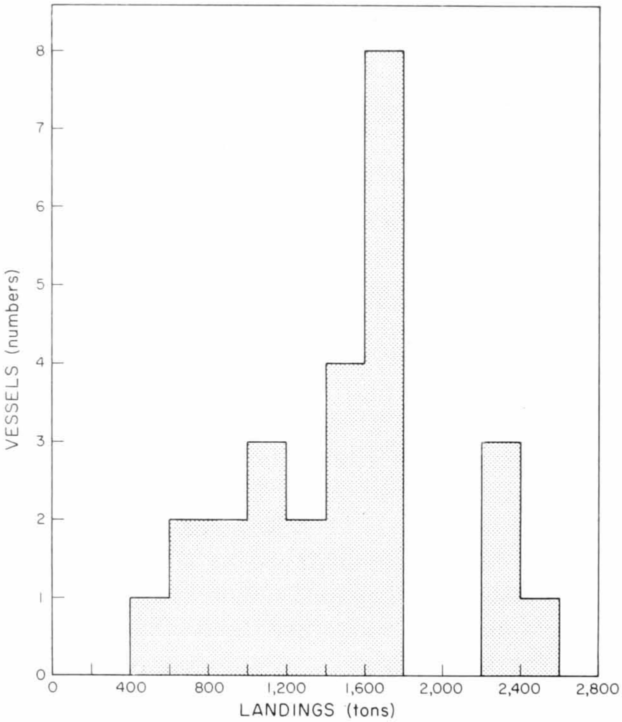

Figure 6.—Frequency distribution of total landings per vessel for 1967 by San Pedro wetfish boats. This graph is based on unpublished landings data furnished by the California Department of Fish and Game.

For this analysis, profits (or losses) shown in Profit and Loss Statements have been adjusted by adding salaries paid to officers of the corporations. Wages, commissions, and bonuses paid to these officers for serving as crew members are part of the corporation's operating costs (included in crew wages). Salaries in general were a form of draws on account of future profits, but in some situations part of these salaries might be considered as managerial cost. Since, from the records made available, it was not possible to separate these two types of payments, all salaries paid to officers were added to profits. With these adjustments, the average values of gross profit (before taxes) for the whole fleet ranged from $5,100 per vessel in 1963 to $10,726 in 1966 (Table 9A). Although some vessels showed losses as the end result of their operations, most closed each year with a profit. Of 65 vessel-years analyzed, 51 (or 78.5 percent) were profitable.

The two subgroups of vessels from Table 9A are further characterized by the range of profits or losses in each year and by the quartile values of profits. Table 9B shows the range of profits, as well as the range of losses. In general, the median values (Q_2 in Table 9C) are lower than are the mean values shown in Table 9A.

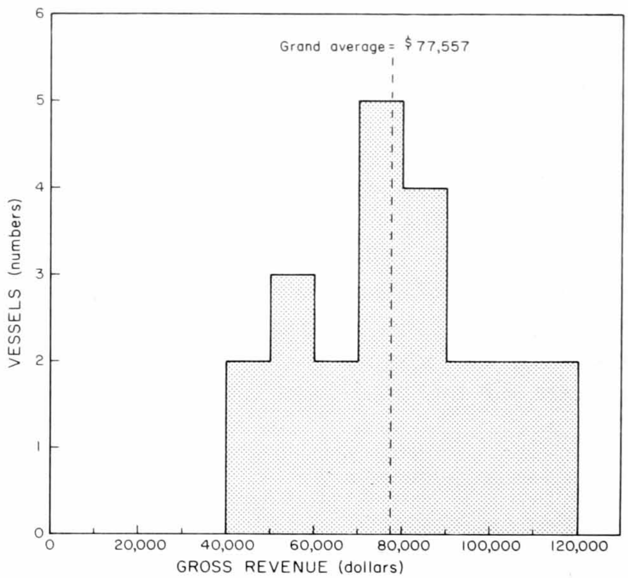

Figure 7.—Frequency distribution of average annual gross revenue per vessel from 1963 to 1967. The graph is based on settlement data. The averages for four vessels that entered the sample after 1963 were adjusted on the basis of the assumption that their efficiencies relative to the other vessels were the same before and while they were in the sample.

Table 9A.—Average values of gross revenue and profit (or loss) per vessel, 1963-67

Year	Data for: All vessels			Profitable vessels			Nonprofitable vessels		
	Vessels	Gross revenue	Profit before taxes	Vessels	Gross revenue	Profit before taxes	Vessels	Gross revenue	Profit before taxes
	Number	*Dollars*	*Dollars*	*Number*	*Dollars*	*Dollars*	*Number*	*Dollars*	*Dollars*
1963	12	77,770	5,100	9	84,893	7,706	3	56,400	—2,719
1964	12	76,072	7,600	11	77,710	8,504	1	58,058	—2,355
1965	12	76,847	5,660	10	82,671	7,191	2	47,726	—1,992
1966	14	98,105	10,726	12	103,950	13,329	2	63,034	—4,888
1967	15	78,110	5,104	9	91,113	10,577	6	58,604	—3,106

Note: These figures are based on data from profit and loss statements.

Table 9B.—Range of profits on profitable vessels and of losses on unprofitable vessels, 1963-67

Year	Range of profits	Range of losses
	Dollars	*Dollars*
1963	1,416 - 14,570	803 - 3,737
1964	1,453 - 27,568	(See note)
1965	2,291 - 17,641	1,072 - 2,912
1966	1,869 - 39,558	415 - 9,361
1967	1,366 - 33,741	210 - 6,524

Note: In 1964, only one vessel closed the year with a loss.

A regression of profit on gross revenue (Figure 8) shows that the breakeven point for a vessel in the fleet in 1967 was about $70,000 gross revenue. In that year, gross revenue ranged to over $150,000.

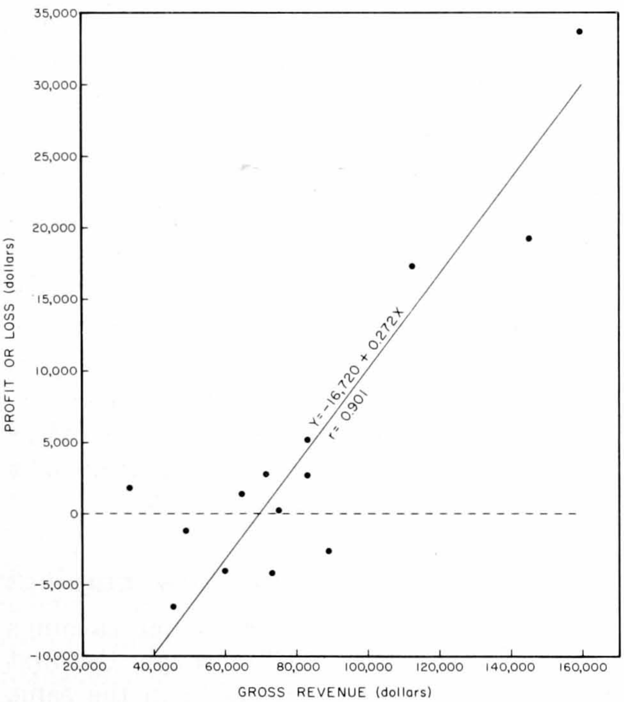

Figure 8.—Relation between profit or loss and gross revenue for 14 San Pedro wetfish boats in 1967. This plot is based on profit and loss statements.

Table 9C.—Quartile values of profits, 1963-67

Year	Profits in quartile: Q1	Q2	Q3
	Dollars	*Dollars*	*Dollars*
1963	6,256	7,067	10,551
1964	2,180	6,708	11,534
1965	2,712	4,894	12,310
1966	3,971	8,249	31,159
1967	2,281	5,248	18,341

B. CAPITAL STRUCTURE AND RETURN ON INVESTMENT

The 1967 balance sheets for 15 vessels showed total assets of $476,700 or $31,780 per vessel. The assets for individual vessels ranged from $4,679 to $63,844. On the average, 82.8 percent of the total assets were made up of fixed assets--that is, of the depreciated value of the vessels and equipment. Current assets (cash in the bank, accounts receivable, and other) formed the remaining 17.2 percent of the total assets.

The average market value of these vessels as estimated by the Office of Assessor, County of Los Angeles, was about $41,000--that is, it was about 1½ times the book value.

Table 10 shows the sources from which the total assets were financed.

This capital structure reflects rather unfavorable financial conditions in the fleet as a whole. The low amount of quick assets (which in this case is equivalent to current assets) relative to current liabilities, as indicated by a ratio of about 0.5:1, might be a reason for banks to refuse loans. Although a sizable part of total assets (27.4 percent) was financed by stockholders in the form of notes and loans, 51 percent of all notes and

Table 10.—Sources from which the total assets of all wetfish boats and nine of the stronger corporations were financed in 1967

Sources of financing	Amount relative to the total liabilities and capital			
	Assets of all wetfish boats		Assets of nine of the stronger corporations	
	Individual items	Sums	Individual items	Sums
	Percent	*Percent*	*Percent*	*Percent*
Accounts payable	14.32	--	12.06	--
Notes payable	8.25	--	9.38	--
Notes from stockholders	8.99	--	None	--
Total current liabilities	--	31.56	--	21.44
Mortgages and long-term loans	34.93	--	22.20	--
Loans from stockholders	18.40	--	11.36	--
Total long-term liabilities	--	53.33	--	33.56
Capital stock plus accumulated earnings	--	15.11	--	45.00
Total liabilities and capital = assets	--	100.00	--	100.00

long-term liabilities (that is, those over $171,000) came from canneries that receive fish landed by this fleet. This financial dependence on canneries probably puts the vessel owners in a disadvantageous position when they negotiate prices for fish.

The low level of equity capital for the whole group (average 15.1 percent) is effected mainly by six corporations, which show a deficit of $5,000 to $36,000 (average $13,500). Table 10 shows the capital structure for the remaining nine companies.

In this group of nine vessels, current liabilities exceeded current assets by about $2,500 per vessel, indicating a need for working capital. The average equity capital for a vessel in this group was $17,500, whereas fixed assets averaged $34,000 per vessel. The average profit of $8,300 per vessel indicates the following rates of return on investment:

47.4 percent — when related to equity capital,
24.3 percent — when related to fixed assets.

It should be pointed out that the high rate of return on equity capital (47.4 percent) is artificially inflated by abnormal financing practices for these vessels. We observed that a major part of profits is being drawn each year by the corporation's officers in the form of salaries or bonuses. This action leaves the corporations with low equity capital and with no working capital (see previous section).

For a group of five vessels with equity capital ranging from $18,355 to $37,970 the return on investment was 13.3 percent. The median value for this group, $28,162 is used below for predicting the return on investment for old vessels. An actual anticipated value for equity capital should be substituted by a prospective vessel operator.

C. CREW EARNINGS

We calculated the individual crew share for each settlement by dividing the crew share of net proceeds (gross revenue minus trip expenses) by the average number of crewmen (to the nearest whole man) on the vessel during the period covered by the settlement.

1. Fleet Average for 1963-67

The average crewman's earnings in the fleet for each year was calculated by multiplying the average individual crew share per settlement (above) by the average number of settlements per vessel during the year (Table 11). The average crew earnings did not increase during the period, and the real earnings (actual earnings adjusted by consumer price index) decreased 9.2 percent.

2. Vessel Variation in Crew Earnings

The average crewman's annual earnings for each vessel from 1963 through the first quarter of 1968 were calculated in the same manner described earlier and are presented in Table 12. In accordance with the wishes of the vessel owners, we do not identify the

Table 11.—Average crewman's earnings in San Pedro wetfish-boat fleet, 1963-68

Year	Average crewman's share per settlement	Average settlements per vessel	Average crewman's earnings per year[1]	Average crewman's real earnings for year[2]	Sample size	
					Settlements	Vessels
	Dollars	Number	Dollars	Dollars	Number	Number
1963	438	9.44	4.134	4,134	168	18
1964	440	9.11	4.008	3,953	159	18
1965	445	8.22	3,658	3,551	171	21
1966	493	8.90	4,388	4,140	191	22
1967	480	8.52	4,090	3,752	177	22
1968[3]	324	2.36	--	--	50	22

Note: The fishing season extends over the full calendar year, with an average of about 17 fishing days per month.
[1] The average crewman's earnings per year includes nontaxable provisions, which averaged $585 per crewman in 1967.
[2] The average crewman's real earnings for the year were adjusted to the 1963 level with consumer price index (Long, 1969).
[3] First quarter.

Table 12.—Average crewman's earnings for San Pedro wetfish boats, 1963-67 and 1968 (1st quarter)

Vessel Number	Average crewman's share per settlement	Average settlements per year	Average crewman's earnings for year
	Dollars	Number	Dollars
1	353	6.29	2,219
2	358	6.67	2,387
3	292	9.53	2,781
4	322	10.48	3,374
5	352	9.67	3,402
6	366	9.53	3,486
7	414	8.57	3,549
8	400	8.95	3,582
9	359	10.29	3,692
10	420	8.95	3,761
11	392	9.72	3,809
12	467	8.57	4,004
13	472	8.57	4,047
14	467	8.76	4,171
15	457	9.14	4,179
16	537	8.57	4,601
17	486	9.91	4,814
18	534	9.53	5,086
19	582	8.95	5,211
20	580	10.27	5,957
21	735	8.95	6,581
22	591	11.36	6,716
Grand average	453	9.15	4,164

Note: These figures are based on settlement data. For vessels entering the sample after 1963, the crewman's earnings for the year were adjusted to the 1963 level with the consumer price index (Long, 1969).

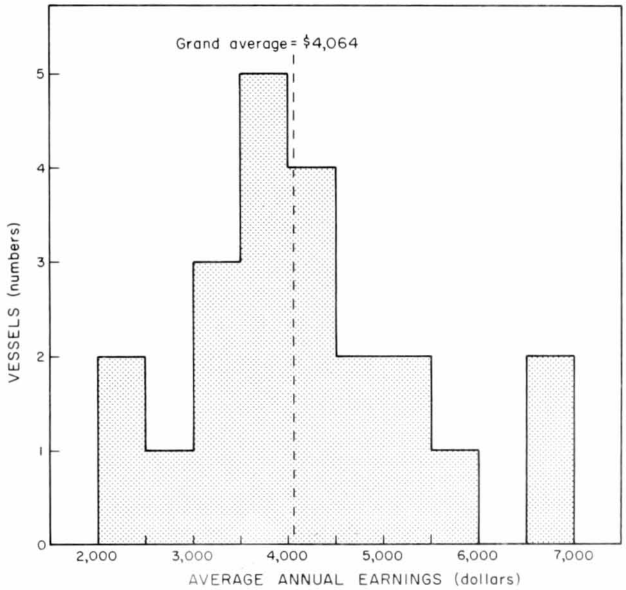

Figure 9.—Frequency distribution of crewman's average annual earnings 1963-67. The graph is based on settlement data.

estimates by vessel. Figure 9 presents the frequency distribution of the estimates in $500 intervals. The variation in crew earnings has two major components--namely, (1) the variation in the crewman's share per settlement and (2) the variation in the number of settlements per year. The latter variation is not amenable to analysis, because it is determined by (1) different response to labor disputes by management, (2) different tieup periods for gear and vessel modification and repairs, and (3) different fishing success. The factors affecting crewman's share per settlement, the other source of variation, are examined later in the section on predicting earnings.

D. EMPLOYMENT

The size of crew on the vessels (Table 13) as well as the number of vessels in the fleet

Table 13.—Average size of crew in the San Pedro wetfish-boat fleet, 1963-68

Year	Men in crew
	Number
1963	10.29
1964	10.28
1965	9.94
1966	9.65
1967	9.74
1968[1]	9.52

Note: These figures are based on settlement data.
[1] First quarter.

decreased during 1963 to 1967. The combined effect of these two factors was a 30-percent decrease in the number of full-time jobs (Figure 10) from about 381 jobs in 1963 to 238 in 1968. These estimated totals do not include employment in other phases of the wetfish industry, such as processing, maintenance of vessels, and supply.

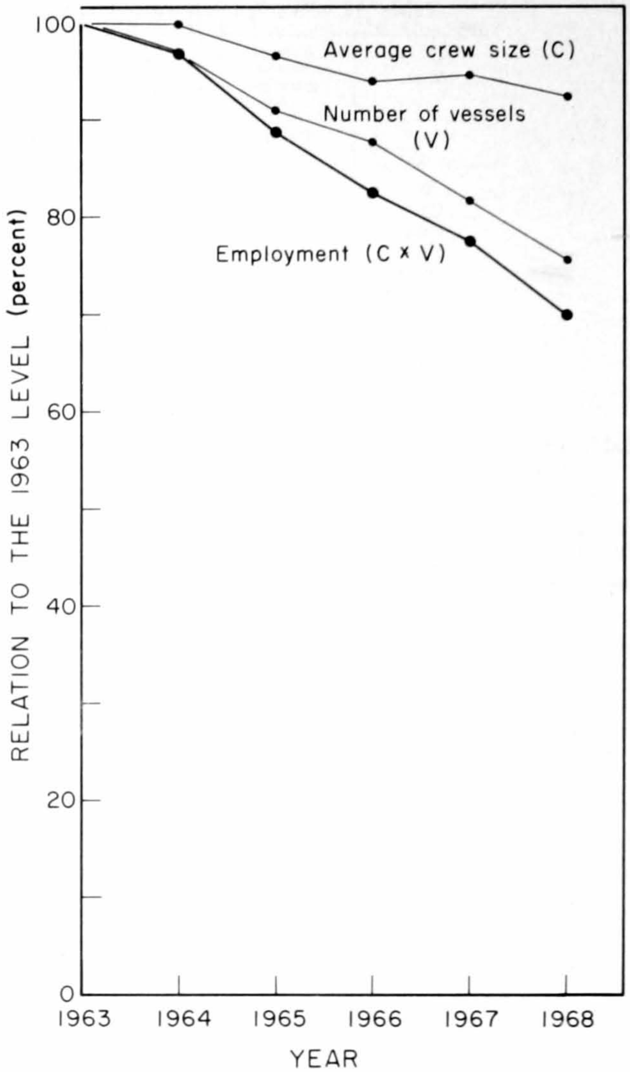

Figure 10.—Combined effect of decreasing size of fleet and decreasing size of crew on employment in the San Pedro wetfish-boat fleet, 1963-68. This graph is based on Figure 2 and Table 12.

II. COSTS AND EARNINGS MODEL

Having examined the financial condition of the fleet, we turn now to the costs and earnings model. We first analyze costs and then predict earnings.

A. ANALYSIS OF COSTS

Average total costs per vessel (operating costs or "trip expense" and owner's costs; crew's share not deducted) reached a high in 1966 (Table 14) and then decreased in 1967. The ratio of costs to value (total costs divided by the value of the catch) increased to a high in 1965 and then decreased (coincidentally with the advent of the anchovy fishery) to below the 1963 level.

Table 14.—Average total costs per vessel (operating costs + owner's costs exclusive of the payments to the crew on "crew's share") for San Pedro wetfish boats, 1963-67

Year	Total costs	Ratio of cost to value of catch
	Dollars	
1963	31,547	0.432
1964	31,549	.432
1965	31,022	.544
1966	37,394	.534
1967	32,882	.422

Note: These figures are based on settlement data and annual financial data.

Operating costs and owner's costs are discussed separately in the following section, and a submodel is developed for each cost category.

1. Operating Costs

The owner and the crew share operating costs or "trip expenses" (described in section on share-out procedures above). Two major items of costs are fuel and airplane spotting services. The price of diesel fuel in 1968 was 14.5 cents per gallon. When airplane spotting is used, 5 percent of the value of the catch goes to the spotter. Welfare and other fund contributions are calculated as a percentage of gross revenue or as a charge per ton of fish landed. Other costs are related to the time spent at sea and to the size of the main engine, and still others include expenses trat are incurred sporadically and that have no relation either to the time spent at sea or to the proceeds from fishing.

Average operating costs per vessel remained almost constant during 1963 to 1967 (Table 15). Costs per pound of fish landed increased to a high in 1965 and then decreased when anchovies entered the landings.

Table 15.—Average operating costs per vessel and per pound of fish landed by the San Pedro wetfish-boat fleet, 1963-67

Year	Operating costs	
	Dollars per vessel	*Cents per pound of fish landed*
1963	10,317	0.363
1964	10,597	.378
1965	9,990	.499
1966	10,341	.412
1967	10,027	.396

Note: These figures are based on settlement data.

The multispecies makeup of the catch of the San Pedro wetfish fleet demands that operating costs be examined for varying compositions of catch. This requirement becomes even more important when we recognize that a future expanded wetfish fleet will perhaps have to depend more on low-priced fish--that is, on anchovies--and less on high-priced fish--that is, on tuna--than does the present fleet. Because two or more species are usually landed by each vessel during any given settlement period, operating costs could not be related directly to species. A multiple regression analysis based on monthly settlement data for 1967, however, indicated that a significant linear correlation exists between the amount of operating expenses (dependent variable) and landings of mackerel, tuna, bonito, and anchovies (independent variables). The regression is of the form:

$$\hat{Y} = 914 + 0.00103X_1 + 0.00519X_2 + 0.00399X_3 + 0.00038X_4$$

where $\hat{Y}$ = operating costs, in dollars

X_1 = pounds of mackerel (jack and Pacific) landed

X_2 = pounds of tuna (bluefin, albacore, and skipjack) landed

X_3 = pounds of bonito landed

X_4 = pounds of anchovies landed

(t_b, in order, = 4.63, 3.33, 11.91, 3.78; $p<0.001$, R_2 = 0.75)

The differences in operating-costs coefficients between species reflect species differences in schooling behavior and in geographical distribution. Tuna are caught a few tons at a time, but a vessel may be loaded with anchovies in two sets of the net. Although jack mackerel are often caught as far as 50 to 100 miles from port, anchovies are usually caught within 10 miles of port.

A statistically significant and positive relation was found between operating costs and the horsepower of the main engine (in the range of 150 to 335 horsepower), but the maximum effect on predicted costs at $150,000 gross revenue for the present fleet was only $132; consequently, the variable was dropped from the equation. Capacity of the vessel was found to be of low significance (t_b = 1.67), therefore that variable was also dropped from the regression.

Figure 11 shows the fit of predicted annual operating costs to actual operating costs for 15 vessels in 1967. To obtain the annual estimates, we multiplied the Y-intercept of the regression equation times the number of settlements made during 1967 and multiplied the coefficients times the landings of the four species.[4]

[4] California Department of Fish and Game furnished the landings data.

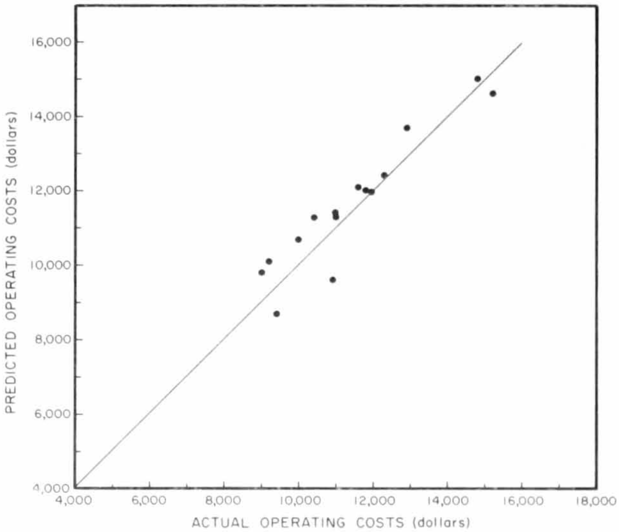

Figure 11.—Fit of operating costs model to actual operating costs. The curve is a 45° line (slope = 1, correlation coefficient = 1) along which the points would lie if the model were a perfect fit.

Using the prices of fish in 1967, we can rewrite the operating costs relation in terms of cost per dollar's worth of fish landed annually:

$$\hat{Y} = 8{,}052 + 0.0275X_1 + 0.0419X_2 + 0.0939X_3 + 0.0380X_4 \qquad \text{(Equation 1)}$$

where $\hat{Y}$ = predicted annual operating costs, in dollars

X_1 = value of mackerel landings, in dollars

X_2 = value of tuna landings, in dollars

X_3 = value of bonito landings, in dollars

X_4 = value of anchovy landings, in dollars

We obtained the value $8,052 by multiplying the Y-intercept for the monthly operations cost regression times 8.81, the average number of settlements per year for the fleet during 1963 to 1967. If no strikes, layups for repairs, or very slack fishing months are anticipated, the value $10,968 (12 months multiplied by $914 per month, the Y-intercept for the monthly operating costs regression) should be used as the constant. According to this relation, the maximum predicted effect of species composition of landings on annual operating costs at a gross-revenue level of $150,000 (arbitrarily chosen) is the difference between the predicted cost for an all-mackerel catch and that for an all-bonito catch, or $9,960.

2. Owner Costs

Owner costs are those deducted from the owner's share of the net proceeds and are categorized here under (a) parts and repairs, (b) netting and supplies, (c) insurance, (d) payroll taxes, (e) interest on loan, (f) moorage, (g) State and county taxes, (h) depreciation, and (i) a miscellaneous category "office expenses and other costs."

Table 16 presents average values for these costs for the fleet for each year from 1963 to 1967. The purchases of new engines and anchovy nets for many of the vessels in 1966 account for the high values for that year. As a measure of dispersion, we include the coefficient of variation. Methods of estimating owner costs are outlined below. Where appropriate, we use different means of estimation for predicting costs for existing vessels of the type now in the fleet and for hypothetical newly constructed vessels.

Table 16.—Average annual owner's costs per vessel, 1963-67

Source of cost	Costs in:						Coefficient of variation
	1963	1964	1965	1966	1967	1963-67 average	
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Percent*
Parts and repairs	4,664	5,118	4,167	5,398	4,891	4,855	45.6
Netting and supplies	3,158	2,007	2,720	3,842	2,456	2,847	63.1
Insurance	4,472	4,261	4,827	4,971	4,692	4,645	24.8
Payroll taxes	2,954	2,923	2,996	4,329	3,246	3,270	29.7
Interest on loan	463	251	436	790	420	504	121.6
Moorage	513	438	464	431	438	465	30.5
State and county taxes	773	666	607	614	750	688	41.0
Depreciation	2,614	3,004	3,075	4,496	4,410	3,604	61.3
Office expenses and other costs	1,619	2,284	1,740	2,182	1,552	1,873	47.6
Total	21,230	20,952	21,032	27,053	22,855	22,751	19.4

Note: These data were derived from statements of profit and loss.

a. Parts and repairs.—Included in parts and repairs are expenditures for repairs and maintenance, including parts, of the vessel, the seine skiff, and the gear exclusive of the net. The crew furnishes labor for repairs to the net, and the cost of webbing is included under "Netting and Supplies."

(1) Existing vessels.—The vessels are put into drydock once a year on a regular basis for maintenance and insurance inspection. No relation was found between size of vessel, or capacity, and cost of repairs. The great variation in cost of repairs for vessels of similar size is explainable by two factors pointed out by Green and Broadhead (1965) in their study of costs and earnings of tuna seiners. Some owners, especially those of vessels that do relatively poorly on the fishing grounds, habitually postpone upkeep and renovation, and they make only those repairs that are absolutely needed to keep the vessel in operation. Also, some owners with mechanical skills may take care of many of the repairs themselves and may thereby save on labor costs.

A significant relation was found between owner's share in net proceeds and repair costs, perhaps a reflection of the factors mentioned above. The estimating equation is of the form:

$$\hat{Y} = 24 + 0.0787X_2 + 0.0552X_3 \quad \text{(Equation 2)}$$

where $\hat{Y}$ = the costs of repairs in Year t, in dollars

X_2 = the owner's share in the net proceeds in Year t, in dollars

X_3 = the owner's share in the net proceeds in Year (t − 1), in dollars

(t_b in order, 3.92, 2.36; F = 18.96 with 2, 41 DF; $r^2 = 0.48$)

(2) New vessels.—Presumably, owners of new seiners will possess adequate working capital and will want to keep their vessels in top condition. We therefore used comparable data on new steel shrimp trawlers, based in ports on the Gulf of Mexico, to estimate the maintenance and repair costs of new wetfish seiners. The sample consisted of 17 shrimp vessels, ranging from 61 to 85 feet registered length (the average was 72 feet). The actual costs for 1967 or 1968 were increased by 20 percent, to account for possible additional maintenance costs on wetfish seiners (such as for power block and refrigeration).

The estimating equation is of the form:

$$\hat{Y} = -17{,}619 + 341.15X \quad \text{(Equation 3)}$$

where $\hat{Y}$ = the maintenance and repair costs, in dollars

X = the registered length of the vessel, in feet

($t_b = 3.12$, $p<0.01$, $r^2 = 0.39$)

b. Netting and supplies. — Netting and supplies include expenditures for net webbing, seine cables, line, hardware, tools, and miscellaneous supply items. Seine cables are replaced about once a year, at a cost of about $500. Worn webbing is replaced every other year on a routine basis, also at a cost of about $500, in addition to that replaced to repair the net when it is torn.

A linear correlation was found between these costs and the quantity of fish landed. The least-squares regression based on data for 1967 is of the following form:

$$\hat{Y} = -240 + 2X \quad \text{(Equation 4)}$$

where $\hat{Y}$ = costs in dollars

X = tons of fish landed

($t_b = 3.77$, $p<0.005$, $r^2 = 0.53$)

This regression indicates that the costs of nets and supplies increase by $2 per ton of fish caught. The addition of the owner's share in proceeds, as a second possible variable in the regression, is not significant statistically.

Insurance.—Insurance is a major expense. Three types of coverage are carried by all boat owners. Hull and machinery insurance covers total loss of the vessel as well as damage caused by fire, stranding, and collision, with a usual deductible amount of $500 per accident. The amount of the insurance premium is based on the market value of the vessel. The seine skiff is covered under this insurance. Net insurance covers full value of the net (depreciated straight line over 5 years, with renovation added to the value) against loss or damage, with a $500 deductible amount for fire only. Protection and indemnity insurance covers illness and injuries of crew members and a broad range of possible liability to other parties. The usual practice is to insure to $100,000 for a single claim, with a $1,000 deductible amount for property liability. Premiums are based on a complex formula that varies with the insurance company and that has to do with such factors as size of crew, age of vessel, and size of vessel. The premiums are about $2,000 per year for a vessel with a crew of 10.

(1) Existing vessels.—Analysis of costs categorized under "insurance" in the financial reports examined in the present study revealed a variability too great to allow us to estimate insurance costs empirically. This variation is due to differences in coverage and in premium-payment schedules. For purposes of cost prediction, hull and machinery premiums were computed at 6.75 percent of the market value, net insurance premiums were computed at 5 percent of the value of the nets, and protection and liability premiums were computed at $200 per crewman. In 1968, these premiums provided the coverage described above. Values of vessels and nets are discussed below in the section on depreciation (h).

The equation for insurance costs for existing vessels is as follows:

$$\hat{Y} = 0.0675X_1 + 0.0500X_2 + 200X_3 \quad \text{(Equation 5)}$$

where $\hat{Y}$ = the estimated insurance costs, in dollars
X_1 = the market value of the vessel, in dollars
X_2 = the market value of the nets, in dollars
X_3 = the maximum size of the crew

(2) New vessels.—For new vessels, the cost of hull and machinery insurance is lower than for old vessels. The estimating equation therefore becomes:

$$\hat{Y} = 0.0375X_1 + 0.0500X_2 + 200X_3 \quad \text{(Equation 6)}$$

where $\hat{Y}$ = the estimated insurance costs, in dollars
X_1 = the market value of the vessel, in dollars
X_2 = the market value of the nets, in dollars
X_3 = the maximum size of the crew

d. Payroll taxes.—Social Security taxes are computed as a percentage of a maximum annual amount of wages for each crew member. If the membership of the crew changes during the year, the taxes paid by the owner are higher than during a year in which the crew is stable. The following least-squares regression accounts for 77 percent of the variance for 58 observations:

$$\hat{Y} = 1.073 + 0.057X \quad \text{(Equation 7)}$$

where $\hat{Y}$ = estimated annual payroll taxes, in dollars
X = annual crew wages, in dollars
(t_b = 13.72, $p<0.001$, $r^2 = 0.77$)

e. Interest on loans.—The amounts paid by various corporations for interest on loans range from a few dollars to more than $2,000 in a given year. The dispersion of payments by any corporation over the years is also very high. In many profit-and-loss statements, no interest payments are shown, although the balance sheet shows a substantial loan. The amounts in Table 2 therefore may not reflect the real situation. We use the grand average value ($504) for predicting costs for old vessels; but interest on assumed loans should be used for estimations for new vessels. The rate used here for prediction is 7.5 percent.

f. Moorage.—The Harbor Department computes the moorage fee on the basis of the length and of the type of vessel. Of 22 vessels analyzed, 16 (50 to 79 feet long, 60- to 110-ton capacity) paid $450 per year, and 6 (80 feet and longer, 110- to 150-ton capacity) paid $540 per year.

g. State and county taxes.—In 1968, the California State income tax rate for corporations was 7 percent, with a minimum of $100. We use this rate in the predictions below. Since the companies are small corporations, they pay no Federal corporate income tax. Taxable income is reported in the personal returns of the shareholders.

The modal value for county property taxes was about $450. Under a new law (effective 1968), commercial fishing vessels registered in Los Angeles County are assessed at 1 percent of their market value. The current tax rate is about $10 per $100 assessed valuation, making the effective tax rate about 0.1 percent of market value per year.

In terms of an equation:

$$\hat{Y} = 0.001X_1 + 0.07X_2 \quad \text{(Equation 8)}$$

where $\hat{Y}$ = the estimated county and State taxes, in dollars

X_1 = the market value of the vessel, in dollars

X_2 = the taxable income during previous year, in dollars

$0.07X_2$ may not be less than $100

h. Depreciation.—Considered here is the depreciation both for existing and new vessels (including their nets).

(1) Existing vessels.—The straight-line method and the declining balance method of computing depreciation are alternatively applied to the various component parts of the vessels (for example, vessel, engine, and skiff) and equipment (for example, power block, electronics, and netting). The age of the vessels (all are more than 20 years old, and about half of the fleet is more than 30 years old), explains why the cost of depreciation is rather low on the average (Table 16). In 1968, the market value of the vessels ranged from $25,000 to $60,000 (average value, $41,530; modal value, $45,000). (Note: The modal value is used below for predicting insurance costs for existing vessels in sample calculations.) The depreciation claimed in 1967 does not show a significant linear relation with market value, because most of the depreciation claimed is on nets, skiffs, electronics, refrigeration, and other vessel improvements, which retain a high market value beyond the span of their short book lives. The grand average value of depreciation for 1963-67 (Table 16) is used below for predictions.

(2) New vessels.—Depreciation for new vessels and skiffs is estimatd at straight line for 15 years on 85 percent of the unsubsidized portion of new construction costs. Table 17 contains estimated costs of new-vessel construction for 12 steel vessels of various lengths, capacities, and horsepower. The total cost of a new net is depreciated straight line over 5 years. A new seine costs about $12,000. Most vessel operators own two seines--one for mackerel and one with a smaller mesh for anchovies. In equation form:

$$\hat{Y} = 0.057X_1 + 0.2X_2 \qquad \text{(Equation 9)}$$

where $\hat{Y}$ = estimated depreciation, in dollars

Table 17.—Estimated costs of new vessel construction (steel)

	Vessel data									Skiff data			
Vessel Number	Length	Beam	Depth	Fish capacity	Size of motor	Speed		Cost	Remarks	Length	Beam	Size of motor	Cost
						Light	Loaded						
	Feet	*Feet*	*Feet*	*Short tons*	*Horse-power*	*Knots*	*Knots*	*Dollars*		*Feet*	*Feet*	*Horse-power*	*Dollars*
1	54.0	16.5	8.0	61	160	9.5-9.8	8.5	120,000	Combination boat. In 1959 it cost $80,000 for a basic boat and $110,000 for a fully equipped one for seining and trawling.	16	8	60	8,000
2	58.0	18.0	9.0	66	240	10.2	--	140,000	Seiner.	16-17	9	--	9,000
3	58.0	--	--	60	--	--	--	160,000	Seiner.	--	--	--	--
4	60.0	20.0	--	60	275	10.5	--	140,000	Combination boat.	--	--	--	--
5	66.0	19.5	9.5	110	260	10.2	8.5-9.0	160,000-180,000	Combination boat. In 1968 it cost $230,000 as a fully equipped crab boat.	20	10	100	11,000
6	70.0	22.0	--	110	365	11.0	--	285,000	Combination boat.	--	--	--	--
7	70.0	--	--	120	--	--	--	200,000	Seiner.	--	--	--	--
8	73.0	21.9	10.5	154	350	10.0-10.5	9.0-9.5	180,000-200,000	Combination boat.	22	--	100	14,000
9	80.0	24.0	--	135	510	12.0	--	400,000	Combination boat.	--	--	--	--
10	80.0	--	--	175	--	--	--	260,000	Seiner.	--	--	--	--
11	83.0	24.0	11.5	210	350-400	11.0	9.5	220,000-240,000	Combination boat. Spray refrigerator would cost about $25,000 more.	22	--	100	14,000
12	90.0	25.0	12.0	264	560	11.5-12.0	10.5	280,000-300,000	Combination boat. In 1968 it cost $350,000 as a crab boat; $450,000 as a completely equipped combination boat for trawling, seining, crabbing, scalloping, or salmon hauling; and $400,000 for a crab-bing scalloping combination.	24	12	100	15,000

Note 1: The data on cost are for a vessel fully equipped for seining, except for nets and skiffs; the data do not include the cost of refrigeration. The estimates were made in the fall of 1968.
Note 2: These figures are based on data furnished by vessel builders (see Acknowledgments).

X_1 = value of vessel and gear exclusive of nets, in dollars (for 1st year, = 85 percent of new construction cost or full amount of unsubsidized cost for subsidized vessel)

X_2 = value of nets, in dollars

i. Office expenses and other costs.—Table 18 shows the main components of office expenses and other costs.

Table 18.–Office expenses and other costs

Item	Cost
	Dollars
Accounting	450-500
Automobile	400-500
Dues and contributions	200-300

The rest of these costs consists of items such as licenses, legal fees, promotional expenses, telephone, donations, and "miscellaneous." For the predictions below, we use the average figure of $1,873 for the fleet in 1967.

B. MODEL FOR PREDICTION OF EARNINGS

With our analysis of costs, we can construct our model for the prediction of earnings. In so doing, we consider first the prediction of revenue and then the prediction of the aspects of earnings that depend on revenue--namely, profits, return on investment, and crew earnings.

1. Revenue

Predicting revenue turned out to be difficult--in fact, impossible at present. In this section, we describe the problem and how we handled it.

a. Problem of predicting revenue.—Revenue proved difficult to predict because little relation was found in the present study between landings or gross revenue and vessel characteristics such as length, capacity, horsepower of the main engine, or age. Three possible causes of this lack of observed relation are (1) the nature of the fishery, (2) an overriding factor of skill, and (3) insufficient data.

(1) Nature of fishery.—Because the vessels are seldom loaded to capacity (the usual load of mackerel is 10 to 50 tons), differential capacity is of minor importance. The exception to this underloading of the vessel occurs in the anchovy fishery, in which the vessels are loaded to capacity on most trips. Because the fishing grounds are within a few hours run from the harbor at most and, in some places, within a few minutes run, the importance of differential horsepower is minimized. Also, the catches of some species are subject to limits set by processors.

(2) Overriding skill factor.—Setting a purse seine around a school of fish requires great skill. Schooling behavior varies widely from species to species and even from one school to another within a particular species, and empty hauls are common. Differences in the fishing ability of vessel captains may therefore be the major source of variation in landings and revenue.

(3) Insufficient data.—Few data were available for the present study on fishing effort (days at sea, scouting time, and number of net sets) correlated with landings data. The staff of Marine Resources Operations of the California Department of Fish and Game, however, is now collecting effort data for the fleet. When adjustments can eventually be made for differences in fishing effort, we may find that differences in efficiency are correlated with vessel characteristics.

b. Solution to the problem of predicting earnings.—Because of our difficulty in predicting revenue, we use arbitrary levels of revenue to predict the costs and earnings in the following section. Our range of values includes levels of revenue attained by vessels in the fleet in recent years (Figures 6 and 7).

2. Profit, Return on Investment, and Crew Earnings

Profit, return on investment, and crew earnings may be predicted for given levels of gross revenue by the use of the cost relations developed earlier. The following subsection gives details both for the older vessels of the type now in the fleet and for hypothetical new vessels.

a. Existing vessels.—In this section, we are concerned with sample calculations--that is, with showing our technique to calculate predictions of profit, return on investment, and crew earnings. Table 19 is a guide to illustrate the method used to estimate profit and return on investment. The following example, which is keyed to Table 19 by column numbers, illustrates the details of computation. Sources of the relations or values used in the computations are indicated in parentheses.

Given: Vessel size = 100 tons capacity

Market value = $45,000 (modal value for fleet; actual market value should be substituted by the prospective vessel operator)

Gross revenue = $150,000

Catch = One-half mackerel and one-half anchovies, by value

Nets = One for anchovies and one for mackerel, at $12,000 each

Then:

	Column in Table 19
1. Operating costs (by Equation 1) = $8,052 + 0.0275 × value of mackerel landings + 0.0419 × value of tuna landings + 0.0939 × value of bonito landings + 0.0380 × value of anchovy landings = $8,052 + 0.0275 × $75,000 + 0.0380 × $75,000 = $12,965	1
2. Tons of mackerel = value of mackerel landings ÷ price per ton (from Table 3; the current price should be substituted by the prospective vessel operator) = $75,000 ÷ $75.42 per ton = 994 tons	2
3. Tons of anchovies = the value of the anchovy landings ÷ the price per ton (from Table 3; the current price should be substituted by the prospective vessel operator) = $75,000 ÷ $20 per ton = 3,750 tons	5
4. Total tons of fish = Column 2 + Column 3 + Column 4 + Column 5 = 4,744 tons	6
5. Minimum number of trips, assuming a capacity load each trip = total tons (Column 6) ÷ capacity of vessel = 994 tons + 3,750 tons ÷ 100 tons = 48 trips (= about 1 trip per week)	7
6. Net proceeds = gross revenue — operating costs (Column 1) = $150,000 — $12,965 = $137,035 .	8
7. Percentage to crew (from Table 4) = 61 percent	9
8. Gross crew share = percentage to crew (Column 9) × net proceeds (Column 8) ÷ 100 = 61 percent × $137,035 ÷ 100 = $83,591	10
9. Individual crew share = gross crew share (Column 10) ÷ size of crew (from Table 4) = $83,591 ÷ 11 or 10 = $7,599 to $8,359 per individual	11
10. Owner's share = net proceeds (Column 8) — gross crew share (Column 10) = $137,035 — $83,591 = $53,444	12
11. Parts and repairs (using Equation 2) = $24 + 0.0787 × owner's share (Column 12) + 0.0552 × owner's share in the preceding year (assumed here to be same as for the year 1969) = $24 + 0.0787 × $53,444 + 0.0552 × $53,444 = $7,180	13
12. Netting and supplies (using Equation 4) = — $240 + $2 per ton × tons of fish landed (Column 6)	

Table 19.—Sample calculations of predicted earnings for existing vessels, at gross revenue = $150,000

Catch composition by value	Vessel capacity	Column 1 Operating cost	Column 2 Mackerel	Column 3 Tuna	Column 4 Bonito	Column 5 Anchovies	Column 6 Total fish	Column 7 Trips
	Tons	*Dollars*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Number*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	70	15,270	994	60	441	1,125	2,620	38
	100	15,270	994	60	441	1,125	2,620	27
	120	15,270	994	60	441	1,125	2,620	22
	150	15,270	994	60	441	1,125	2,620	18
50 percent mackerel and 50 percent anchovies	70	12,965	994	0	0	3,750	4,744	68
	100	12,965	994	0	0	3,750	4,744	48
	120	12,965	994	0	0	3,750	4,744	40
	150	12,965	994	0	0	3,750	4,744	32
100 percent anchovies	70	13,752	0	0	0	7,500	7,500	108
	100	13,752	0	0	0	7,500	7,500	75
	120	13,752	0	0	0	7,500	7,500	63
	150	13,752	0	0	0	7,500	7,500	50

Catch composition by value	Vessel capacity	Column 8 Net proceeds	Column 9 Proportionate crew share	Column 10 Gross crew share	Column 11 Individual crew share	Column 12 Owner's share	Column 13 Parts and repairs
		Dollars	*Percent*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	70	134,730	62.5	84,206	8,421-9,356	50,524	6,789
	100	134,730	61.0	82,185	7,471-8,219	52,545	7,060
	120	134,730	60.5	81,512	7,410-8,151	53,218	7,150
	150	134,730	58.5	78,817	6,568-7,165	55,913	7,511
50 percent mackerel and 50 percent anchovies	70	137,035	62.5	85,647	8,565-9,516	51,388	6,905
	100	137,035	61.0	83,591	7,599-8,359	53,444	7,180
	120	137,035	60.5	82,906	7,537-8,291	54,129	7,272
	150	137,035	58.5	80,165	6,680-7,288	56,870	7,639
100 percent anchovies	70	136,248	62.5	85,155	8,516-9,462	51,093	6,865
	100	136,248	61.0	83,111	7,556-8,311	53,137	7,139
	120	136,248	60.5	82,430	7,494-7,971	53,818	7,230
	150	136,248	58.5	79,705	6,642-7,246	56,543	7,595

Catch composition by value	Vessel capacity	Column 14 Netting and supplies	Column 15 Insurance	Column 16 Payroll taxes	Column 17 Interest on loans	Column 18 Moorage	Column 19 State and county taxes
		Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	70	5,480	6,658	5,873	504	450	1,480
	100	5,480	6,858	5,758	504	450	1,480
	120	5,480	6,858	5,719	504	540	1,480
	150	5,480	7,058	5,566	504	540	1,480
50 percent mackerel and 50 percent anchovies	70	9,248	6,658	5,955	504	450	1,235
	100	9,248	6,858	5,838	504	450	1,235
	120	9,248	6,858	5,799	504	540	1,235
	150	9,248	7,058	5,642	504	540	1,235
100 percent anchovies	70	15,240	6,658	5,927	504	450	780
	100	15,240	6,858	5,810	504	450	780
	120	15,240	6,858	5,772	504	540	780
	150	15,240	7,058	5,616	504	540	780

Catch composition by value	Vessel capacity	Column 20 Depreciation	Column 21 Office expenses	Column 22 Total owner's costs	Column 23 Net profit	Column 24 Equity capital investment	Column 25 Return on investment
		Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Percent*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	70	3,604	1,873	32,711	17,813	28,162	63.3
	100	3,604	1,873	33,067	19,478	28,162	69.2
	120	3,604	1,873	33,208	20,010	28,162	71.2
	150	3,604	1,873	33,616	22,297	28,162	79.2
50 percent mackerel and 50 percent anchovies	70	3,604	1,873	36,442	14,946	28,162	53.1
	100	3,604	1,873	36,790	16,654	28,162	59.1
	120	3,604	1,873	36,943	17,186	28,162	61.0
	150	3,604	1,873	37,353	19,517	28,162	69.3
100 percent anchovies	70	3,604	1,873	41,901	9,192	28,162	32.6
	100	3,604	1,873	42,258	10,879	28,162	38.6
	120	3,604	1,873	42,401	11,417	28,162	40.5
	150	3,604	1,873	42,810	13,733	28,162	48.8

Column in Table 19

= — \$240 + \$2 × 4,744 = \$9,248 14

13. Insurance (using Equation 5) = 0.0675 × market value of vessel + 0.05 × value of nets + \$200 per crewman × maximum crew size (from Table 4) = 0.0675 × \$45,000 + 0.0500 × \$24,000 (assuming two new nets at \$12,000 each) + \$200 × 11 = \$6,858 15

14. Payroll taxes (using Equation 7) = \$1,073 + 0.057 × gross crew share of net proceeds (Column 10) = \$1,073 + \$.057 × \$83,591 = \$5,838 16

15. Interest on loans (using average value for 1967 from Table 16; the prospective vessel operator should substitute his actual estimate) = \$504 17

16. Moorage (using average paid by vessels under 80 feet long, Moorage section) = \$450 18

17. State and county taxes (using Equation 8) = 0.001 × market value of vessel + 0.07 × previous year's profit (assumed here to be \$17,000), with the limitation that this term may not be less than \$100 (the prospective vessel operator should substitute \$100 as the State tax during his first year of operation) = 0.001 × \$45,000 + 0.07 × \$17,000 = \$1,235 19

18. Depreciation (using average value for 1963 to 1967 from Table 16; the prospective vessel operator should substitute his actual estimate) = \$3,604 20

19. Office expenses and other costs (using average value for 1967 from Table 16) = \$1,873 21

20. Total owner's costs = parts and repairs (Column 13) + netting and supplies (Column 14) + insurance (Column 15) + payroll taxes (Column 16) + interest on loans (Column 17) + moorage (Column 18) + State and county taxes (Column 19) + depreciation (Column 20) + office expenses and other costs (Column 21) = \$7,180 + \$9,248 + \$6,858 + \$5,838 + \$504 + \$450 + \$1,235 + \$3,604 + \$1,873 = \$36,790 22

21. Net profit = owner's share (Column 12) — total owner's cost (Column 22) = \$53,444 — \$36,790 = \$16,654 23

22. Equity capital investment (from Capital Structure and Return on Investment section; the actual anticipated capital investment should be substituted by the prospective vessel operator) = \$28,162 24

23. Return on investment = net profit (Column 23) ÷ capital investment (Column 24) = \$16,654 ÷ \$28,162 = 59.1 percent 25

b. New vessels. — Before predicting profits and return on investment for new vessels, we must hypothesize a capital structure (Table 20).

Table 21 illustrates the method used to predict earnings for hypothetical new vessels. The vessel types are selected from Table 17. The following example is keyed to Table 21 by column numbers.

Given: Vessel size = 110 tons capacity (vessel-type Number 5 in Table 17)

Vessel cost (including skiff, two nets, and spray, refrigeration) = \$226,000 (Table 17)

Gross revenue = \$150,000

Table 20.—Capital structure for new vessel owners, under various levels of government vessel-construction subsidy

Capital structure with no subsidy:

Vessel type (from Table 16)	Fixed capital: Vessel	Fixed capital: Skiff	Fixed capital: Refriger-ation	Fixed capital: Nets	Fixed capital: Total	Working capital[1]	Total capital	Borrowed capital[2]	Net worth
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1	120,000	8,000	19,000	24,000	171,000	8,550	178,550	113,000	65,550
2	140,000	9,000	19,000	24,000	192,000	9,600	200,600	127,000	73,600
3	160,000	9,000	19,000	24,000	212,000	10,600	221,600	140,000	81,600
4	140,000	10,000	21,000	24,000	195,000	9,750	203,750	129,000	74,750
5	170,000	11,000	21,000	24,000	226,000	11,300	236,300	150,000	86,300
6	285,000	14,000	23,000	24,000	346,000	17,300	362,300	230,000	132,300
7	200,000	14,000	23,000	24,000	261,000	13,050	273,050	173,000	100,050
8	190,000	14,000	23,000	24,000	251,000	12,550	262,550	166,000	96,550
9	400,000	15,000	25,000	24,000	464,000	23,200	486,200	308,000	178,200
10	260,000	14,000	25,000	24,000	323,000	16,150	338,150	214,000	124,150
11	230,000	14,000	25,000	24,000	293,000	14,650	306,650	194,000	112,650
12	290,000	15,000	25,000	24,000	354,000	17,700	370,000	235,000	135,700

Capital structure with 40-percent subsidy:

Vessel type (from Table 16)	Fixed capital: Vessel[3]	Fixed capital: Nets	Fixed capital: Total	Working capital[1]	Total capital	Borrowed capital[2]	Net worth
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1	88,000	24,000	112,000	8,550	120,550	75,000	45,550
2	101,000	24,000	125,000	9,600	134,600	83,000	51,600
3	113,000	24,000	137,000	10,600	147,600	91,000	56,600
4	103,000	24,000	127,000	9,750	136,750	85,000	51,750
5	121,000	24,000	145,000	11,300	156,300	97,000	59,300
6	193,000	24,000	217,000	17,300	234,300	145,000	89,300
7	142,000	24,000	166,000	13,050	179,050	111,000	68,050
8	136,000	24,000	160,000	12,550	172,550	107,000	65,550
9	264,000	24,000	288,000	23,200	311,200	192,000	119,200
10	179,000	24,000	203,000	16,150	219,150	135,000	84,150
11	161,000	24,000	105,000	14,650	199,650	123,000	76,650
12	198,000	24,000	222,000	17,700	239,700	148,000	91,700

Capital structure with 50-percent subsidy:

Vessel type (from Table 16)	Fixed capital: Vessel[3]	Fixed capital: Nets	Fixed capital: Total	Working capital[1]	Total capital	Borrowed capital[2]	Net worth
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1	73,500	24,000	97,500	8,550	106,050	65,000	41,050
2	84,000	24,000	108,000	9,600	117,600	72,000	45,600
3	94,000	24,000	118,000	10,600	128,600	79,000	49,600
4	86,000	24,000	110,000	9,750	119,750	73,000	46,750
5	101,000	24,000	125,000	11,300	136,300	83,000	53,300
6	161,000	24,000	105,000	17,300	202,300	123,000	79,300
7	118,000	24,000	142,000	13,050	155,050	95,000	60,050
8	114,000	24,000	138,000	12,550	150,550	92,000	58,550
9	220,000	24,000	244,000	23,200	267,200	163,000	104,200
10	150,000	24,000	174,000	16,150	190,150	116,000	74,150
11	135,000	24,000	159,000	14,650	173,650	106,000	67,650
12	165,000	24,000	189,000	17,700	206,700	126,000	80,700

[1] Working capital consists of 5 percent of full value of fixed capital.
[2] Borrowed capital consists of 66.6 percent of fixed capital.
[3] For subsidized vessels, the fixed capital in the vessel includes the skiff and the refrigeration.

Catch = One-half mackerel and one-half anchovies, by value.

Then: Column in Table 21

1. Operating costs (using Equation 1) = $8,052 + 0.0275 × value of mackerel landings + 0.0419 × value of tuna landings + 0.0939 × value of bonito landings + 0.0380 × value of anchovy landings = $8,052 + 0.0275 × $75,000 + 0.0380 × $75,000 = $12,964 1
2. Tons of mackerel = value of mackerel landings ÷ price per ton for 1967 (from Table 3; the current price should be substituted by the prospective vessel operator) = $75,000 ÷ $72.50 per ton = 1,034 tons 2
3. Tons of anchovies = the value of anchovy landings ÷ the price per ton of anchovies (from Table 3; the current price should be substituted by the prospective vessel operator) = $75,000 ÷ $20 per ton = 3,750 tons 5
4. Total tons of fish = Column 2 + Column 3 = Column 4 + Column 5 = 4,784 tons 6
5. Minimum number of trips, assuming a capacity load each trip = total tons (Column 6) ÷ capacity of the vessel = 4,784 ÷ 110 tons per trip = 44 trips 7
6. Net proceeds = gross revenue — operating costs (Column 1) = $150,000 — $12,964 = $137,036 .. 8
7. Percentage to crew (from Table 4) = 60.5 percent 9
8. Gross crew share = percentage to crew (Column 9) × net proceeds (Column 8) = 60.5 percent × $137,036 = $82,907 10
9. Individual crew share = the gross crew share (Column 10) ÷ the size of the crew (from Table 4) = $83,768 ÷ 11 and 10 = $7,537 to $8,291 11
10. Owner's share = the net proceeds (Column 8) — the gross crew share (Column 10) = $137,036 — $82,907 = $54,129 12
11. Parts and repairs (using Equation 3) = — $17,619 + $341.15 per foot × length of vessel = — $17,619 + $341.15 per foot × 66 feet (from Table 21) = $4,897 13
12. Netting and supplies (using Equation 4) = — $240 + $2 per ton × tons of fish landed (Column 6) = — $240 + $2 × 4,784 = $9,328 . 14
13. Insurance (using Equation 6) = 0.0375 × value of vessel (including skiff and refrigeration) + 0.05 × value of nets + $200 per crew member × maximum crew size (from Table 4) = 0.0375 × $202,000 + 0.05 × $24,000 + $200 × 11 = $10,975 15
14. Payroll taxes (using Equation 7) = $1,073 + 0.057 × gross crew share of net proceeds (Column 9) = $1,073 + 0.057 × $82,907 = $5,799 16
15. Interest on loans (7.5 percent of borrowed capital for vessel number 5 in Table 20) = $11,250 17
16. Moorage (using average paid by vessels under 80 feet long, Moorage section) = $450 18
17. State and county taxes (using Equation 8) = 0.001 × value of fixed assets (Table 20) + 0.07 × previous year's profit (assumed here to be $0) = 0.001 × $226,000 + 0.07 × $0 = $226.00 19
18. Depreciation (using Equation 9) = 0.057 × value of vessel and gear

Table 21.—Sample calculations of predicted earnings for new vessels,

Catch composition by value	Vessel capacity	Column 1 Operating cost	Column 2 Mackerel	Column 3 Tuna	Column 4 Bonito	Column 5 Anchovies	Column 6 Total fish	Column 7 Trips
	Tons	*Dollars*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Number*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	66	15,119	1,034	60	452	1,125	2,671	41
	110	15,119	1,034	60	452	1,125	2,671	25
	154	15,119	1,034	60	452	1,125	2,671	18
	210	15,119	1,034	60	452	1,125	2,671	13
	264	15,119	1,034	60	452	1,125	2,671	11
50 percent mackerel and 50 percent anchovies	66	12,964	1,034	0	0	3,750	4,784	73
	110	12,964	1,034	0	0	3,750	4,784	44
	154	12,964	1,034	0	0	3,750	4,784	31
	210	12,964	1,034	0	0	3,750	4,784	23
	264	12,964	1,034	0	0	3,750	4,784	19
100 percent anchovies	66	13,752	0	0	0	7,500	7,500	114
	110	13,752	0	0	0	7,500	7,500	69
	154	13,752	0	0	0	7,500	7,500	49
	210	13,752	0	0	0	7,500	7,500	36
	264	13,752	0	0	0	7,500	7,500	29

Catch composition by value	Vessel capacity	Column 14 Netting and supplies	Column 15 Insurance	Column 16 Payroll taxes	Column 17 Interest on loans	Column 18 Moorage	Column 19 State and county taxes
	Tons	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	66	5,102	9,500	5,878	9,525	450	292
	110	5,102	10,975	5,724	11,250	450	226
	154	5,102	12,112	5,494	12,450	450	251
	210	5,102	13,688	5,494	14,550	540	293
	264	5,102	15,975	5,494	17,625	540	354
50 percent mackerel and 50 percent anchovies	66	9,328	9,500	5,955	9,525	450	192
	110	9,328	10,975	5,799	11,250	450	226
	154	9,328	12,112	5,564	12,450	450	251
	210	9,328	13,688	5,564	14,500	540	293
	264	9,328	15,975	5,564	17,625	540	354
100 percent anchovies	66	14,760	9,500	5,927	9,525	450	192
	110	14,760	10,975	5,772	11,250	450	226
	154	14,760	12,112	5,539	12,450	450	251
	210	14,760	13,688	5,539	14,550	540	293
	264	14,760	15,975	5,539	17,625	540	354

Column in Table 21

(unsubsidized portion) exclusive of nets + 0.2 × value of nets = 0.057 × $202,000 + 0.2 × $24,000 = $16,314 20

19. Office expenses and other costs (using the average value for 1967 from Table 16) = $1,873 21

20. Total owner's costs = parts and repairs (Column 13) + netting and supplies (Column 14) + insurance (Column 15) + payroll taxes (Column 16) + interest on loans (Column 17) + moorage (Column 18) + State and county taxes (Column 19) + depreciation (Column 20) + office expenses and other costs (Column 21) = $4,897 + $9,328 + $10,975 + $5,799 + $11,250 + $450 + $226 + $16,314 + $1,873 = $61,112 22

21. Net profit = owner's share (Column 12) — total owner's costs (Column 22) = $54,129 — $61,112 = —$6,983 23

22. Capital investment (net worth in Table 20) = $86,000 24

23. Return on investment = net profit (Column 23) ÷ capital investment (Column 24) = —$6,983 ÷ $86,300 = — 8.1 percent 25

at gross revenue = $150,000 and with no construction subsidy

Catch composition by value	Vessel capacity	Column 8 Net proceeds	Column 9 Proportionate crew share	Column 10 Gross crew share	Column 11 Individual crew share	Column 12 Owner's share	Column 13 Parts and repairs
	Tons	*Dollars*	*Percent*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	66	134,881	62.5	84,301	8,430-9,367	50,580	2,168
	110	134,881	60.5	81,603	7,418-8,160	53,278	4,897
	154	134,881	57.5	77,557	6,463-7,051	57,324	7,285
	210	134,881	57.5	77,557	6,463-7,051	57,324	10,696
	264	134,881	57.5	77,557	6,463-7,051	57,324	13,084
50 percent mackerel and 50 percent anchovies	66	137,036	62.5	85,647	8,565-9,516	51,389	2,168
	110	137,036	60.5	82,907	7,537-8,291	54,129	4,897
	154	137,036	57.5	78,796	6,566-7,163	58,240	7,285
	210	137,036	57.5	78,796	6,566-7,163	58,240	10,696
	264	137,036	57.5	78,796	6,566-7,163	58,240	13,084
100 percent anchovies	66	136,248	62.5	85,155	8,516-9,462	51,093	2,168
	110	136,248	60.5	82,430	7,494-8,243	53,818	4,897
	154	136,248	57.5	78,343	6,529-7,122	57,905	7,285
	210	136,248	57.5	78,343	6,529-7,122	57,905	10,696
	264	136,248	57.5	78,343	6,529-7,122	57,905	13,084

Catch composition by value	Vessel capacity	Column 20 Depreciation	Column 21 Office expenses	Column 22 Total owner's costs	Column 23 Net profit	Column 24 Equity capital investment	Column 25 Return on investment
	Tons	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Percent*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	66	14,376	1,873	49,164	1,416	73,600	1.9
	110	16,314	1,873	56,811	−3,533	86,300	−4.1
	154	17,739	1,873	62,756	−5,432	96,550	−5.6
	210	20,133	1,873	72,369	−15,045	112,650	−13.4
	264	23,610	1,873	83,657	−26,333	135,700	−19.4
50 percent mackerel and 50 percent anchovies	66	14,376	1,873	53,367	−1,978	73,600	−2.7
	110	16,314	1,873	61,112	−6,983	86,300	−8.1
	154	17,739	1,873	67,052	−8,812	96,550	−9.1
	210	20,133	1,873	76,665	−18,425	112,650	−16.4
	264	23,610	1,873	87,953	−29,713	135,700	−21.9
100 percent anchovies	66	14,376	1,873	58,771	−7,678	73,600	−10.4
	110	16,314	1,873	66,517	−12,699	86,300	−14.7
	154	17,739	1,873	72,459	−14,554	96,550	−15.1
	210	20,133	1,873	82,072	−24,167	112,650	−21.5
	264	23,610	1,873	93,360	−35,455	135,700	−26.1

III. ECONOMIC FEASIBILITY OF FLEET EXPANSION AND NEW-VESSEL CONSTRUCTION

We can use our model to calculate the feasibility of expanding the fleet and of constructing new vessels. We consider first the expansion of the fleet with existing vessels and then consider the addition of new construction.

A. FLEET EXPANSION WITH EXISTING VESSELS

In this section, we present a table summarizing predicted earnings for old vessels, and then analyze the table and reach a conclusion as to the economic feasibility of fleet expansion with existing surplus vessels from other fisheries.

1. Summary Table

Table 22 summarizes predicted earnings for old vessels under varying conditions of gross revenue.

2. Analysis of Summary Table and Conclusions

Within the limits of the summary table (Table 22), the crew share is most affected by the size of the vessel (maximum effect at $200,000 gross revenue = $3,015) and is little affected by the species composition of the catch (maximum effect at $200,000 gross revenue = $179). The highest crew share at any level of revenue is achieved on a 70-ton vessel with a half-mackerel, half-anchovy catch, by value.

Table 22.—Summary table of predicted annual earnings for existing vessels

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of:							
		Same species in same proportions as in landings for 1967 (Figure 4)				100 percent mackerel			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*		*Percent*
50,000	70	871	2,745	−4,882	−17.3	663	2,258	−3,187	−11.3
	100	871	2,411	−4,534	−16.1	663	2,204	−2,970	−10.5
	120	871	2,392	−4,442	−15.8	663	2,186	−2,878	−10.2
	150	871	2,102	−3,913	−13.9	663	2,114	−2,343	− 8.3
100,000	70	1,742	6,068	5,828	20.7	1,326	6,080	7,328	26.0
	100	1,742	5,330	6,829	24.2	1,326	5,340	8,341	29.6
	120	1,742	5,287	7,142	25.4	1,326	5,297	8,745	31.1
	150	1,742	4,647	8,696	30.9	1,326	4,656	10,071	35.8
150,000	70	2,620	9,350	17,813	63.3	1,988	9,396	19,188	68.1
	100	2,620	8,219	19,478	69.2	1,988	8,254	20,861	74.1
	120	2,620	8,151	20,010	71.2	1,988	8,186	22,004	78.1
	150	2,620	7,165	22,297	79.2	1,988	7,196	23,694	84.1
200,000	70	3,484	12,696	29,035	103.1	2,652	12,719	30,544	108.5
	100	3,484	11,152	31,373	111.4	2,652	11,132	32,881	116.8
	120	3,484	11,061	32,121	114.1	2,652	11,081	33,629	119.4
	150	3,484	9,723	35,353	125.5	2,652	9,740	36,817	130.7

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of:							
		50 percent mackerel, 50 percent anchovies				100 percent anchovies			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*
50,000	70	1,561	2,799	−6,037	−21.4	2,500	2,781	−7,934	−28.2
	100	1,561	2,459	−5,678	−20.2	2,500	2,443	−7,635	−27.1
	120	1,561	2,439	−5,583	−19.8	2,500	2,423	−7,541	−26.8
	150	1,561	2,144	−5,038	−17.9	2,500	2,130	−7,001	−24.9
100,000	70	3,122	6,157	4,576	16.2	5,000	6,121	919	3.3
	100	3,122	5,408	5,604	19.9	5,000	5,377	1,911	6.8
	120	3,122	5,365	5,917	21.0	5,000	5,333	2,200	7.8
	150	3,122	4,715	7,361	26.1	5,000	4,688	3,528	12.5
150,000	70	4,744	9,516	14,946	53.1	7,500	9,462	9,192	32.6
	100	4,744	8,359	16,644	59.1	7,500	8,311	10,879	38.6
	120	4,744	8,291	17,186	61.0	7,500	7,971	11,417	40.5
	150	4,744	7,288	19,517	69.3	7,500	7,246	13,733	48.8
200,000	70	6,244	12,875	24,728	87.8	10,000	12,802	17,324	61.5
	100	6,244	11,309	27,037	96.0	10,000	11,245	19,683	69.9
	120	6,244	11,217	27,893	99.0	10,000	11,153	20,445	72.6
	150	6,244	9,860	31,026	110.1	10,000	9,804	23,431	83.2

For the vessel operator, profit and return on investment are most affected by the composition of the catch (maximum effect at $200,000 gross revenue = $13,386, between 100 percent mackerel and 100 percent anchovy catch). A dichotomy of interest exists between the crewman and the vessel owner in that the effect of vessel size on profit and return on investment is opposite to that on crew share (maximum effect at $200,000 = $2,730). The highest profit and return on investment at any level of revenue is on a 150-ton vessel with an all-mackerel catch. The break-even point for a 150-ton vessel ranges from a gross revenue of about $65,000 for an all-mackerel catch to about $90,000 for an all-anchovy catch. We conclude that, given favorable market conditions, it is economically feasible to expand the wetfish fleet with surplus vessels from other fisheries at present levels of landings and prices.

B. FLEET EXPANSION AND BOAT REPLACEMENT WITH NEW BOATS

Using the same approach as with old vessels, we first present our tables summarizing the data and then present our analyses of the tables and our conclusions regarding the economic feasibility of new-vessel construction.

1. Summary Tables

Tables 23A, 23B, 23C, and 24 summarize predicted earnings under varying conditions of gross revenue, size of vessel, composition of catch, and construction subsidy. For these computations we assumed an arbitrary 7.5 percent interest rate on borrowed capital, which in turn was set also arbitrarily at 66.6 percent of fixed capital (Table 20). In this way the return to total capital has been split into two parts: return to borrowed capital (in the form of interest paid, as part of fixed costs) and return to equity capital (in the form of profits, as shown in Tables 23A, B, and C). The rate of return to equity capital depends then on the assumed interest rate on borrowed capital. Since this interest rate may vary greatly, it is appropriate to calculate the rate of return to total capital as an alternative way of expressing the return on investment. For this purpose the interest costs were added to profits, and the new profit values were then related to total capital from Table 20. These rates of return to total capital are summarized in Table 24.

2. Analysis of Summary Tables and Conclusions

As was found for vessels of the type now in use (Table 22), the crew share is most affected by the size of the vessel. Profit is also greatly affected by the size of the vessel (maximum effect at $250,000 gross revenue with a 50-percent subsidy = $14,310). Profit is most affected by the species composition of the catch (maximum effect at $250,000 gross revenue with 50-percent subsidy = $17,982). The highest profit at the $250,000 level of gross revenue is attained on the 154-ton vessel with an all-mackerel catch. At lower levels of gross revenue, the profit is greatest with the smallest vessel (66 tons capacity). The highest rate of return on investment is also with the smallest vessel, at all levels of gross revenue. The break-even point for a 66-ton vessel with no subsidy and with an all-mackerel catch is about $140,000, which is near the upper end of the range of gross revenue for the existing fleet in 1967 (Figure 8). A new 66-ton vessel, landing a catch with the same species composition as that in the 1967 landings of the fleet, would have to have a gross revenue of over $250,000 to achieve the levels of profit obtained by the top boats in the existing fleet in 1967 ($30,000, about a 30-percent return on investment for a new 66-ton vessel). This revenue is well above the maximum achieved by any boat in the existing fleet in any year. With a 50-percent construction subsidy, the amount of revenue needed drops to about $225,000, which is still a very high figure relative to the revenue obtained by the fleet in the past. For an all-anchovy catch, the break-even point for a 66-ton vessel with a 50-percent subsidy is about $145,000 gross revenue (7,250 tons of anchovies, or 110 capacity loads), and the profit at $250,000 gross revenue (12,500 tons of anchovies, or 190 capacity loads--a probably unachievable rate of catch) is only $22,321, an amount less than the profit for the top vessels in the existing fleet in 1967.

The predicted unprofitability of new vessels is caused by the high investment base. The lowest cost of a new vessel (from Table 20) is $147,000 (vessel with skiff and refrigeration), whereas the average market value of a vessel in the existing fleet is $45,000. This difference in value causes an extremely high increase in the following categories of fixed costs: insurance, depreciation, and interest on capital. The increase in fixed costs is partly offset by lower repair costs on new vessels. On two comparable vessels, for example, shown in the sample calculations of foregoing sections, the total owner's costs at a level of $150,000 gross revenue have risen from $36,800 on an old vessel to $61,112 on a new one. This means a 66-percent increase in owner's cost effected by higher investment costs, while the owner's share in net proceeds from fishing remains on the same level (about $54,000).

We must conclude that, at present catch rates and fish prices, the construction of new wetfish seiners, even with construction subsidies, for either vessel replacement or fleet expansion is not economically feasible. This situation may change in the future if the efficiency of wetfish seining can be improved through technological research or if new markets can be developed that will yield higher prices for wetfish.

Table 23A.—Summary table of predicted annual earnings for new vessels, with no construction subsidy

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of: Same species in same proportions as in landings for 1967 (Figure 4)				100 percent mackerel				50 percent mackerel, 50 percent anchovies				100 percent anchovies			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*
	66	1,781	6,058	−12,873	−17.5	1,379	6,194	−11,404	−15.5	3,190	6,158	−15,204	−20.7	5,000	6,121	−19,001	−25.8
	110	1,781	5,278	−18,930	−21.9	1,379	5,396	−17,419	−20.2	3,190	5,365	−21,230	−24.6	5,000	5,333	−25,040	−29.0
100,000	154	1,781	4,560	−22,339	−23.1	1,379	4,663	−20,765	−21.5	3,190	4,635	−24,493	−25.5	5,000	4,608	−28,419	−29.4
	210	1,781	4,560	−31,952	−28.4	1,379	4,663	−30,378	−27.0	3,190	4,635	−34,206	−30.4	5,000	4,608	−38,032	−33.8
	264	1,781	4,560	−43,240	−31.9	1,379	4,663	−41,666	−30.7	3,190	4,635	−45,494	−33.5	5,000	4,608	−49,320	−36.3
	66	2,671	9,367	1,416	1.9	2,069	9,571	3,476	4.7	4,784	9,516	−1,978	−2.7	7,500	9,462	−7,678	−10.4
	110	2,671	8,160	−3,533	−4.1	2,069	8,338	−1,269	−1.5	4,784	8,291	−6,983	−8.1	7,500	8,243	−12,699	−14.7
150,000	154	2,671	7,051	−5,432	−5.6	2,069	7,204	−3,037	−3.1	4,784	7,163	−8,812	−9.1	7,500	7,122	−14,554	−15.1
	210	2,671	7,051	−15,045	−13.4	2,069	7,204	−12,650	−11.2	4,784	7,163	−18,425	−16.4	7,500	7,122	−24,167	−21.5
	264	2,671	7,051	−26,333	−19.4	2,069	7,204	−23,938	−17.6	4,784	7,163	−29,713	−21.9	7,500	7,122	−35,455	−26.1
	66	3,561	12,676	14,864	20.2	2,759	12,948	17,609	23.9	6,378	12,874	10,512	14.3	10,000	12,803	3,407	4.6
	110	3,561	11,042	11,088	12.8	2,759	11,280	13,908	16.1	6,378	11,217	5,854	6.8	10,000	11,153	−358	−.4
200,000	154	3,561	9,542	10,724	11.1	2,759	9,745	13,730	14.2	6,378	9,691	6,513	6.7	10,000	9,636	−242	−.3
	210	3,561	9,542	1,740	1.5	2,759	9,745	4,746	4.2	6,378	9,691	−2,644	−2.3	10,000	9,636	−9,855	−8.7
	264	3,561	9,542	−9,426	−6.9	2,759	9,745	−6,210	−4.6	6,378	9,691	−13,932	−10.3	10,000	9,636	−21,143	−15.6
	66	4,452	15,984	28,310	38.5	3,449	16,325	31,743	43.1	7,974	16,233	22,867	31.1	12,500	16,142	13,991	19.0
	110	4,452	13,925	25,475	29.5	3,449	14,222	29,001	33.6	7,974	14,142	20,101	23.3	12,500	14,063	11,200	13.0
250,000	154	4,452	12,031	26,524	27.5	3,449	12,286	30,298	31.4	7,974	12,219	21,258	22.0	12,500	12,151	12,316	12.8
	210	4,452	12,031	17,540	15.6	3,449	12,286	21,314	18.9	7,974	12,219	12,274	10.9	12,500	12,151	3,332	3.0
	264	4,452	12,031	6,991	5.2	3,449	12,286	10,765	7.9	7,974	12,219	1,725	1.3	12,500	12,151	−7,723	−5.7

Table 23B.—Summary table of predicted annual earnings for new vessels, with 40-percent construction subsidy

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of: Same species in same proportions as in landings for 1967 (Figure 4)				100 percent mackerel				50 percent mackerel, 50 percent anchovies				100 percent anchovies			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*
	66	1,781	6,058	−5,754	−11.2	1,379	6,194	−4,285	−8.3	3,190	6,158	−8,085	−15.7	5,000	6,121	−11,882	−23.0
	110	1,781	5,278	−10,338	−17.4	1,379	5,396	−8,827	−14.9	3,190	5,365	−12,638	−21.3	5,000	5,333	−16,448	−27.7
100,000	154	1,781	4,560	−12,727	−19.4	1,379	4,663	−11,153	−17.0	3,190	4,635	−14,981	−22.9	5,000	4,608	−18,807	−28.7
	210	1,781	4,560	−20,471	−26.7	1,379	4,663	−18,897	−24.7	3,190	4,635	−27,725	−29.6	5,000	4,608	−26,551	−34.6
	264	1,781	4,560	−29,191	−31.8	1,379	4,663	−27,617	−30.1	3,190	4,635	−31,445	−34.3	5,000	4,608	−35,271	−38.5
	66	2,671	9,367	8,070	15.6	2,069	9,571	9,722	18.8	4,784	9,516	4,805	9.3	7,500	9,462	−559	−1.1
	110	2,671	8,160	4,728	8.0	2,069	8,338	6,633	11.2	4,784	8,296	1,504	2.5	7,500	8,243	−4,107	−6.9
150,000	154	2,671	7,051	3,907	6.0	2,069	7,204	6,161	9.4	4,784	7,163	700	1.1	7,500	7,122	−4,942	−7.5
	210	2,671	7,051	−3,564	−4.6	2,069	7,204	−1,169	−1.5	4,784	7,163	−6,944	−9.1	7,500	7,122	−12,686	−16.6
	264	2,671	7,051	−12,638	−13.8	2,069	7,204	−9,889	−10.8	4,784	7,163	−15,664	−17.1	7,500	7,122	−21,406	−23.3

Table 23B.—Continued

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of:															
		Same species in same proportions as in landings for 1967 (Figure 4)				100 percent mackerel				50 percent mackerel, 50 percent anchovies				100 percent anchovies			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*
	66	3,561	12,676	21,518	41.7	2,759	12,948	23,449	45.4	6,378	12,874	17,165	33.3	10,000	12,803	10,059	19.5
	110	3,561	11,042	19,118	32.2	2,759	11,280	21,515	36.3	6,378	11,217	14,818	25.0	10,000	11,153	7,695	13.0
200,000	154	3,561	9,542	19,708	30.7	2,759	9,745	22,713	34.6	6,378	9,691	15,496	23.6	10,000	9,636	8,339	12.7
	210	3,561	9,542	12,471	16.3	2,759	9,745	15,475	20.2	6,378	9,691	8,258	10.8	10,000	9,636	1,079	1.4
	264	3,561	9,542	4,322	4.7	2,759	9,745	7,326	8.0	6,378	9,691	17	0	10,000	9,636	—7,541	—8.2
	66	4,452	15,984	34,964	67.8	3,449	16,325	37,176	72.0	7,974	16,233	29,520	57.2	12,500	16,142	20,644	40.0
	110	4,452	13,925	33,505	56.5	3,449	14,222	36,397	61.4	7,974	14,142	28,131	47.4	12,500	14,063	19,259	32.5
250,000	154	4,452	12,031	35,508	54.2	3,449	12,286	39,281	59.9	7,974	12,219	32,358	49.4	12,500	12,151	21,299	32.5
	210	4,452	12,031	28,270	36.9	3,449	12,286	32,043	41.8	7,974	12,219	23,004	30.0	12,500	12,151	14,062	18.3
	264	4,452	12,031	20,121	21.9	3,449	12,286	23,894	26.0	7,974	12,219	14,901	16.2	12,500	12,151	5,912	6.4

Table 23C.—Summary table of predicted annual earnings for new vessels, with 50-percent construction subsidy

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of:															
		Same species in same proportions as in landings for 1967 (Figure 4)				100 percent mackerel				50 percent mackerel, 50 percent anchovies				100 percent anchovies			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*
	66	1,781	6,058	—3,960	—8.7	1,379	6,194	—2,491	—5.5	3,190	6,158	—6,291	—13.8	5,000	6,121	—10,088	—22.1
	110	1,781	5,278	—8,148	—15.3	1,379	5,396	—6,637	—12.4	3,190	5,365	—10,448	—19.6	5,000	5,333	—14,258	—26.8
100,000	154	1,781	4,560	—10,348	—17.7	1,379	4,663	—8,774	—15.0	3,190	4,635	—12,602	—21.5	5,000	4,608	—16,428	—28.1
	210	1,781	4,560	—17,714	—26.2	1,379	4,663	—16,140	—23.7	3,190	4,635	—19,968	—29.5	5,000	4,608	—23,794	—35.2
	264	1,781	4,560	—25,660	—31.8	1,379	4,663	—24,086	—29.8	3,190	4,635	—27,914	—34.6	5,000	4,608	—31,740	—39.3
	66	2,671	9,367	9,747	21.4	2,069	9,571	11,806	25.9	4,784	9,516	6,481	14.2	7,500	9,462	1,135	2.5
	110	2,671	8,160	6,781	12.7	2,069	8,338	8,891	16.7	4,784	8,296	3,551	6.7	7,500	8,243	—1,917	—3.6
150,000	154	2,671	7,051	6,130	10.5	2,069	7,204	8,368	14.3	4,784	7,163	2,971	5.1	7,500	7,122	—2,563	—4.4
	210	2,671	7,051	—807	—1.2	2,069	7,204	1,484	2.2	4,784	7,163	—4,187	—6.2	7,500	7,122	—9,929	—14.7
	264	2,671	7,051	—8,753	—10.8	2,069	7,204	—6,358	—7.9	4,784	7,163	—12,133	—15.0	7,500	7,122	—17,874	—22.1
	66	3,561	12,676	23,194	50.8	2,759	12,948	25,905	56.8	6,378	12,874	18,842	41.3	10,000	12,803	11,736	25.7
	110	3,561	11,042	21,164	39.7	2,759	11,280	23,984	45.0	6,378	11,217	16,865	31.6	10,000	11,153	9,742	18.3
200,000	154	3,561	9,542	21,931	37.4	2,759	9,745	24,936	42.6	6,378	9,691	17,719	30.3	10,000	9,636	10,562	18.0
	210	3,561	9,542	15,047	22.2	2,759	9,745	18,052	26.7	6,378	9,691	10,835	16.0	10,000	9,636	3,678	5.4
	264	3,561	9,542	7,621	9.4	2,759	9,745	10,626	13.2	6,378	9,691	3,409	4.2	10,000	9,636	—4,008	—5.0
	66	4.452	15,984	36,640	80.4	3,449	16,325	40,005	87.7	7,974	16,233	31,196	68.4	12,500	16,142	22,321	48.9
	110	4.452	13,925	35,551	66.7	3,449	14,222	39,077	73.3	7,974	14,142	30,178	56.6	12,500	14,063	21,276	39.9
250,000	154	4,452	12,031	37.731	64.4	3,449	12,286	41,504	70.9	7,974	12,219	32,465	55.4	12,500	12,151	23,522	40.2
	210	4.452	12,031	30,847	45.6	3,449	12,286	34,620	51.2	7,974	12,219	25,580	37.8	12,500	12,151	16,638	24.6
	264	4,452	12,031	23,421	29.0	3,449	12,286	27,194	33.7	7,974	12,219	18,194	22.5	12,500	12,151	9,212	11.4

Table 24.—Summary table of predicted returns to capital for new vessels

Gross revenue	Vessel size (capacity)	No construction subsidy				40-percent construction subsidy				50-percent construction subsidy			
		Composition of landings by value:				Composition of landings by value:				Composition of landings by value:			
		As in 1967 (Fig. 4)	100 percent mackerel	50 percent mackerel 50 percent anchovies	100 percent anchovies	As in 1967 (Fig. 4)	100 percent mackerel	50 percent mackerel 50 percent anchovies	100 percent anchovies	As in 1967 (Fig. 4)	100 percent mackerel	50 percent mackerel 50 percent anchovies	100 percent anchovies
Dollars	*Tons*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
	66	−1.7	−0.9	−2.8	−4.7	0.3	1.4	−1.4	−4.2	1.2	2.4	−0.7	−4.0
	110	−3.2	−2.6	−4.2	−5.8	−2.0	−1.0	−3.4	−5.9	−1.4	−0.3	−3.1	−5.9
100,000	154	−3.8	−3.2	−4.6	−6.1	−2.7	−1.8	−4.0	−6.2	−2.3	−1.2	−3.8	−6.3
	210	−5.7	−5.2	−6.4	−7.6	−5.6	−4.8	−6.8	−8.7	−5.6	−4.7	−6.9	−9.1
	264	−6.9	−6.5	−7.5	−8.6	−7.5	−6.9	−8.5	−10.1	−7.8	−7.1	−8.9	−10.8
	66	5.5	6.4	3.7	0.9	10.6	11.8	8.1	4.2	12.8	14.6	10.1	5.5
	110	3.3	4.2	1.8	−0.6	7.6	8.9	5.6	2.0	9.5	11.0	7.1	3.1
150,000	154	2.7	3.6	1.3	−0.8	6.9	8.2	5.0	1.7	8.6	10.1	6.5	2.8
	210	−0.2	0.6	−1.3	−3.1	2.8	4.0	1.1	−1.7	4.1	5.4	2.1	−1.1
	264	−2.3	−1.7	−3.3	−4.8	−0.6	0.5	−1.9	−4.3	0.3	1.5	−1.3	−4.1
	66	12.1	13.5	10.0	6.4	20.6	22.0	17.3	12.0	24.3	26.6	20.6	14.5
	110	9.4	10.6	7.2	4.6	16.8	18.4	14.1	9.5	20.0	22.1	16.9	11.7
200,000	154	8.8	10.0	7.2	4.6	16.0	17.8	13.6	9.4	19.1	21.1	16.3	11.5
	210	5.3	6.3	3.8	1.5	10.8	12.3	8.7	5.1	13.2	14.9	10.8	6.6
	264	2.2	3.0	1.0	−0.9	6.4	7.6	4.6	1.4	8.2	9.7	6.2	2.6
	66	18.8	20.5	16.1	11.7	30.6	32.2	26.5	19.9	35.7	38.6	31.1	23.5
	110	15.5	17.0	13.2	9.5	26.0	27.9	22.6	16.9	30.6	33.2	26.7	20.1
250,000	154	14.8	16.2	12.8	9.4	25.2	27.4	23.4	16.9	29.6	32.1	26.1	20.2
	210	10.4	11.7	8.7	5.8	18.7	20.6	16.1	11.6	22.3	24.5	19.3	14.1
	264	6.6	7.6	5.2	2.6	13.0	14.6	10.8	7.0	15.9	17.7	13.3	9.0

SUMMARY

The San Pedro wetfish-boat fleet has dwindled to half its size of 10 years ago. Large underused stocks of wetfish (jack mackerel and anchovies) exist in the California Current region. If these resources are to be harvested, the wetfish fleet must expand through the construction of new vessels or through the acquisition of surplus vessels from other fisheries. The purposes of the present study were to describe and document the financial condition of the fleet, to develop a model of wetfish-boat costs and earnings, and by means of this model, to examine the economic feasibility of fleet expansion and vessel replacement.

The findings of the study were that the fleet is antiquated, corporate profits are low, corporate net worth is low, working capital is inadequate, crew earnings are very low and are not increasing in pace with inflation, and employment in the fleet has decreased by 30 percent in the last 5 years.

Analysis of costs in several categories yielded equations to be used in predicting earnings at various levels of revenue and with various combinations of vessel size and composition of the catch. Their use showed that, of the four principal wetfish species, mackerel cost the least to land (per unit of value), anchovies and tuna cost about the same (more than mackerel) to land, and bonito cost the most to land.

Predicted crew earnings, profit, and return on investment based on the relations developed in the analysis of costs showed that although the expansion of the fleet through recruitment of existing vessels from other fisheries is feasible, fleet expansion or vessel replacement through construction of new vessels is not economically feasible at present rates of catch and prices of fish.

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MS. #2005

COMMERCIAL FEASIBILITY OF IRRADIATING HADDOCK AND COD FILLETS—1. QUALITY OF HADDOCK AS LANDED AT BOSTON, MASSACHUSETTS

by

John D. Kaylor and Edward J. Murphy

ABSTRACT

Successful commercial preservation of fresh fish fillets by irradiation requires that raw material of a level of quality suitable for irradiation be available. To determine the amount of haddock, *Melanogrammus aeglefinus*, landed in Boston by the New England offshore fleet that meet this level, we surveyed the Boston haddock fishery. About 78 percent of the haddock landed were of a level of quality high enough to warrant their being irradiated. Because haddock and cod, *Gadus morhua*, are handled similarly, this conclusion also applies to cod. Thus, the quality of fish would not be a problem in the irradiation preservation of fresh haddock and cod fillets.

CONTENTS

Authors: John D. Kaylor, *Supervisory Food Technologist*, and Edward J. Murphy, *Food Technologist*, Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Massachusetts 01930.
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INTRODUCTION

As was indicated in our introductory paper (Kaylor and Murphy, 1970) to this series, the purpose of the work reported here was to determine the proportion of haddock landed at Boston that are fresh enough to warrant their being irradiated.

We report first on our experimental observations and then on a computer estimation of the correlations among our test data.

I. EXPERIMENTAL OBSERVATIONS

A. PROCEDURE

1. Method of Sampling

For the purpose of this survey, we were interested chiefly in the landings of the offshore fleet (medium-sized and large-sized trawlers), because the offshore trawlers stay out on the fishing banks longer than the smaller trawlers of the inshore fleet do. As a consequence, the offshore fleet lands a greater proportion of fish that are older in terms of the time that has elapsed since they are caught.

We tried two sampling plans — an on-ship plan and an on-wharf plan. Between both methods of sampling, we covered the important variations in seasonal temperature and were able to sample 34 percent of the medium-sized and large-sized trawlers of the Boston fishing fleet from one to five times each.

a. On-ship plan.—Our on-ship sampling plan, which was based upon statistical considerations, was as follows:

1. For trips of 20,000 to 40,000 pounds, take from each pen a sample consisting preferably of 25 fish but not less than 20 fish.
2. For trips of 40,000 to 60,000 pounds, take from each pen a sample consisting preferably of 20 fish but not less than 15 fish.
3. For trips of 60,000 to 100,000 pounds, take from each pen a sample consisting preferably of 15 fish but not less than 10 fish.

We tried this sampling plan for three trips each of Trawlers 1 and 6 and part of one trip of Trawler 2 (Table 1) in the winter.

b. On-wharf plan.—Subsequently, we adopted a different method of sampling — one that we did on the wharf rather than in the hold of the trawler. This method was as follows:

1. Take, at random, a haddock dumped into the weigh box from the canvas discharge basket of the trawler.
2. Examine the fish objectively and subjectively.
3. Continue examining the fish until all the fish have been unloaded.

We started this method of subsequently sampling in summer and continued it into autumn.

2. Method of Testing

We determined the temperature of the fish and the quality of the fish, as follows:

a. Temperature.—The temperatures of the haddock caught in the winter were measured in the hold of the trawlers as the fish pens were broken down prior to unloading the fish from the vessel. The temperatures of fish caught in the summer and autumn were measured at the point of discharge from the trawler into weigh boxes on the wharf.

We measured the temperatures by inserting stainless-steel temperature-sensing probes into each haddock, immediately forward of the first dorsal fin and through the thick fleshy portion down to the backbone and about half an inch along the side of it. Each probe was con-

Table 1.–Freshness survey of haddock landed at Boston 1965

Trawler Number	Date	Fish sampled	Temperature	Organoleptic etsimation					
				Damage	Skin	Eyes	Gills	Texture	Odor
		Number	*° F.*	*Scale of 1-4, with 1 being the highest value*					
1	Jan. 12	63	32.2	1.1	2.0	2.0	2.4	2.0	2.3
	Jan. 26	80	32.4	1.1	1.6	1.5	1.8	1.8	1.9
	Feb. 8	90	32.8	1.1	1.0	1.7	1.8	1.7	1.9
	Sept. 9	180	35.4	1.6	2.0	1.9	2.0	2.0	1.9
	Sept. 22	160	35.4	1.8	2.2	2.5	2.7	2.5	2.5
2	Feb. 9	32	32.2	1.0	1.0	1.1	1.5	1.5	1.8
	Aug. 31	120	34.0	1.6	2.1	2.5	2.6	2.6	2.4
	Sept. 13	180	34.7	1.6	1.9	2.1	2.2	2.0	2.0
	Oct. 5	111	33.6	2.0	2.2	2.6	2.6	2.6	2.4
	Nov. 1	65	35.3	2.0	2.2	2.4	2.2	2.2	2.2
3	Aug. 30	180	34.0	1.6	2.1	2.3	2.6	2.5	2.3
	Sept. 8	180	35.4	1.6	2.1	2.1	2.3	2.1	1.9
	Sept. 28	160	33.9	2.2	2.1	2.4	2.4	2.6	2.3
	Oct. 13	105	33.6	2.0	2.1	2.4	2.5	2.4	2.2
	Nov. 3	65	34.6	1.8	2.3	2.6	2.8	2.9	2.4
4	Aug. 26	60	36.2	1.7	2.1	2.4	2.5	2.5	2.3
	Oct. 6	109	32.8	2.0	2.1	2.1	2.3	2.3	2.2
	Oct. 18	131	34.3	1.8	2.0	2.1	2.2	2.1	2.0
	Oct. 28	15	34.0	1.7	1.4	1.4	1.7	1.7	1.6
5	Sept. 7	160	36.3	1.5	2.1	2.2	2.4	2.3	2.2
	Sept. 16	100	34.1	1.7	2.1	2.2	2.4	2.2	2.3
	Sept. 27	100	34.3	1.9	2.1	2.4	2.5	2.4	2.4
	Oct. 7	85	32.8	2.1	2.1	2.2	2.2	2.3	2.2
6	Jan. 18	46	32.4	1.3	2.0	2.0	2.0	2.1	2.0
	Feb. 1	62	32.8	1.0	1.0	1.5	1.5	1.7	1.7
	Feb. 10	80	33.7	1.0	1.0	1.8	1.9	1.9	2.0
7	Aug. 23	160	36.0	1.6	2.1	2.9	2.9	2.6	2.5
	Sept. 23	60	37.4	1.6	2.1	2.4	2.2	2.2	2.2
	Oct. 11	107	34.6	1.9	1.8	1.8	1.8	2.0	1.7
8	Aug. 27	172	34.2	1.8	2.1	2.4	2.5	2.7	2.2
	Sept. 2	160	33.7	1.3	1.9	1.8	2.1	2.2	1.9
	Nov. 4	120	36.6	1.8	2.0	1.7	1.7	1.9	1.6
9	Aug. 27	120	36.1	1.6	2.0	2.3	2.6	2.6	2.2
	Oct. 4	107	33.4	1.9	2.2	2.4	2.2	2.3	2.2
10	Oct. 8	100	33.5	1.8	2.0	2.1	2.2	2.2	1.9
	Nov. 2	71	33.2	2.1	2.3	2.5	2.6	2.7	2.4
11	Aug. 24	150	34.9	1.9	2.1	2.4	2.9	3.0	2.6
12	Oct. 14	100	34.0	2.1	2.1	2.0	2.1	2.1	1.9
13	Sept. 1	160	33.9	1.6	2.1	2.3	2.5	2.5	2.2
14	Sept. 3	92	33.0	1.3	1.8	1.7	2.0	1.9	1.5
15	Oct. 15	100	--	1.9	2.1	1.8	1.8	2.1	1.8
16	Oct. 22	80	34.1	1.8	1.8	1.6	1.8	1.6	1.8
17	Oct. 21	16	35.0	1.2	1.2	1.4	1.2	1.4	1.4
Total		4,594	4,494						
Average				1.6	1.9	2.1	2.2	2.2	2.0

nected to a Model 42 SF Tele-Thermometer (Yellow Springs Instrument Co.).[1] This instrument has an accuracy of ±1° F. in the range of —40° F. to 302° F. We allowed the instrument to come to equilibrium before we recorded the temperature reading.

[1] The use of trade names is merely to facilitate descriptions of the exact experimental procedure; no endorsement of commercial products is implied.

b. Quality.—Described in this section are the criteria of quality we used and the basis for acceptance or rejection of a trip for the purposes of this survey.

(1) Criteria of quality used.—In planning the survey, we tried to develop suitable criteria for freshness and other quality characteristics. The criteria we chose consisted of

only four categories, which were assigned numerals indicating their relative score values. In the criteria, only the very freshest or perfect fish were assigned a value of 1 for each organoleptic characteristic such as damage, skin, eyes, and gills; the lowest quality fish were assigned a value of 4 for the corresponding characteristics. Table 2 shows the detailed criteria.

The classification of quality characteristics into only four categories had two advantages. First, it was based on a system that, in previous work, we had found successfully describes the changes taking place in the fish as they age. Second, the system could readily be adapted for use in automatic data processing.

(2) Basis used for acceptance or rejection of a trip load.—Organoleptic examinations formed the basis for all our judgments of acceptance or rejection. Although we recorded six subjective factors (Table 1), we used only the last four of these factors (eyes, gills, texture, and odor) to decide whether to accept or reject a trip load.

To decide on the proportion of haddock of a freshness level suitable for irradiation processing, we had to adopt certain cut off points. On the basis of past work, we decided that haddock (and scrod haddock) would be acceptable if:

1. The average score for appearance of eyes, color of gills, texture of flesh, and odor of gill cavity was less than 2.5.
2. The average score for odor of gill cavity did not exceed 2.3.
3. Less than 1 percent of the fish samples had a score of 4 for both color of gills and odor of gill cavity.

B. RESULTS

1. Temperature

Table 1 shows the results of the temperature measurements on a trip basis, and Table 3 summarizes the data on a seasonal basis. The temperature of fish caught in the winter is definitely lower than that of fish caught in the summer or in the autumn, but the difference is small.

2. Quality

Reported here are (a) the number of trips "rejected" on the basis of quality and (b)

Table 2.–Organoleptic criteria for judging fresh fish

Factor	Rating	Characteristics
Damage to the whole fish	1	No physical damage. Skin intact (except for evisceration cuts).
	2	Slight damage or suffusion of blood under the skin. Minor break in skin surface.
	3	Fork holes or torn flesh evident. Crushed. Belly blown with some viscera visible in whole fish.
	4	Badly torn or crushed. Belly blown with viscera protruding in whole fish.
Condition of the skin surface	1	Skin surface has high sheen, not faded. Moderate amount of clear, evenly distributed slime. Whole appearance bright as though alive.
	2	Skin surface somewhat faded in luster. Slime thicker and beginning to become opaque.
	3	Skin faded, dull. Scales loose. Slime thick and opaque.
	4	Skin very faded. Very dull. Scales loose and detach easily. Slime thick, opaque, and knotted or ropy.
Appearance of the eyes	1	Clear, bright, slightly protruding to bulging (depending on species), black pupil, transparent cornea.
	2	Cornea slightly cloudy, slightly dull, not protruding. Pupil tending to become cloudy.
	3	Dull, flat, or commonly sunken. Cornea opaque. Pupil definitely cloudy or milky.
	4	Sunken, very dull. Cornea discolored — reddish or yellowish. Pupil opaque.
Color of the gills	1	Bright to dark red to bright pink, depending on species. Free of slime. No odor.
	2	Less color intensity. Dull red to pink. Slightly slimy. May have slight odor.
	3	Pink to pale pink. Slimy. Number 3 odor classification (see Odor).
	4	Faded pink, to discolored, tan yellow, grey, or brown. Number 4 odor classification (see Odor).
Texture of the flesh	1	Flesh very firm and elastic (in rigor mortis — body rigid). Indented finger marks disappear readily.
	2	Flesh losing elasticity. Indented finger marks disappear slowly.
	3	Flesh moderately soft. Resiliency lost. Pressure marks remain.
	4	Flesh soft and limp. Pits readily on being pressed.
Odor of the gill cavity	1	Odor characteristic of freshly caught fish of the particular species.
	2	Practically no odor. Neutral or very faint fishy odor.
	3	Slight fishy odor.
	4	Strong fishy, ammoniacal, or other repugnant odors associated with decomposition in varying degrees.

Table 3.–Seasonal difference of haddock landings at Boston 1965

Season	Trips	Samples	Temper-ature	Average of all measurements of each factor					
				Subjective data on:					
				Damage	Skin	Eyes	Gills	Texture	Odor
	No.	No.	° F.	Subjective evaluation on a scale of 1 to 4					
Winter	7	453	32.6	1.1	1.4	1.5	1.8	1.8	2.0
Summer	15	2,174	34.8	1.6	2.0	2.2	2.4	2.4	2.2
Autumn	21	1,967	34.3	1.9	2.0	2.1	2.2	2.2	2.0

Note: See Table 2 for a definition of the subjective evaluation.

the seasonal variation in the quality of the haddock.

a. Number of trips rejected.—For our purpose, we rejected nine complete trawler landings even though most of the fish in each trip would have passed inspection according to our criteria. Only 1 haddock scoring 4 on the basis of gills and odor could negate the entire trip if less than 100 fish were sampled. Occasionally, no fish had a score of 4 for both gills and odor, but we rejected the entire trip simply because the general level of freshness as judged by the condition of the eyes, gills, texture, and odor was too low by our standard.

This rejection does not mean that the fish were unfit for consumption or that they violated food laws. Instead, it means that, although the fish were acceptable for immediate consumption or freezing, most of them had been caught for too long a time to permit them to have as long a shelf life after irradiation as fresher fish would.

b. Seasonal variation in quality.—Table 3 summarizes the data on quality according to season. In every category, the quality of fish caught in the winter was superior to that of those caught in the summer and in the autumn.

II. COMPUTER ESTIMATION OF CORRELATIONS AMONG TEST DATA

When this survey was begun, we were interested in determining what correlation, if any, we would find, with the aid of a computer, (1) between organoleptic evaluations and temperature and (2) among all six organoleptic factors, each one against the remaining five.

A. PROCEDURE

The data from each trawler trip were punched on a card and fed into a computer that had been programed to give correlations, first on a trip basis and then on the basis of one large population instead of on the basis of 34 separate populations.

B. RESULTS

1. Trip Basis

When the data were programed on a trip basis, the results were inconclusive, because the differences among the factors of each trip were not large enough for the computer to distinguish.

2. One-Large-Population Basis

When the data were programed on the basis of one large population, however, the results were strikingly different. By means of the data obtained with the aid of the computer, we now found differences that only a skilled fish inspector could recognize before.

a. Correlations of organoleptic evaluations with temperature.—The temperatures were quite uniformly low (Table 1), and the difference between winter and summer temperatures (Table 3) was relatively small. Nevertheless, the computer showed a correlation between organoleptic score and temperature that was significant at the 1-percent level of probability.

b. Correlations within the group of six organoleptic factors studied.—The highest degrees of correlation was found within the group of the six organoleptic factors. In this group, the lowest correlations were between damage and the remaining five organoleptic factors and between skin and the remaining five organoleptic factors.

This result supported our original choice of using only four factors (eyes, gills, texture, and odor) upon which to pass final judgment to accept or reject trips as shown in Table 1. Furthermore, the data obtained with the computer agreed completely with what skilled inspectors have maintained are the two most reliable factors of all — appearance of the gills and odor. The correlation between these two factors was highly significant, indicating a value that is larger than would be expected by chance at the 1-percent level of probability.

SUMMARY

We surveyed haddock landings in Boston, Massachusetts, to determine whether the level of freshness was high enough to warrant the use of radiation to extend the shelf life of fresh fillets.

The survey was made during the winter, summer, and autumn so as to reflect the effect of temperature differences of the principal seasons, with spring and autumn being considered equivalent. Criteria for subjective measurements of freshness were developed and applied to over 4,500 individual samples of haddock. Objective measurements of temperature were made by Tele-Thermometer.

All data were fed into a computer that was programed to give correlations among the temperature measurements and the expert subjective judgments. The computer showed that subjective examinations had significant to highly significant correlations at the 1-percent level of probability, but the judgment of highly skilled fish examiners was superior to the findings of the computer in distinguishing and recording fine distinctions.

CONCLUSIONS

During the winter, summer, and autumn of 1965, 78.6 percent of the haddock examined by us at the Boston Fish Pier was fresh enough to justify the use of irradiation. Because haddock and cod are handled alike, this conclusion also applies to cod. Thus, the freshness of fish would not be a problem in the irradiation preservation of haddock and cod fillets.

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COMMERCIAL FEASIBILITY OF IRRADIATING HADDOCK AND COD FILLETS—2. TEMPERATURE PATTERNS DURING SHIPMENTS OF FRESH FILLETS BY TRUCK AND BY RAIL

by

John D. Kaylor and Edward J. Murphy

ABSTRACT

For fresh haddock and cod fillets to be irradiated and shipped commercially to distant points in the United States, the fillets must be kept near the temperature of ice during distribution. To check on the temperatures to be expected, we surveyed the principal methods of commercial distribution of fresh fishery products. We found that present commercial methods of distributing fresh haddock fillets result in fillet temperatures that average less than 40° F., a temperature that would be sufficiently low to permit shipment of irradiated fillets to the most distant parts of the country.

CONTENTS

Authors: John D. Kaylor, *Supervisory Food Technologist*, and Edward J. Murphy, *Food Technologist*, Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Massachusetts 01930.
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INTRODUCTION

The ultimate goal in the present series of studies was to determine whether it is commercially feasible to irradiate fresh cod and haddock fillets for shipment by common carrier to distances well beyond present-day markets, and keep them at a high level of freshness.

To ensure a minimum expenditure of experimental funds, we decided that the first step in this study was to determine what proportion of fresh haddock landed at Boston, Massachusetts, has the high quality that would justify irradiation. This study showed that about 78 percent of the haddock (and presumably also of cod) were suitable for this purpose and that the quality of fresh cod and haddock therefore would not be a limiting factor.

To ensure further a minimum expenditure of funds, we decided to determine whether temperatures of fillets in channels of commercial distribution would be a limiting factor. The purpose of the work reported in this paper, therefore, was to determine patterns of temperature that would be encountered during commercial shipment of fresh fillets by truck and by rail from Massachusetts fishery centers to distant markets.

I. SHIPMENT BY TRUCK

Shipments by truck were of four kinds: (A) processor-distributor shipments, (B) frozen-food shipments, (C) refrigerated fresh-fish shipments, and (D) nitrogen-gas refrigerated shipments.

A. PROCESSOR-DISTRIBUTOR SHIPMENTS

1. Procedure

Described here are: (a) preparation of the samples, (b) recording of the data, (c) types of shipping containers used, and (d) methods of shipment.

a. Preparation of samples.— To measure the temperature of fillets that are transported by common carrier, we obtained the permission and cooperation of fishery firms to use their regular commercial shipments of fillets. In addition, we purchased haddock fillets on the open market and shipped them under commercial conditions to supplement the data gained from the industry shipments.

The internal temperature of the fillets was obtained by inserting sterilized temperature-sensing probes into the center of fillets wrapped in cellophane and packed in fillet cans or in fibre boxes, with the wire leads running to the outside of the bulk shipping containers. These containers were wooden barrels or wooden boxes, depending upon the distance the fish were to be shipped. This arrangement required us to enter the vehicle to record the temperatures. In some instances, however, we were able to use long wire leads run from the shipping containers through the truck-body drain holes to the outside of the trailer. The second arrangement permitted us to read and record fillet temperatures without opening trailer doors during shipment. Normally, the trailer doors are not opened until the trailer arrives at its destination.

b. Recording of data.— The temperature was measured with a widespan transistorized thermometer (YSI Model 42SF Tele-Thermometer[1]), which was carefully calibrated before each shipment. It had an accuracy of ±1° F. and a range from —40° F. to +302° F., divided into three subranges. Temperatures of the air in the vehicle were obtained by means of a bimetallic spring-wound, 7-day recording thermometer with a circular paper chart. Outside air temperatures were obtained by means of a general-purpose, all-metal thermometer in which the temperature-sensing element was a bimetallic double helix coil. A Bureau of Commercial Fisheries food technologist accompanied each shipment from the originating shipping point to the city of destination. His

[1] The mention of trade names is merely to facilitate description; no endorsement is implied.

duties were to record the temperatures of the fillets, make observations on handling practices, and ship the fillets back to Gloucester by air for further testing. The methods of distribution we studied reflected widespread industry practices, and we made the shipments to embrace the extremes of temperature conditions to be found in present and prospective market areas.

c. Types of shipping containers. — Fresh fillets are shipped most commonly in 10-, 20-, or 30-pound-capacity oblong metal cans or, less commonly, in waxed fibreboard containers of 10- or 20-pound capacity. These containers are buried in ice inside bulk shipping containers of two types. The most common bulk shipping container is a wooden box that will hold five 20-pound containers and about 80 pounds of ice. This wooden container is being replaced, to a small extent, by a heavily waxed fibreboard container. Both the wooden and fibreboard containers are shipped exclusively by truck. The second type of shipping container is a wooden barrel that is capable of holding five 20-pound fillet cans and about 150 pounds of ice.

When the fillets are packed in boxes, they are always shipped in insulated, refrigerated trucks to destinations usually located no farther from Boston than cities in Kentucky and Ohio. When the fillets are packed in barrels, they are shipped to more distant points, such as cities in Texas, and are transported entirely by rail in noninsulated, nonrefrigerated freight cars along with general merchandise. Because of the longer distances to which they are shipped, the barrels are re-iced one or more times in transit, depending upon the temperature and the distance of the destination to which the shipment is being made.

d. Methods of shipment.—Formerly, some fish processors acted as their own distributors, although comparatively few such individuals are active in the industry now. The distributor whose operation we studied has a small fleet of trucks and makes sales in Western Massachusetts and nearby Eastern New York. Round trips are made weekly in well-insulated, two-compartmented trucks in good physical condition and take about a day. Fresh seafoods, which are carried in the forward compartment, are invariably well iced. No mechanical refrigeration is available in this compartment, so ice is the sole means of refrigeration. The doors to the fresh-seafood compartment may be opened as many as 30 times during deliveries. Frozen foods are carried in the rear compartment where the temperature is maintained by an electrical system of refrigeration.

2. Results

Table 1 indicates that, in general, the temperature of fresh fillets at the beginning of any trip are higher than desirable (over 40° F.). Although the temperature of the fillets generally drops by the end of the sales-distribution trip, the interval is too short (less than a day) to achieve the most desirable cooling effect by means of ice alone.

B. FROZEN-FOOD SHIPMENTS

1. Procedure

Long-distance hauls of fresh fillets are made in well-insulated mechanically refrigerated

Table 1.—Temperature of fresh haddock fillets shipped by processor's truck from Gloucester, Massachusetts, to the Albany, New York, area, 1965

Month	Weight of fillets shipped	Length of time fillets were in transit	Temperature of fillets at: Start of trip, Maximum	Start of trip, Minimum	Start of trip, Average	End of trip, Maximum	End of trip, Minimum	End of trip, Average
	Pounds	*Hours*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
January	2,500	27	54	44	50.0	33	33	33.0
January	3,000	26	48	41	44.2	38	35	36.6
July	4,500	22	50	42	45.1	39	39	39.0
September	3,500	22	56	48	52.0	42	42	42.0
November	2,000	20	44	39	42.5	41	37	39.0

Note 1: The truck was insulated but was not refrigerated.
Note 2: The average temperatures shown were the averages of 60 recordings per trip.

trailer trucks, which carry frozen seafoods as the main cargo to points as far as Florida. These vehicles carry the frozen seafoods in the main section of the mechanically refrigerated trailer and carry the boxed iced fish in small portion of the rear of the trailer. Usually, the frozen and fresh seafoods are separated by a canvas or plastic drop curtain or sometimes by 4-inch insulated wall. The trips to Florida commonly take 5 or 6 days, depending on the number of delivery stops the driver must make.

A common feature of this method of shipment by truck is that the fresh fillets at the rear of the trailer become partly frozen by the time the vehicle arrives in Northern Florida. At this point, the fresh fillets are usually transferred to a different truck that is used exclusively for delivery of fresh food products. The partly frozen fresh fillets are allowed to thaw before final delivery.

2. Results

Table 2 shows that the temperature of fresh fillets is always lowered to below 32° F. regardless of the initial temperature of fillets.

C. REFRIGERATED FRESH-FISH SHIPMENTS

1. Procedure

Fresh seafoods exclusively are shipped several times a week from Boston to Ohio cities in well-insulated, mechanically refrigerated trailer trucks. Fresh fillets cans are buried in ice in wooden boxes or in heavily waxed fibreboard boxes. The covers of the wooden boxes are fastened securely by nails, and those of the fibreboard boxes are fastened by wire strapping. Throughout the trip, the temperature of the air in the trailer is maintained at about 28° F. by means of mechanical refrigeration. The combination of ice immediately surrounding the fillet containers and the mechanically refrigerated air in the trailer ensure that the temperature of the fillets is maintained at slightly above the freezing point of the fillets.

2. Results

Table 3 shows that this method of transportation always succeeds in lowering the temperature of the fresh fillets to ideally low levels by the time the shipment arrives at the city of destination. This lowering invariably occurs regardless of the temperature of the fillets at the start of the trip.

D. NITROGEN-GAS REFRIGERATED SHIPMENTS

1. Procedure

Substantial amounts of fresh fillets (chiefly flounder) are shipped from New Bedford, Massachusetts, in insulated, nitrogen-gas refrigerated trailer trucks. We wished to compare the temperature pattern of this method of distribution against that of the dominant

Table 2.—Temperature of fresh haddock fillets shipped by frozen-food truck from Gloucester, Massachusetts, to Miami, Tampa, and Jacksonville, Florida, 1965

Month	Weight of fillets shipped	Length of time fillets were held:		Temperature of fillets at:					
				Start of trip			End of trip		
		At MPDI	In transit	Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	*Hours*	*Hours*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
February	240	--	117	39	37	37.5	19	16	17.5
March	240	--	120	53	46	49.0	28	26	27.9
May	160	--	119	42	36	38.8	32	30	31.0
May	160	--	119	41	35	38.2	30	28	29.2
August	100	--	119	46	42	43.7	30	24	28.0
September	100	--	137	47	42	44.8	20	19	19.5
October	160	22	113	42	33	36.0	24	23	23.2
November	100	19	77	50	49	49.5	31	30	30.5

Note 1: The truck was refrigerated and insulated; the minimum load was 24,000 pounds.
Note 2: MPDI (Marine Products Development Irradiator, Bureau of Commercial Fisheries, Gloucester, Massachusetts).
Note 3: The average temperatures shown were the averages of 111 recordings per trip.

refrigerated fresh-fish shipments by mechanically refrigerated truck. Shipments from New Bedford are made in round fillet cans rather than in the customary oblong fillet cans. The round cans have soldered side seams to make them watertight, because the custom for nearly 30 years has been to add about a pint of brine to the containers immediately before they are closed. These fillet cans are buried in ice as are the oblong fillet cans.

2. Results

Table 4 shows the temperature pattern of a commercial shipment of flounder fillets from New Bedford, Massachusetts, to Baltimore, Maryland. Although the temperature of the trailer is uniformly low, the temperatures of the fillets are not as low as are those found in the conventional mechanically refrigerated trailer trucks that are used exclusively for hauling shipments of fresh fishery products.

Table 3.–Temperature of fresh haddock fillets shipped by refrigerated fresh-fish trucks from Boston, Massachusetts, to Cleveland, Ohio, 1965

Month	Weight of fillets shipped	Length of time fillets were held		Temperature of fillets at:					
				Start of trip			End of trip		
		At MPDI	In transit	Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	*Hours*	*Hours*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
March	240	--	67	42	38	39.0	32	30	30.9
March	240	--	66	44	32	39.4	31	28	29.6
April	240	--	66	46	45	45.1	32	30	31.4
June	240	--	66	52	48	49.6	32	31	31.6
August	240	3	66	62	51	54.8	29	29	29.0
November	240	--	66	39	34	37.2	32	30	30.8

Note 1: The truck was refrigerated and insulated; the minimum load was 24,000 pounds.
Note 2: MPDI (Marine Products Development Irradiator, Bureau of Commercial Fisheries, Gloucester, Massachusetts).
Note 3: The average temperatures shown were the averages of 108 recordings per trip.

Table 4.–Temperature of fresh flounder fillets shipped by nitrogen-gas refrigerated truck from New Bedford, Massachusetts, to Baltimore, Maryland, 1966

Month	Weight of fillets shipped	Length of time fillets were in transit	Temperature of fillets at:					
			Start of trip			End of trip		
			Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	*Hours*	° *F.*	° *F.*	° *F.*	° *F.*	° *F*	° *F.*
April	240	48	42	40	41	47	32	40

Note 1: The truck was refrigerated and insulated; the minimum load was 20,000 pounds.
Note 2: The average temperatures show the averages of 60 recordings.

II SHIPMENT BY RAIL

The oldest commercial method of interstate distribution of fresh fillets is by rail. We made rail shipments from Boston, Massachusetts, to three cities: Jacksonville, Florida; Texarkana, Texas; and Seattle, Washington.

A. SHIPMENT TO JACKSONVILLE, FLORIDA

1. Procedure

The preparation of samples and the recording of data were identical for both truck and rail shipments. The containers for rail shipments differed from those used in truck shipments. We followed the customary industry practice of placing five 20-pound fillet cans in a wooden barrel with about 150 pounds of ice. The top of each barrel was covered with a specially treated combination of plastic and burlap to provide a flexible cover, which was coopered in place.

The barrels were shipped by regular noninsulated, nonrefrigerated railway freight cars that carry general freight. The temperature of the air in the cars frequently rose into the 80's and 90's Fahrenheit. The barrels, therefore, were re-iced in transit one or more times, depending upon the amount of ice that was melted. The flexible covers of the barrels aid re-icing in transit, whereas wooden boxes with covers that are nailed fast are too inconvenient to re-ice.

2. Results

Table 5 shows how effectively this method of distribution operates either to maintain fillets at initially low temperatures or to prevent excessive rise of temperature during the hot season.

B. SHIPMENT TO TEXARKANA, TEXAS

1. Procedure

All shipments by rail were made in barrels as described in the preceding procedure.

2. Results

Table 6 shows how effectively desirable low temperatures (less than 40° F.) are maintained with this relatively primitive method of distribution.

C. SHIPMENT TO SEATTLE, WASHINGTON

1. Procedure

All shipments by rail were made in barrels as previously described.

2. Results

Table 7 shows that during long shipments of about 4 to 5 days, the rise in temperature of the fillets is slight and well below the borderline temperature of 40° F.

Table 5.—Temperature of fresh haddock fillets shipped by rail from Boston, Massachusetts, to Jacksonville, Florida, 1965

Month	Weight of fillets shipped	Length of time fillets were held		Temperature of fillets at:					
				Start of trip			End of trip		
		At MPDI	In transit	Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	*Hours*	*Hours*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*
January	120	72	38	32	32	32.0	34	33	33.3
May	120	78	39	34	33	33.3	34	33	33.8
August	100	92	44	34	33	33.3	37	33	36.0
October	100	74	38	36	32	33.5	34	33	33.2

Note 1: The general freight car was nonrefrigerated and noninsulated.
Note 2: MPDI (Marine Products Development Irradiator, Bureau of Commercial Fisheries, Gloucester, Massachusetts).
Note 3: The average temperatures shown were the averages of 55 recordings per trip.

Table 6.—Temperature of fresh haddock fillets shipped by rail from Boston, Massachusetts, to Texarkana, Texas, 1965 and 1966

Month	Weight of samples shipped	Length of time fillets were held		Temperature of fillets at:					
				Start of trip			End of trip		
		At MPDI	In transit	Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	*Hours*	*Hours*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*
April	200	--	50	40	33	37.4	36	34	34.4
April	200	--	49	39	36	37.6	33	33	33.0
July	200	--	49	39	32	35.9	44	35	38.0
October	200	72	51	36	35	34.6	33	33	33.0
December	200	75	52	34	34	34.0	34	34	34.0
February	200	73	51	34	33	33.2	34	33	33.5

Note 1: The general freight car was nonrefrigerated and noninsulated.
Note 2: MPDI (Marine Products Development Irradiator, Bureau of Commercial Fisheries, Gloucester, Massachusetts).
Note 3: The average temperatures shown were the averages of 96 recordings per trip.

Table 7.—Temperature of fresh haddock fillets shipped by rail from Boston, Massachusetts, to Seattle, Washington, 1965 and 1966

Month	Weight of fillets shipped	Length of time fillets were held:		Temperature of fillets at:					
				Start of trip			End of trip		
		At MPDI	In transit	Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	*Hours*	*Hours*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
September	300	73	91	33	33	33.0	35	34	34.4
October	600	70	111	33	32	32.7	35	33	34.6

Note 1: The general freight car was nonrefrigerated and noninsulated.
Note 2: MPDI (Marine Products Development Irradiator, Bureau of Commercial Fisheries, Gloucester, Massachusetts).
Note 3: The average temperatures shown are the averages of 139 recordings per trip.

SUMMARY

Before embarking on a costly program of research to test the commercial feasibility of irradiating haddock and cod fillets, we wanted to determine whether or not some practice in the industry would preclude the success of irradiating fish. We particularly wanted to know two things: (1) whether the haddock being landed in Boston, Massachusetts, are sufficiently fresh to warrant their being irradiated to extend their shelf life and (2) whether the temperature of the fillets when shipped by common carrier is sufficiently low to ensure that irradiated fillets will arrive at distant points in the nation in a fresh condition.

The first study in the series showed that the freshness level of haddock was more than adequate.

The study reported here looked into the problem of temperature of fresh fillets being shipped by common carriers. We investigated, during all seasons of the year, the temperature of fresh fillets shipped by two means of transportation: truck and train.

We found that shipments by truck could be divided into four categories: (1) processor-distributor shipments, (2) frozen-food shipments, (3) refrigerated fresh-fish shipments, and (4) nitrogen-gas refrigerated shipments.

One method of shipping by truck for short distances was found to be too short in duration to achieve the maximum cooling of fresh fillets under the conditions of shipment. Shipment by refrigerated trucks designed for transportation of frozen foods resulted in partial freezing of the fresh fillets. The most common method of shipping fresh fishery products using a combination of ice and mechanical refrigeration maintained the fresh fillets at optimum temperatures. One study of a more recent method of truck refrigeration using nitrogen gas showed that it had no advantage over the dominant method of refrigeration.

Three studies of shipment by rail showed that fresh fillet temperatures were maintained at optimum temperatures by a method of refrigeration that has been in long use — namely, shipment of the fresh fillets in cans packed in ice in wooden barrels, which are re-iced enroute when needed.

CONCLUSIONS

The survey showed that all the common commercial methods of transporting fresh fish interstate ensure fillet temperatures of 40° F. or lower. This temperature would be sufficiently low to permit shipment of irradiated fresh fillets in good condition to the most distant parts of the continental United States.

ACKNOWLEDGMENTS

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DIRECTORY

Bureau of Commercial Fisheries
Technological Laboratory
P.O. Box 128
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Technological Laboratory
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