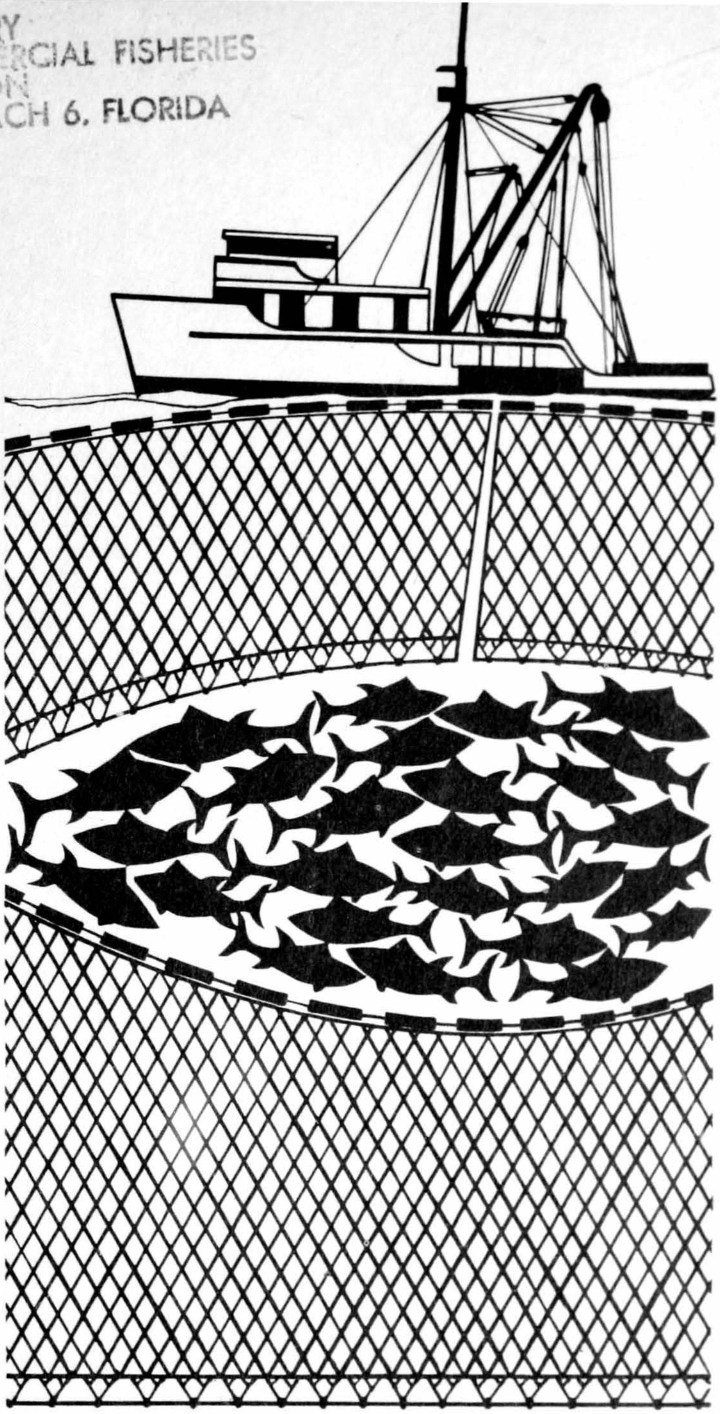

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Created in 1849, the Department of the Interior—a department of conservation—is concerned with the management, conservation, and development of the Nation's water, fish, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and Territorial affairs.

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OCCURRENCE OF POMFRET *(Brama japonica)* IN THE NORTHEASTERN PACIFIC OCEAN

by

Charles R. Hitz and Robert R. French

ABSTRACT

During investigations by the Bureau of Commercial Fisheries in the Northeastern Pacific, pomfret were found to be widely distributed, from north of Latitude 42° North and from Longitude 175° East to the coast of North America. Pomfret were taken mainly during August and September at surface-water temperatures of 11° to 14° C. The catches by the Bureau and others suggest that pomfret may occur in certain areas of the Northeastern Pacific in commercially harvestable quantities.

INTRODUCTION

Pomfret belong to the family Bramidae. The nomenclature in this group is confused, apparently because of the scarcity of specimens and of the great ontogenetic changes that occur (Mead, 1957). A number of different scientific names—such as *Brama raii, B. raji, B. rayi,* and *B. brama*—have been used in the literature for pomfret (Figure 1) captured in the Northeastern Pacific. Mead, an expert on the taxonomy of bramid fishes, believes that the population of pomfret *(B. brama)* in the Northern Atlantic is similar to the population in the Southern Hemisphere but that the population in the Northern Pacific differs in certain respects and should be considered as being a separate species (Mead, 1962 to 1964[1]). The oldest established Northern Pacific name of *B. japonica* should therefore be used.

Pomfret are widely distributed in temperate and tropical waters throughout the world (Briggs, 1960). They are fished commercially in the Atlantic off the coast of Spain and in the Pacific off the east coast of Japan (Abe, 1952). Jordan (1924), Crawford (1927), Pritchard (1930), Cowan (1938), Van Cleve and Thompson (1938), and Fitch (1950) have reported pomfret along the coast of California, Washington, British Columbia, and Alaska. Off Vancouver Island, it has aroused considerable interest because it has occurred in large numbers sporadically (Clemens and Wilby, 1961). Research vessels operating in the Northeastern Pacific since 1955 have frequently taken pomfret (Powell, 1958; Larkins, 1964). Because pomfret occur commonly in the Northeastern Pacific and are a food fish in other parts of the world, they are a potential food resource of the Northeastern Pacific Area.

The Bureau of Commercial Fisheries has analyzed data collected during 1950 to 1962 by various agencies. The purpose of the analysis is to provide basic information on the occurrence of pomfret in the Northeastern Pacific for the future exploration of this resource. Accordingly, the main divisions of the present report deal with (1) surveys in 1950 to 1962 and (2) future explorations.

SURVEYS, 1950 TO 1962

During surveys in the Northeastern Pacific by the Bureau of Commercial Fisheries, many types of fishing gear have been used. No pomfret were taken in the Bureau's bottomfish or shrimp surveys with bottom trawls or in its pelagic surveys with tuna lures and longline gear; pomfret were frequently taken, however, in pelagic surveys with gill nets and purse seines.

In the present study, 2 sources of data were used: (1)The gill-net data collected by the Bureau of Commercial Fisheries during salmon investigations (1953 and 1955-1962) and tuna investigations (1950 and 1952) and (2) the purse-seine data collected by the

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[1] Giles W. Mead. 1962 to 1964. Personal correspondence. Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.

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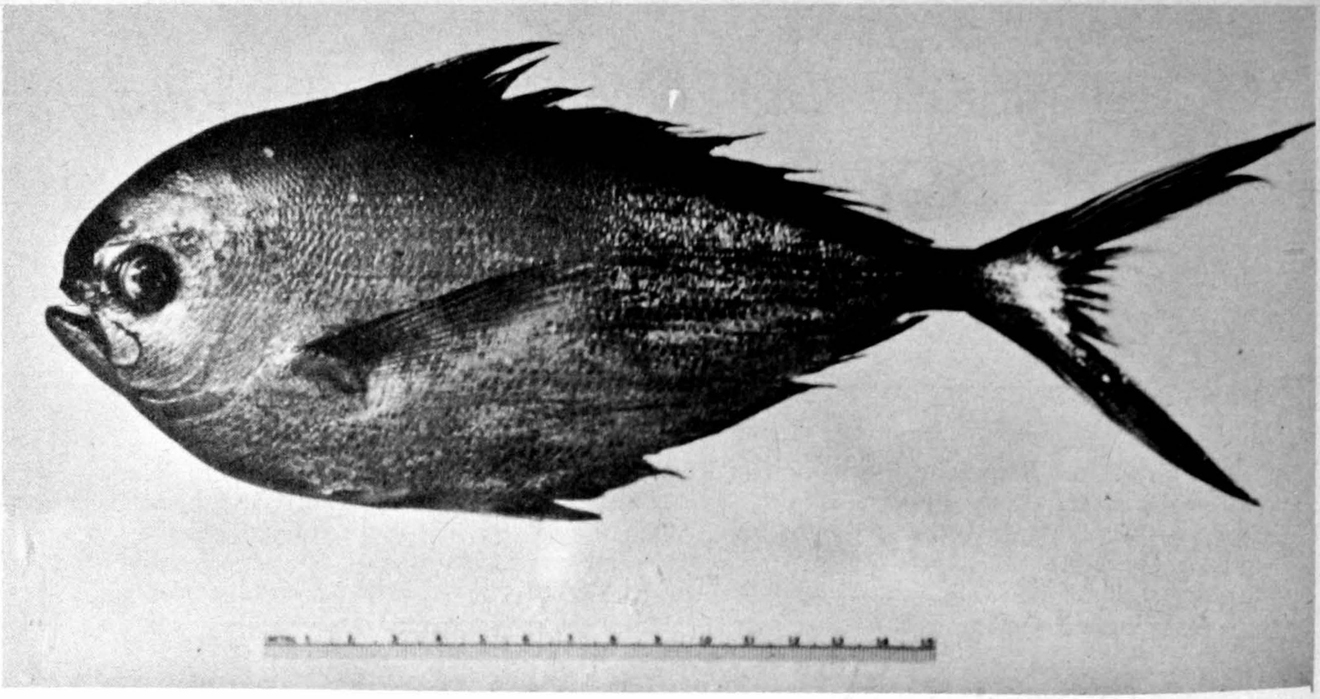

Figure 1.—A Northeastern Pacific pomfret with a total length of 29.5 centimeters.

Fisheries Research Institute of the University of Washington during salmon-tagging studies (1956-1962) under contract to the Bureau. The purse seines used were described by Hartt (1962); the salmon gill nets, by Powell and Peterson (1957); and the tuna gill nets, by Powell, Alverson, and Livingstone (1952).

To compare catches of the various sets of both purse seines and gill nets, we used the number of pomfret caught per set. This number was satisfactory for purse-seine catches, since there was little change in fishing methods or gear from year to year. It appeared at first, however, that the catch per set for gill nets was not a usable unit of effort because of selectivity by mesh size and variation in the proportion of different mesh sizes used from year to year. For example, the number of shackles (50 fathoms each) of the different mesh sizes per gill-net string varied from 1 to 5 shackles of 2-1/2-inch mesh, 2 to 8 shackles of 3-1/4-inch mesh, 2 to 24 shackles of 4-1/2-inch mesh, and 2 to 11 shackles of 5-1/4-inch mesh during the 9 years of salmon investigations. In the 2 exploratory trips for tuna in 1950 and 1952, 2 shackles each of 7-inch mesh, 8-inch mesh, and 9-inch mesh were fished. The catch per gill-net set was found to be a usable unit of effort for comparing the catches from the salmon investigation when the following relation was used: About 93 percent of the pomfret caught in salmon gill nets in 1960 to 1961, when the incidental species were recorded by mesh size, were taken in the 2 larger mesh sizes—4-1/2-inch and 5-1/4-inch. Of these, the catch per shackle of the 5-1/4-inch mesh was about 4 times that per shackle of the 4-1/2-inch mesh. The gill-net strings fished over the years were therefore weighted according to their efficiency for catching pomfret by multiplying the number of 5-1/4-inch-mesh nets by 4 to put the net string in terms of 4-1/2-inch-mesh nets. When weighted in this manner, the string contained about the same number of 4-1/2-inch-mesh nets each year; therefore, the fishing effort was considered to be similar each year. Catches taken in the 2 exploratory sets for tuna were treated separately from those taken in the salmon investigation.

Gill-Net Catches

The intensity of sampling varied from year to year. In 1950 and 1952, sampling was conducted off Washington and Oregon during explorations for tuna. In 1953, salmon were searched for off the Aleutian Islands, and this exploration was followed in 1955 by studies of the distribution of salmon. The sampling during 1955 to 1962 was primarily centered around the Aleutian Islands; but in 1956, 1961, and 1962, the sampling was extended to include the Gulf of Alaska. In these surveys, 900 night sets were made—243 in the Bering Sea and 657 in the Northeastern Pacific Ocean from the Aleutian Islands to Oregon (Figure 2).

Pomfret were caught throughout the Northeastern Pacific north of about Latitude 42° North and from Longitude 175° East to the coast of North America. Heaviest concentrations appeared in the Western Gulf of Alaska and in the Central Aleutian Area (Figure 3). Of the 657 sets made in the Northeastern Pacific,

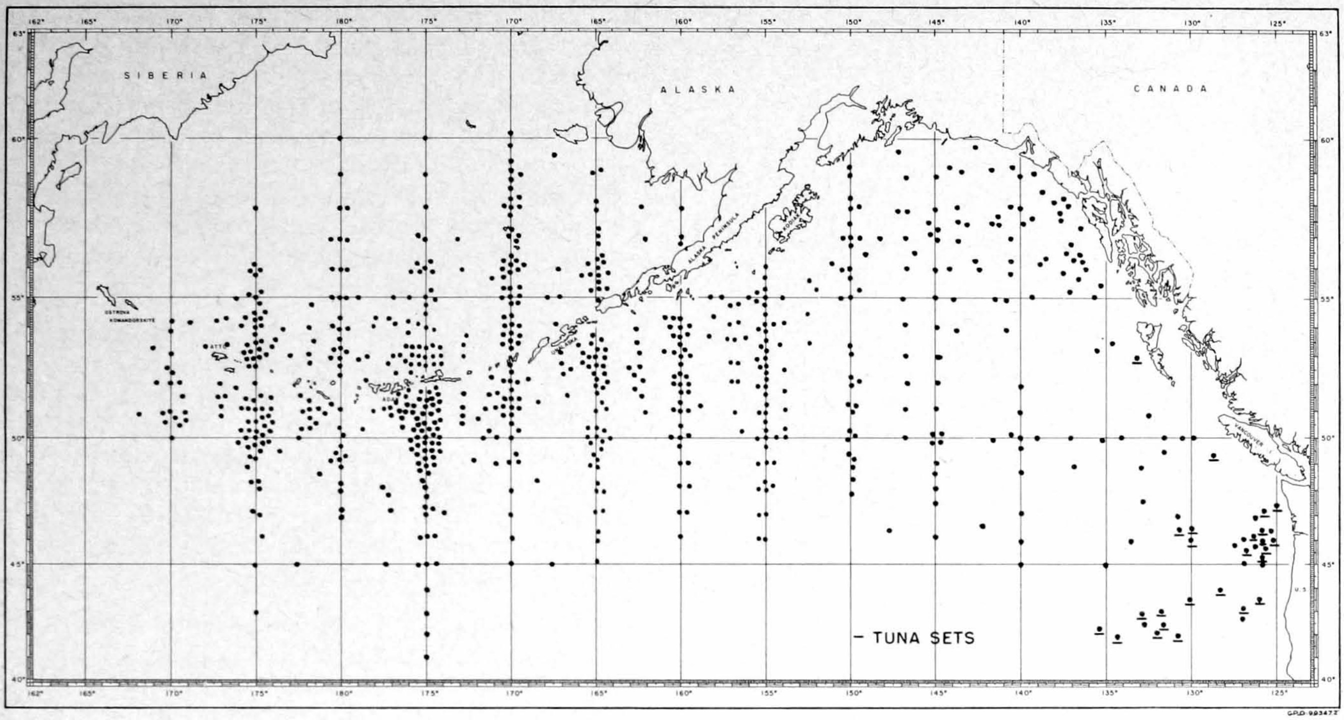

Figure 2.—Distribution of the gill-net sets.

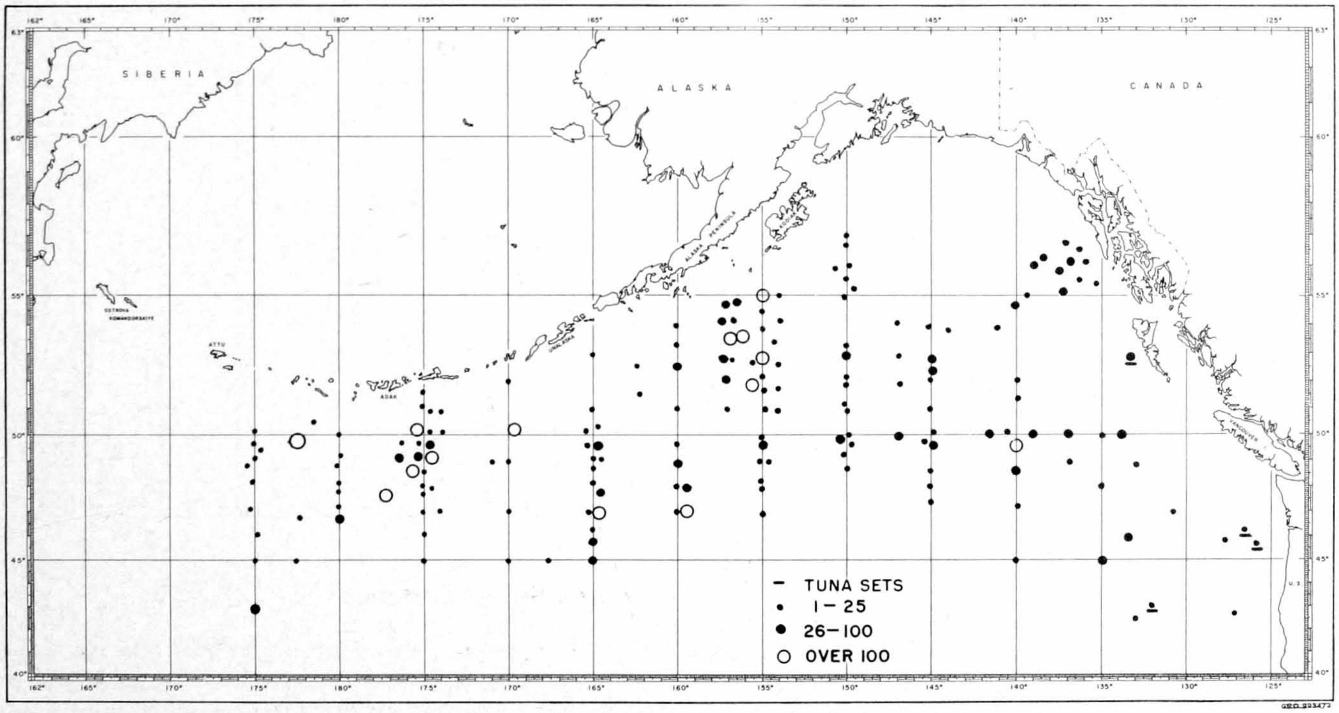

Figure 3.—Relative availability of pomfret, based on the number captured per gill-net set.

Table 1.—Total number of gill-net sets and the number of corresponding sets that caught pomfret in the Northeastern Pacific Ocean, by year and month

Year	February		March		April		May		June		July		August		September		October		November		Total	
	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
1950[1]									5	1	5	1	2	1	1	0					13	3
1952[1]									3	0	6	2	4	0							13	2
1953									8	0	9	0									17	0
1955									2	0	21	0	46	29	21	17	1	1			91	47
1956							5	0	5	2	34	14	66	44	25	14					135	74
1957							3	0	5	0	20	5	31	19	5	3					64	27
1958							2	0	3	0	13	0	16	7							34	7
1959					1	0	10	0	9	0	22	3	5	3							47	6
1960							13	0	11	0	21	0	8	0							53	0
1961							3	0	26	0	21	0	30	15	16	14					96	29
1962	6	0	14	0	4	0	1	0	10	0	14	0	34	20	6	6			5	0	94	26
Total	6	0	14	0	5	0	37	0	87	3	186	25	242	138	74	54	1	1	5	0	657	221
Percent of sets with pomfret	0		0		0		0		3.4		13.4		57.0		73.0		100		0		33.6	

[1] Exploratory sets for tuna.

221 (34 percent) took pomfret. The 221 sets averaged 25.8 pomfret per set with a range of 1 to 232 per set. The area encompassing the heaviest concentrations of catches of pomfret (over 100 fish per set) extended over a large part of the North Pacific. For example, the distance from Longitude 155° West to Longitude 175° West is about 800 miles. This would indicate that the population of pomfret in this general area can be substantial. No pomfret were taken in the Bering Sea.

Movement of pomfret into the Northeastern Pacific apparently occurs in late spring and early summer (Table 1). No pomfret appeared in gill-net catches until June, although many sets were made in May. Pomfret appeared most frequently in the catches during August and September. Neave and Hanavan (1960) showed a northward shift of the northern limits of the distribution of pomfret in the Gulf of Alaska in summer.

Gill-net sampling was conducted at surface-water temperatures that ranged from 1° to 19° C., with about 62 percent of the sets being in waters ranging from 1° to 10° C. Pomfret were caught in surface waters that ranged from 9° to 19° C. The highest rates of catch occurred between 11° and 14° C. (Table 2). Pinchard (1957) reported similar temperatures when pomfret were caught in gill nets off British Columbia.

Table 2.—Catch of pomfret in gill-net sets, by water temperature

Water temperature		Salmon sets	Pomfret caught in salmon sets		Tuna sets	Pomfret caught in tuna sets	
°F.	*°C.*	*No.*	*No.*	*No./set*	*No.*	*No.*	*No./set*
33.8-46.4	1-8	335	0	0	0		
48.2	9	78	144	1.9	0		
50.0	10	116	276	2.4	0		
51.8	11	83	1,304	15.7	0		
53.6	12	75	1,937	25.8	1	0	0
55.4	13	53	1,310	24.7	1	7	7.0
57.2	14	29	297	10.2	8	103	12.9
59.0	15	21	67	3.2	5	0	0
60.8	16	23	195	8.5	7	11	1.6
62.6	17	7	53	7.6	4	0	0
64.4	18	1	4	4.0	0		
66.2	19	2	3	1.5	0		
Total		823	5,590	6.8	26	121	4.7

Purse-Seine Catches

Purse-seine effort and catch data (Figures 4 and 5) are presented in a manner similar to that for the gill nets. The majority of the daylight purse-seine sets were made close to the south side of the Aleutian Islands. The major fishing effort in the Gulf of Alaska was in 1958, 1961, and 1962. During

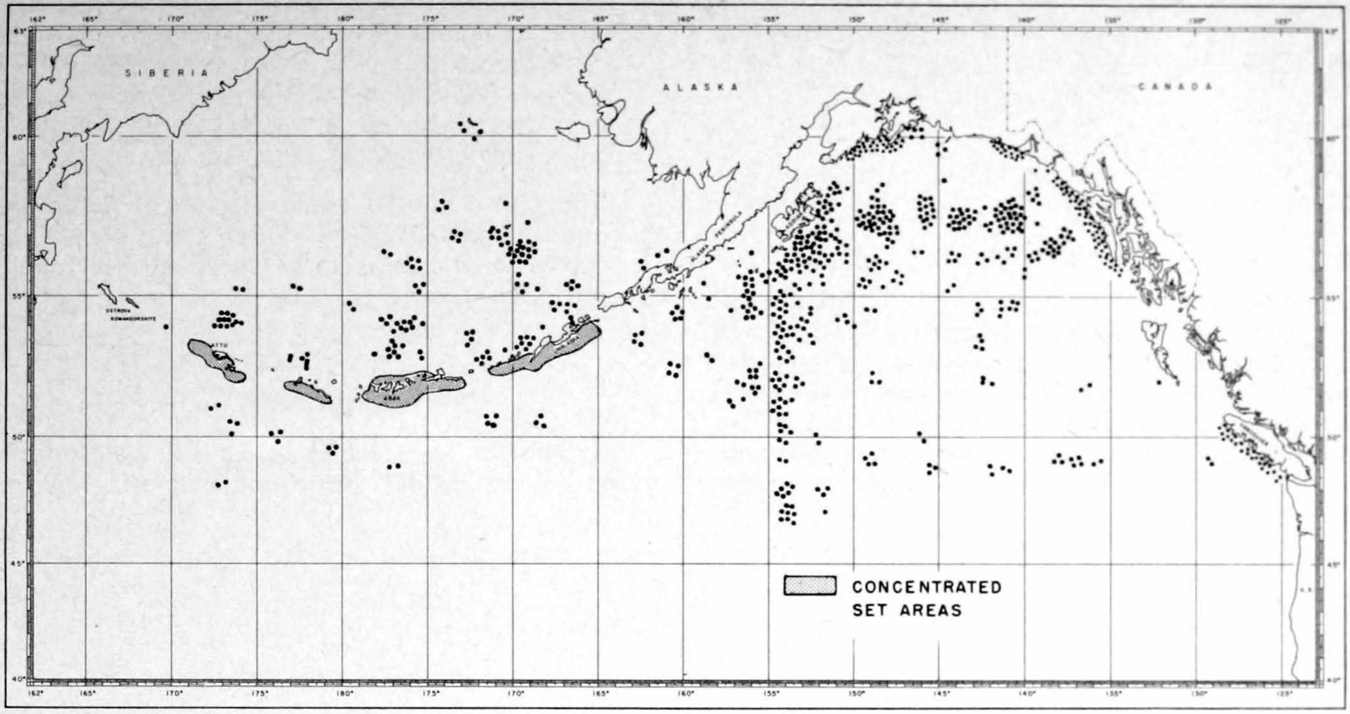

Figure 4.—Distribution of the purse-seine sets.

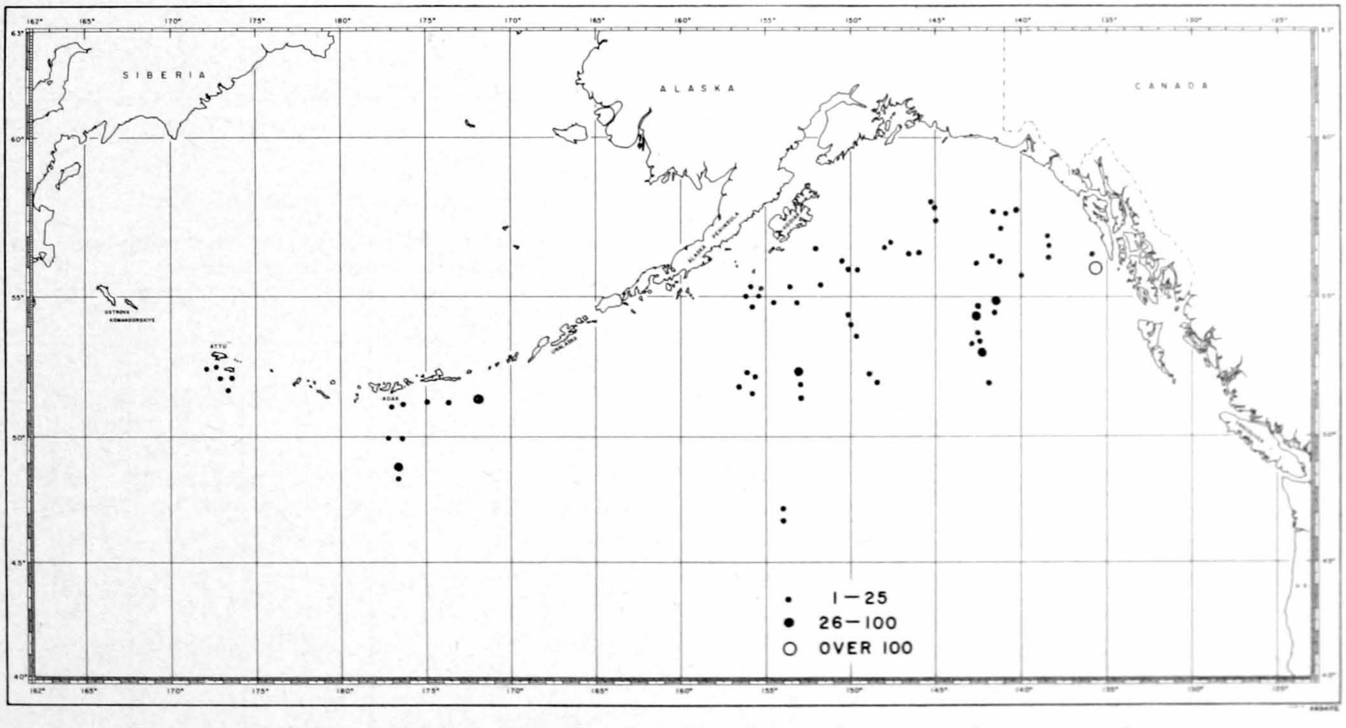

Figure 5.—Relative availability of pomfret, based on the number captured per purse-seine set.

the 7 years of sampling, 1,701 daylight purse-seine sets were made—249 in the Bering Sea and 1,452 in the Aleutian Chain (Figure 4).

The heaviest concentrations appeared in the Eastern Gulf of Alaska (Figure 5). Of the 1,452 sets made in the Northeastern Pacific, only 73 (5 percent) took pomfret; the numbers caught ranged from 1 to 110 with an average of 13.2 per set.

The purse-seine data indicated, as did the gill-net data, that pomfret occurred primarily in August and September (Table 3). The seine sampling was conducted in water in which the surface temperature ranged from 1° to 17° C.; about 83 percent of the sets were made at surface-water temperatures ranging from 1° to 10° C. Pomfret were caught in waters ranging from 9° to 14° C., with the best rate of catch occurring at 11° to 14° C. (Table 4).

Table 3.—Number of purse-seine sets and number that took pomfret in the Northeastern Pacific Ocean, by year and month

Year	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.	Tot. sets	Sets with pom.
	April		May		June		July		August		September		October		Total	
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
1956			4	0	64	0	21	0	28	2	22	6			139	8
1957			16	0	42	0	81	0	45	2	16	1			200	3
1958			10	0	32	0	51	0	56	18	14	6			163	24
1959	2	0	4	0	28	0	28	0	19	9	9	2	1	1	91	12
1960	9	0	41	0	41	0	49	0	19	0					159	0
1961			15	0	105	0	108	2	76	14	33	0			337	16
1962			114	0	144	2	102	8	3	0					363	10
Total	11	0	204	0	456	2	440	10	246	45	94	15	1	1	1,452	73
Percent of sets with pomfret	0		0		0.4		2.3		18.3		16.0		100		5.0	

Table 4.—Catch of pomfret for the purse-seine sets, by surface-water temperature

Water temperature		Sets	Pomfret caught	
°F.	*°C.*	*No.*	*No.*	*No./set*
33.8-46.4	1-8	997	0	0
48.2	9	187	2	<0.1
50.0	10	156	37	0.2
51.8	11	151	397	2.6
53.6	12	116	111	1.0
55.4	13	63	257	4.1
57.2	14	19	159	8.4
59.0	15	4	0	0
60.8	16	5	0	0
62.6	17	3	0	0
Total		1,701	963	6.6

The temperature ranges in which both gill nets and purse seines caught pomfret are very similar, as are the temperature ranges of the best catches. Thus, there appears to be a direct relation between the temperature of the surface water and the occurrence of pomfret. This relation could explain (1) why no pomfret were taken in the colder Bering Sea, (2) why the gill nets caught more pomfret than the purse seines, and (3) why the best catches occurred in the Gulf of Alaska and south of the Aleutian Chain in the summer.

FUTURE EXPLORATIONS

Exploratory fishing in pomfret waters would be necessary to determine if pomfret can be taken in commercial quantities and which gear is the most efficient for taking them. Pomfret, as indicated in this report, occur in the Northeastern Pacific in late summer and early fall in surface waters with temperatures of 11° to 14° C.

The distribution of pomfret south of the areas reported here is unknown. These fish are believed to spawn in waters south of their summer range. Possibly, the spawning areas, once known, would be the areas of highest concentration.

SUMMARY

1. Pomfret were found in surface waters from north of Latitude 42° North and east of Longitude

175° East to the western coast of the United States and Canada, mainly in August and September. They were never found in the Bering Sea.

2. There appears to be a relation between the occurrence of pomfret and the temperature of the surface water. Pomfret were caught in surface water at 9° to 19° C., with the best rates of catch occurring between 11° and 14° C.

3. The observed widespread distribution of pomfret and their common occurrence in the Northeastern Pacific Ocean suggest that this species may occur in commercially harvestable quantities.

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Emerson, John A.

Irradiation of food products. Presented at University of Michigan course in fisheries technology and economics, Ann Arbor, Michigan, February 15.

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A survey of technological problems of the fresh water commercial industry. Presented at Michigan State Extension Service Seminar, Saugatuck, Michigan, August 10.

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[1] If you wish information on any of these articles, the directory is on page 21. Please give complete information as shown in this article.

Gnaedinger, R. H.

Thiaminase in fish—detection and inactivation. Winter meeting, Great Lakes Section, Institute of Food Technologists, Ann Arbor, Michigan, February 14.

Fish proteins and enzymology. Presented at University of Michigan course in fisheries technology and economics, Ann Arbor, Michigan, April 15.

Process and product development studies relating to the utilization of thiaminase-containing fish for mink feeding. Presented at 5th Informal Mink Nutrition Conference, Milwaukee, Wisconsin, April 20.

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College Park, Maryland

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Present status of the pepsin digestibility test. Presented at the Ninth Annual Atlantic Fisheries Technologists Conference, Martha's Vineyard, Massachusetts, October 11-14.

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Current status and plans on physical processing methods. Presented at the meeting of the National Academy of Sciences, Scientific Advisory Committee on Marine Protein Concentrates, Washington, D. C., March 23.

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Value of menhaden fish meal as a protein supplement to practical swine diets. III. Corn-meat and bone meal. Presented at the 1964 Meeting of the American Society of Animal Science, Knoxville, Tennessee, August 12.

Utilization of fishery products in swine diets. Presented at the Informal Conference on Fish Meal Utilization, Bureau of Commercial Fisheries Technological Laboratory, College Park, Maryland, September 10.

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An automatic method for the determination of calcium in the presence of magnesium and phosphate ions. Presented at the Technicon International Symposium, "Automation in Analytical Chemistry," New York City, New York, September 16-18.

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The biological availability of calcium and phosphorus in menhaden fish meals. Presented at the 53rd Annual Meeting of the Poultry Science Association, University of Minnesota, St. Paul, Minnesota, August 5.

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Gloucester, Massachusetts

Anderson, Margaret L.

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MS #1497

INFLUENCE OF TEMPERATURE ON THE FATTY ACID PATTERN OF MUSCLE AND ORGAN LIPIDS OF THE RAINBOW TROUT

(Salmo Gairdneri)

by

Werner G. Knipprath and James F. Mead

ABSTRACT

Fatty acids of the total lipids of 2 groups of rainbow trout kept at different water temperatures were analyzed.

Both muscle and organ lipids tended to incorporate more highly unsaturated fatty acids at lower temperatures. The specific fatty acids that were incorporated, however, differed in the 2 types of tissues.

INTRODUCTION

The influence of the environmental temperature on the fatty acid pattern of the lipid of several forms of aquatic life has been studied by several authors.

Holton, Blecker, and Onore (1964) reported on the fatty acids of blue-green algae *(Anacystis nidulans)*. For this alga, in which palmitic (16:0) and hexadecenoic (16:1) acids account for 90 percent of the total fatty acid mixture, the ratios of the unsaturated to the saturated fatty acids remained about 1.0 for algae grown at 26°, 32° and 35° C., whereas a ratio of 0.7 was calculated for algae grown at 41° C. The major change was due to a relative decrease in 16:1 acid.

Lewis (1962) investigated the fatty acid composition of some marine poikilothermic animals from temperate and from arctic regions and found that the influence of the lower temperature was visualized in the loss of stearic (18:0) acid and a reduction in the 16:0 acid level, with an increase in 16:1 acid. He points out the possibility of a connection between the change in fatty acids and the preservation of protoplasmic viscosity to enable the organism to maintain its normal metabolism.

An aquatic food-chain experiment by Kayama, Tsuchiya, and Mead (1963) showed a marked influence of the environmental temperature,. In an experiment dealing with the feeding of brine shrimp *(Artemia salina)* to guppies *(Lebistes reticulatus)* kept at different temperatures, these authors found a distinct variation in the composition of the fatty acids of the guppies. The fish kept in warmer water showed an increase percentage of 16:0 and 18:0 and a relative decrease in 16:1, oleic (18:1), and docosahexaenoic (22:6) acid.

A comparison of the water temperature with iodine values of the fat of crustacean plankton from Lake Balaton, Hungary, over a period of 3 years (Farkas

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Authors' note.—Werner G. Knipprath, *Assistant Research Biochemist*, and James F. M. Mead, *Professor*, Department of Biophysics and Nuclear Medicine, School of Medicine, University of California at Los Angeles.

and Herodek, 1964) gave convincing evidence for a correlation between temperature and degree of unsaturation of fat in these crustaceans. During the entire time of the experiment, the melting point of the lipid from planktonic copepods was found to be somewhat lower than the temperature of the lake. The unsaturated fatty acids with chain lengths of 20 and 22 carbon atoms increased with the lower temperature.

According to Reiser, Stevenson, Kayama, Choudhury, and Hood (1963), the fatty acid pattern did not change significantly with temperature when certain teleost fish were depleted of long-chain fatty acids and later fed with linoleic (18:2) and linolenic (18:3) acids.

Recent investigation by Johnston and Roots (1964) on the effect of temperature differences, particularly on the fatty acids of brain lipids of goldfish *(Carassius auratus* L.), indicated that the fatty acids tend to become more highly unsaturated as the environmental temperature decreases, especially in relation to the 18-carbon acids and the long-chain polyunsaturated acids.

The purpose of our investigation was to find a suitable experimental subject for a study of the mechanism of the temperature effect on lipid composition in fish. Obviously, the experimental subjects for such a study must show a pronounced change in fatty acid unsaturation with change in temperature and, at the same time, be amenable to laboratory conditions of raising and handling.

Unfortunately, the rainbow trout that were available from the hatchery for this study had been changed to different environmental temperatures seasonally, with the result that the groups of fish held at different temperatures differed in age. Despite this difference in age from 1 group to another, we carried out the study because we assumed that age is not a significant variable in the relation of temperature to fatty acid composition.

The 2-year-old rainbow trout used were kept in water of 10°-14° C. for 18 months and were then transferred to colder water (0°-9° C.) 6 months prior to this investigation. One has to assume that the adaptation was completed during the 6 months. Actually, the acclimation seems to be a rapid process. Our experiments with mosquito fish *(Gambusia affinis)* and guppies indicate that the adaptation is in good progress after 2 days and that it is presumably completed after 4 weeks, as shown by the changes of the fatty acid pattern.

The lipids from muscle and organs (liver, heart, and spleen) were investigated separately. The muscle lipids consist largely of deposited storage triglycerides and thus contain the more common fatty acids; whereas the more highly unsaturated acids are found in the phospholipids of the organs, so it is probable that the maintenance of their physical properties at different environmental conditions may be of considerably greater importance.

I. TROUT USED

The rainbow trout were raised in the Mt. Whitney Hatchery, Independence, California, as brood stock, and their diet, during their entire lives, consisted of about 2/3 slaughter-house scrap meat and organs and 1/3 ocean fish, mainly anchovies. There was no possibility for controlling the diet by means of chemical analysis. The diet remained the same, however, for all groups of fish.

The 1-year-old fish, averaging 24 centimeters in length and 212 grams in weight, had been kept throughout their lives in water of 10°-14° C., whereas the 2-year-old fish, averaging 36.5 centimeters in length and 548 grams in weight, had been kept for 18 months in 10°-14° C. water and for 6 months in 0°-9° C. water.

II. EXTRACTION OF FATTY ACIDS

A. PROCEDURE

As the first step in the extraction of the fatty acids, trout were killed by a blow on the head and then kept at -20° C. overnight. Muscle tissue and organs (liver, heart, and spleen) of 3 fish from each age group were removed and immediately placed on dry ice. The organs within each group were pooled, and all tissues were weighed, dried by lyophilization, weighed again, and extracted 3 times in a Waring blendor[1] with chloroform/methanol 2:1 (v/v). The mixture of tissue and solvent was filtered, and the 3 filtrates resulting from the 3 extractions of each tissue were combined,. The solid matter remaining after filtration was dried in a vacuum desiccator and weighed. The filtrates were freed from solvent; and the residues—that is, the extracted total lipids—were weighed and then saponified overnight at room temperature with 15 times their volumes of 10 percent methanolic KOH containing 5 percent water. The methanol was partially removed on a rotary evaporator at 30° C. under reduced pressure. After the methanol was diluted with an equal volume of water, the unsaponifiable material was extracted 3 times

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[1] Trade names are used merely to simplify the description of the experimental equipment; no endorsement is implied.

with n-pentane. The combined n-pentane solutions were re-extracted once with water/methanol 1:1, and the aqueous layers were combined. After acidification of the combined acqueous layers with HCl, the free fatty acids were extracted 4 times with ether, and the combined ether solutions were washed with water until neutral; they then were dried over $MgSO_4$. Evaporation of the ether yielded the free fatty acids.

B. RESULTS

The findings are reported in Table 1.

Table 1.—Data on rainbow trout tissue components of 2-year-old fish kept at 10°-14° C. (18 months) and 0°-9° C. (6 months) water temperature and of 1-year-old fish kept at 10°-14° C. (12 months) water temperature

Tissue	Water temperature	Tissue data			Lipid in wet tissue (calculated)	Extracted material	Fatty acids	Water (calculated)
		Wet weight	Dry weight	Dry weight after extraction				
	°C.	*Grams*	*Grams*	*Grams*	*Percent*	*Grams*	*Grams*	*Grams*
Muscle	10-14 (18 months) 0-9 (6 months)	76.1	23.0	17.6	7.1	5.4	4.0	70
	10-14 (12 months)	148.4	43.8	35.0	5.9	8.8	7.7	71
Organs	10-14 (18 months) 0-9 (6 months)	7.6	2.0	1.5	6.6	0.5	0.4	74
	10-14 (12 months)	13.1	3.7	2.8	6.9	0.9	0.7	72

III. ANALYSIS OF FATTY ACIDS

A. PROCEDURE

As the first step in the analysis, the resulting 4 samples of fatty acids (2 from the muscle of trout held at 2 temperatures and 2 from the organs of trout held at 2 temperatures) were esterified with ethereal diazomethane solution, the ether was removed, and the methyl ester residues were dissolved in n-pentane. The resulting solutions were analyzed by gas-liquid chromatography with a Barber-Colman Model 10 apparatus with a 40- x 0.25-inch column of ethylene glycol succinate, 16.9 percent on gas chrom P, 80 to 100 mesh. The mass peaks in the chromatograms were calculated by multiplication of the peak height by the peak width at half-height. The possible presence of hydroxy- and branched-chain fatty acids or of any and all fatty acids beyond a chain length of 22 carbon atoms was not ascertained. The other acids were calculated as percentages of the total fatty acids.

Since the esters of octadecatrienoic (18:3) and octadecatetraenoic (18:4) acids had about the same retention time as those of eicosaenoic (20:1) and eicosadienoic (20:2) acids, these acids could not always be distinguished. The total mixtures therefore were separated into fractions with the same chain length by preparative gas chromatography, using a Wilkens Instrument Co. A-100 Aerograph apparatus with a 60- x 0.5-inch column of SE-30 silicone stationary phase, 10 percent on chromosorb W support. The 4 samples containing the methyl esters of the acids with 18 carbon atoms were rechromatographed to achieve purification. Hydrogenation of portions of the samples, followed by analytical gas chromatography, revealed no traces of fatty acids with other than 18 carbon atoms. The unsaturated ester mixtures showed only very small amounts of 18:3 and 18:4 acids. These results permitted the correct identification of the questionable peaks in the chromatogram of the total fatty acid mixture, which were attributed now to eicosaenoic and eicosadienoic acids.

B. RESULTS

The results of the calculations are shown in Table 2.

1. Muscle Tissue

The results obtained from the examination of the lipids from trout-muscle tissue showed the expected overall increase in unsaturation in the lipids with declining temperature. Among the major peaks, docosahexaenoic (22:6) acid showed the greatest increase, followed by docosapentaenoic (22:5) and oleic (18:1) acids, but the palmitoleic (16:1) acid level decreased. The proportion of eicosatetraenoic (20:4) acid was

Table 2.—Gas chromatographic analysis of methyl esters from total lipid of trout

Fatty acids found	Concentration of fatty acids derived from:			
	Muscle of trout held at:		Organs of trout held at:	
	10°-14° C. for 12 months	10°-14° C. for 18 months and 0°-9° C. for 6 months	10°-14° C. for 12 months	10°-14° C. for 18 months and 0°-9° C. for 6 months
	Percent of total lipids			
14:0	2.5	1.4	1.9	0.7
14:1	+	+	+	+
15:0	+	-	+	+
16:0	17.1	16.2	17.2	24.2
16:1	7.5	6.4	7.2	4.3
16:2	+	+	+	+
16:4	+	+	+	-
16:3 and/or 18:0	10.0	8.3	11.4	7.4
18:1	28.4	29.3	23.5	21.8
18:2	6.1	5.1	4.9	3.8
18:3	+	+	+	+
18:4	+	+	+	+
20:0	+	+	+	+
20:1	3.1	3.6	2.5	1.4
20:2	1.5	1.7	1.5	0.7
20:3	1.1	1.2	1.5	1.0
20:4	2.3	2.2	5.3	8.1
20:5 and/or 22:2	6.4	4.8	6.8	7.6
22:3	+	0.5	0.6	0.7
22:4	+	0.2	0.5	0.3
22:5	2.3	3.7	2.4	2.4
22:6	11.7	15.4	12.8	15.6

about the same in both cases. Since the lipids contained only insignificant amounts of linolenic (18:3) and octadecatetraenoic (18:4) acids in both warm- and cold-water fish, the increase of 22:6 acid could not be due to chain elongation and desaturation of 18:3. Hence an increased deposition of 22:6 acid supplied in the food is indicated. Some 22:6 acid might have derived from eicosapentaenoic (20:5) acid, however, as the level of this acid is lower in the cold-water fish than in the warm-water fish.

2. Organs

The pattern for the organs is marked by a strong increase in palmitic (16:0) acid at lower tmeperature, whereas all the other acids with 16 and 18 carbon atoms are decreased. The other major components of the mixture—the polyunsaturated fatty acids such as 20:4, 20:5, and 22:6—are proportionally greater at lower temperature, although 22:5 acid does not change.

3. Muscle Tissue and Organs

For the strong increase of 16:0 acid in the organs of cold-water trout, no explanation can be offered; nor can an explanation be offered for the decrease in linoleic (18:2) acid, which occurs in muscle and organs alike at lower temperature. Focusing attention only on the higher unsaturated long-chain fatty acids, one can summarize that with decreasing temperature, the major change in the fatty acids of trout muscle seems to occur in an increase in 22:6 acid, and the major change in the fatty acids of trout in organ tissue seems to occur in an increase in 22:6 and 20:4 acids.

IV. SUMMARY AND CONCLUSIONS

The effects of environmental temperature on the fatty acid pattern of trout were studied. Muscle tissue and the organs were analyzed separately.

The tendency of the lipids to become more highly unsaturated at lower water temperature was evident, especially in the marked increases in 22:6 and 22:5 acids of the muscle and in 22:6 acid in the organs.

The rainbow trout appears to be a suitable experimental subject for a study of the mechanism of the temperature effect on lipid composition in fish.

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MS #1492

COSTS AND EARNINGS OF TROPICAL TUNA VESSELS BASED IN CALIFORNIA

by

Roger E. Green and Gordon C. Broadhead

ABSTRACT

This paper presents a method of estimating earnings of purse seiners, taking into account effects of vessel size and various tuna prices and rates of harvest on the economics of purse seining. Estimations are made of earnings to crew and net profit or loss to owners for a selected range of prices and catch rates for vessels in the size range 100 to 500 tons capacity. Optimum vessel sizes are examined from standpoints of both owner and crewman.

CONTENTS

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INTRODUCTION

Since 1946, there has been an evolution in methods of harvesting tuna throughout the world. The vessels of the Japanese longline fleet have continuously increased in numbers and in average size and have expanded their operations around the world. In the United States there was a postwar expansion in the long-range fleet during 1946-51. Competition between the tuna fleets to supply the world's demand of tuna led to 8 years of economic difficulty for the United States fleet, beginning about 1952. During this period, the domestic fleet of bait vessels and purse seiners lost strength because casualties and transfers to foreign flags and other fisheries exceeded new construction each year. In these years the purse-seine fleet produced only about 20 percent of the catch, excluding albacore. During 1958-60, the introduction of nylon nets, power blocks, and other technological improvements led to a remarkable increase in the efficiency of the tuna purse-seine vessels. Nearly all the suitable bait-vessel hulls were modified for purse seining to take advantage of the increased catch rates. The fleet now includes about 113 purse seiners. The changes involved in this transformation have been discussed in detail by Orange and Broadhead (1959), McNeely (1961), Broadhead and Marshall (1960), Broadhead (1962), and Schaefer (1962).

A search for further efficiency led to a recent trend toward building larger purse seiners. The standard used by the industry to measure vessel size is tuna-carrying capacity in short tons. 12 new purse seiners and converted military hulls in the capacity range of 450 tons to 1,000 tons have been added to the fleet since 1960. The investments represented by these larger vessels attest to the belief of many owners that returns on investment can be improved by increasing carrying capacity. This belief is founded mainly on the knowledge that as vessel size increases, the cost of construction per ton of capacity decreases, as do many of the operating costs when based on capacity tonnage alone. These advantages, inherent in a large vessel, do not necessarily increase the profitability of the vessel. Opinions differ as to which vessel size will yield the maximum economic return per dollar invested. The factors contributing to gross revenue and operational costs are complex, because they vary considerably with the conditions surrounding vessel operation.

2 studies were made several years ago. The Stanford Research Institute (1954) undertook a study for the Southern California tuna industry entitled, ***The Impact of Imports on the U. S. Tuna Industry.*** The Institute's report, however, is confidential and has limited distribution. The United States Tariff Commission (1958) issued a report, ***Tuna Fish,*** that contains much valuable information on the operational costs for long-range tuna vessels.

Because these studies examined vessel profitability under the prevailing conditions of catch rate and tuna prices for an average-sized vessel, they can seldom be applied to the operation of a vessel of specific size at current rates of harvest.

The purposes of the present study are: (1) to present a method of estimating vessel earnings and (2) to examine vessel profitability by vessel size under varying fishing conditions and prices for tuna. Examination of these data permits, among other things, approximation of the sizes of vessels that are most efficient for owners and for crew under varying conditions.

I. THE DATA

A. SOURCE AND NATURE OF DATA

1. Cost of Operation

Information on the cost of operation of tuna boats used in this report has come from several sources. The United States Tariff Commission (1958) supplied the basic data on the costs of operation of 123 baitboats in 1952-57. Many of these records were duplicated by cost-of-operation data gathered and tabulated by Harold Cary for the American Tunaboat Association on 58 California-based baitboats in 1952-56. Westgate California Corporation supplied valuable data on its fleet operations. More recent cost information was obtained from several private owners of purse seiners and from the files of the Bureau of Commercial Fisheries Office of Loans and Grants at Terminal Island, California.

The costs of operation reported by baitboats and purse seiners were available in the following categories:

Trip expenses - shared by owner and crew:
  1. License fees
  2. Fuel
  3. Other trip expenses

Trip expense - paid by crew only:
  Provisions (including food, cleaning supplies, and other consumable items)

Owner expenses:
  1. Repairs
  2. Depreciation
  3. Insurance
  4. Property tax and social security
  5. Other owner expenses

These categories are defined subsequently under "Cost of Operation".

2. Catch and Fishing Effort

As a basic portion of its research on the stocks of tuna in the Eastern Pacific Ocean, the Inter-American Tropical Tuna Commission has maintained, since its inception in 1950, records of vessel logbooks. Data extracted from these records and analyzed by the Commission staff provided the information on catch rates, numbers of days at sea and days spent fishing, and proportions of each species in catches according to size and type of vessel. These basic data and the details concerning methods of analysis are contained in the research bulletins and annual reports of the Commission.

3. Confidential Nature of Data

Most boat owners were reluctant to have their financial situations examined publicly, as is true for most private enterprise, and supplied cost-of-operation data only under the assurance that information on individual boats would not be disclosed. We gave this assurance. Logbook information supplied to the Tuna Commission by fishermen is given with the same understanding. Most of the graphic and tabular information provided throughout this study is presented in grouped form. We considered that some boats might otherwise be identified by their unique size, horse power, or other vessel characteristics. Furthermore, we will be unable to honor requests for access to original data except with the consent of the individual vessel owners.

B. TREATMENT OF DATA

1. Regressions

All regressions were computed by the least squares method. For analysis, the individual data points were used where they were available. To preserve the anonymity of individual boats, only averages for interval groups were plotted. The number of individual points within each group is shown in parentheses beside each point.

2. Costs of Operation

In some cases it was advantageous to analyze the larger sample of data for more than 100 baitboats, instead of the smaller, but more recently reported, sample of about 20 purse seiners. Correspondence was close between current operating costs of these purse seiners and operating costs of baitboats in 1952-57 after the baitboat data were adjusted for changes in cost of living indexes and known price changes. Purse-seiner costs were usually within 1 sample standard deviation from regressions based on the baitboat data.

3. Accounting Procedures for Tuna Vessels

To understand costs of tuna vessel operation it is necessary to examine the current method of computing division of gross revenue among officers, crew, and vessel owners.

The sum of all trip expenses, except provisions, is subtracted from the gross revenue (income from sale of fish) of each trip. The remainder is divided among crew and owners by a method that is described in the later section "Crew and Owner Shares". The vessel owner pays all other vessel expenses from his share of this division. The cost of provisions is deducted from the crew share. This cost is usually divided equally among crew members, including officers (for example, master and chief engineer). In addition, bonuses may be paid to the officers out of the owner's share; these payments are then a vessel expense. The total amount of bonuses is variable but usually equivalent to 1½ additional shares.

4. Fishing Success

Some measure of fishing success is needed as one of the variable inputs for gross revenue. In this paper, we have used standardized catch rates per day of absence. These catch rates are standardized to purse seiners of the size range from 101 to 200 tons capacity, because vessel efficiency is related to vessel size (Shimada and Schaefer, 1956; Broadhead, 1962). The use of standardized catch rates eliminates the need for presenting a different economic analysis for each size of boat.

5. Bluefin Tuna

Many of the tropical tuna vessels also fish for bluefin tuna, a temperate species, during a short summer season. Bluefin tuna catch statistics were not used in these catch analyses because complete tabulations of bluefin catch and effort are not available. Bluefin prices have remained intermediate between those for yellowfin tuna and skipjack tuna. We have assumed that the vessels fish for yellowfin and skipjack throughout the year, so that error is introduced only by the difference in catch rates for bluefin tuna and those for yellowfin and skipjack tuna. Our estimates of gross revenue may be slightly conservative because catch rates for bluefin tuna are usually higher than those for yellowfin and skipjack tuna. The relative importance of these fisheries is indicated by landings in 1962 and 1963, when 4,017 and 7,741 tons of bluefin tuna were caught by purse seiners of over 200 tons capacity (Inter-American Tropical Tuna Commission, 1963); in these same years, the total California landings by United States fishermen of yellowfin and skipjack tuna were 92,611 tons and 87,966 tons (Pacific Fishermen, 1964).

II. COST OF OPERATION

A. TRIP EXPENSES

1. License Fees

Nearly all the Latin American countries bordering on the Eastern Pacific charge a fee to fish in the waters claimed under their jurisdictions. The requirements for licensing originated when the tropical tuna fleet was predominantly composed of baitboats. These boats commonly fished for bait within 3 miles of shore and occasionally fished close inshore for tuna as well (Anderson, Stolting, and Associates, 1953). Most countries that formerly obtained substantial revenues from sales of bait licenses continue to require licenses for tuna fishing within their territorial waters.

Purse seiners incur less license expense than baitboats. They pay no bait license because their operations are not dependent on a bait supply. In general, they fish in international waters. On the premise that fishing may occur in territorial waters, however, licenses are sometimes purchased as a means of ensuring freedom to operate within the waters off certain countries.

The license cost per trip, 1960-64, of 34 purse seiners is shown in Figure 1. The regression of Figure 1 estimates the expenses incurred for licenses on individual fishing trips according to vessel size (t_b = 13.6, $p < 0.001$). A negative value for 100-ton boats results from the failure of the regression to fit the data at this extreme. We shall, therefore, use zero for the estimation of license cost for 100-ton boats, a not unlikely assumption, since boats o this size rarely fish in areas where licenses are required. Larger vessels, besides paying higher license fees based on their tonnages, travel farther, fish in the territorial waters of more countries, and may buy more licenses per trip than smaller boats. We would expect, however, that this cost would reach a limit and that our curve should flatten in the range beyond 500 tons capacity.

2. Fuel

Fuel consumption per day at sea is directly related to the size of the main engine (Figure 2, t_b = 11.7, $p < 0.001$). The baitboat costs reported in Figure 2 are totals for all machinery, and we have assumed that fuel consumption of auxiliary engines is proportional to fuel consumption of the main propulsion unit. Purse seiners probably consume fuel at the same daily rate as baitboats, since hull configurations were not changed during conversion, and daily running patterns have not changed appreciably. Because prices of diesel fuel have risen 17 percent between 1952 and 1962, the costs reported for each boat were adjusted to bring them to the 1962 level.

Because a linear relation exists between vessel capacity and horsepower of the main engine, at least in the size range of vessels included, it is possible to estimate fuel costs according to vessel capacity. Regressions of engine size on capacity tonnage are given in Figure 3 (t_b for purse seiner regression = 13.9, $p < 0.001$). Engine data for both baitboats and purse seiners were obtained from United States Treasury Department, Bureau of Customs (1959, 1962). The difference between baitboats and purse seiners in this relation is due to a loss in fish-storage space in the conversion from baitboats to purse seiners. The average converted seiner has as much as 13 percent less fish-storage capacity than the average baitboat for similar hull and power size. McNeely (1961) described details of this change.

1 important cause of variation in reported fuel costs is the dumping of fuel at sea. Fuel is fre-

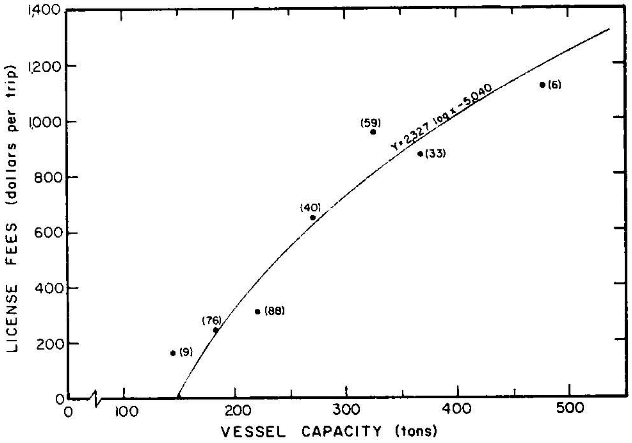

Figure 1.—Relation between cost of foreign licenses per trip and vessel capacity for purse seiners, 1960-64. The number in parentheses refer to numbers of trips made by vessels in each size group.

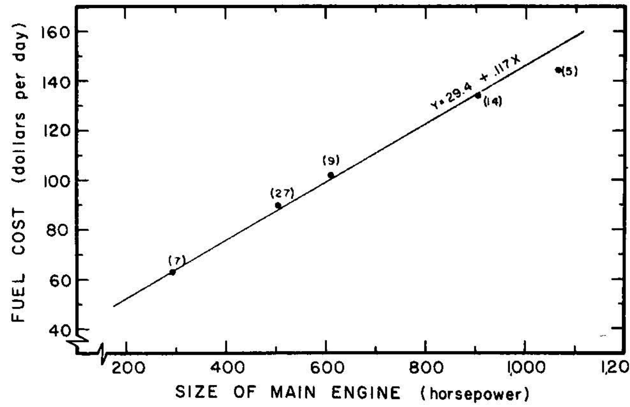

Figure 2.—Relation between fuel cost per day at sea and size of main engine, adjusted to 1962 levels from baitboat costs, 1952-56.

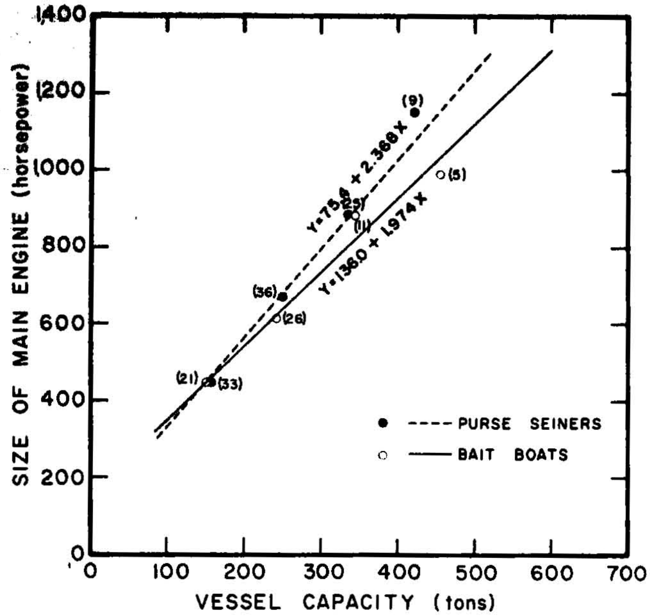

Figure 3.—Relation between size of main engine and vessel capacity for baitboats and purse seiners.

quently stored in some of the fish wells to increase total fuel capacity and is used from these tanks first. When fishing is good, these wells are sometimes required for fish storage before the fuel has been consumed. In such circumstances the less valuable fuel is pumped overboard or, if possible, transferred to a vessel needing fuel, and the wells are cleaned for fish storage. Although no data are available on the amount of fuel expended or transferred in this fashion, it is 1 of the many causes for the large variation in costs reported by boat owners. The standard deviation from regression of Figure 2 is $25.39 per day.

3. Other Trip Expenses

Items of noncapital expense not falling into any of the trip categories previously discussed are lumped here. They comprise such items as salt, ammonia, fathometer rental, aerial fish-spotting service, unloading help, watchman fees in port, and foreign port charges.

The amount included in this category increased substantially with the conversion to purse seiners. Rather than attempt to modify baitboat data, we have shown a regression (Figure 4) of a sample of pusre seiners for 1961 and 1962 ($t_b = 20.4$, $p < 0.001$). Because of the small size of this sample (24), it was impossible to show grouped points on the figure without revealing the identity of 1 or more boats. The standard deviation from regression of Figure 4 is $357.

4. Provisions

Under the current system of shares, the cost of provisions is a trip expense to crew only and is not deducted from the owner's share.

No relation was found between vessel size and food costs for either baitboats or purse seiners. Food costs reported by 43 vessels since 1960 ranged from $31 to $93 (mean, $55.50) per day per vessel. Because mean size of crew was 12.5, we shall use, in our estimations, the value $4.40 per man per day.

B. CREW AND OWNER SHARES

The method used by the industry to divide proceeds (the remainder after subtracting shared trip expenses from gross revenue) between owner and crew is based upon size of vessel and the number of men in the crew. Table 1 depicts the present method used by purse seiners. The percentages were modified by adding the percentage value of an arbitrary 1½ additional shares for bonuses of officers. To obtain individual crew shares it is necessary to divide by 13.5 for 12-man crews and by 14.5 for 13-man crews. An average may be used in the size ranges of overlap. The combination of the percentages for crew and bonus shares represents a departure from the usual accounting method described previously. The result is the same, however, and calculations are simplified by this procedure.

C. OWNER EXPENSES

1. Vessel Repairs

The relation of annual repair costs to vessel size is shown in Figure 5 ($t_b = 3.55$, $p < 0.001$). These costs have been adjusted to 1962 levels by applying the Bureau of Labor Statistics index for machinery and motive products. These costs have risen 14 percent from the average index for 1952-57.

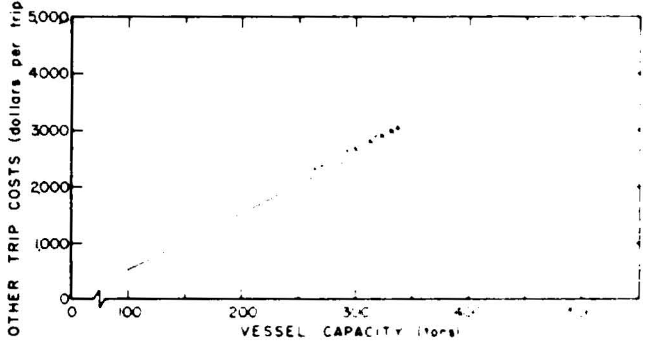

Figure 4.—Relation between other trip costs per trip and vessel capacity for purse seiners, 1961-62.

Table 1.—Current system of determining crew share percentage for purse seiners by size of vessel modified by the addition of 1½ bonus shares per crew

Vessel size	Crew's share			
	12-man crew	12-man crew plus bonus shares	13-man crew	13-man crew plus bonus shares
Tons	*Percent*			
101-125	51	57.38	..	.....
126-150	50	56.25	..	.....
151-175	48	54.00	..	.....
176-200	47	52.88	..	.....
201-250	46	51.75	..	.....
251-300	45	50.62	46	51.31
301-350	..	.....	45	50.19
351-400	..	.....	44	49.07
401-450	..	.....	43	47.96
451-500	..	.....	42	46.85
501-550	..	.....	41	45.73
551 and above	..	.....	40	44.62

Source: Information supplied by the American Tunaboat Association.

The tendency for maintenance costs to level off for larger vessels reflects 1 of the efficiencies that result from increasing the size of vessels. This tendency may be examined further in Figure 6, where the cost of repairs per ton capacity is related to total capacity ($t_b = 4.8$, $p < 0.001$). Obviously, the linear relation obtained cannot extend much beyond the tonnage range under consideration.

Several reasons exist for the relatively smaller repair costs for larger vessels. Many items of electronic equipment, such as radar, fathometers, automatic steering, radios, and the costs of their maintenance and repair, may be the same on boats of different size. The same applies, to some extent, to deck-mounted machinery such as vang winches and pursing drums. Although sizes of main-propulsion units vary considerably, the costs of maintenance are similar. Seine skiffs and nets have similar sizes throughout the fleet, and their repair costs are much the same.

Cost of upkeep depends on other characteristics of vessels besides size, although this is the most obvious. Another characteristic examined was age. As an illustration, the baitboat sample was divided into 2 groups: 40 boats built before January 1946 and 34 built subsequently. The cost per ton in size groups (to minimize effect of vessel size) is compared in Table 2. The costs shown are those reported from 1952-56, unadjusted for price increase. Repair costs increase with age of vessel.

Table 2.—Repair costs, 1952-57, for baitboats in 2 age groups by size of vessel

Size range	Average yearly repair costs			
	Vessels built before 1946		Vessels built in 1946 or later	
Tons	*Dollars per ton*			
100-200	(13)	124.28	(10)	104.73
201-300	(16)	105.55	(11)	96.35
301-400	(7)	70.16	(10)	68.93
401-500	(4)	73.26	(3)	55.35

Note: Sample sizes are given in parentheses.

Individual practices, both operational and in accounting procedures that affect maintenance costs and estimates of cost, cause much of the wide scatter in these costs (the standard deviation for the regression of Figure 5 is $9,809). Some owners habitually postpone upkeep until extensive repairs become necessary, especially in times of poor fishing and for

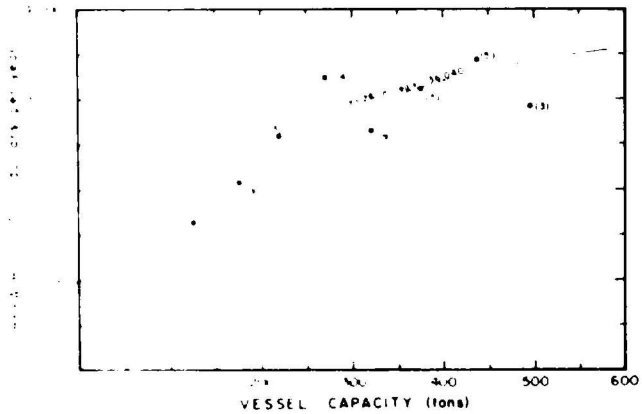

Figure 5.—Relation between annual vessel repair costs and vessel capacity, adjusted to 1962 levels from baitboat costs, 1952-57.

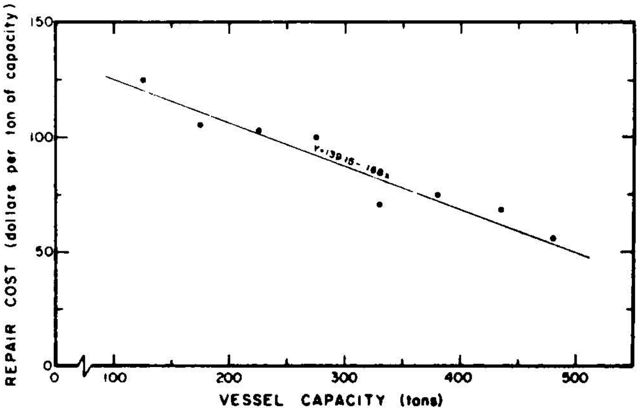

Figure 6.—Relation between annual vessel repair costs per ton of capacity and vessel capacity for baitboats, 1952-57.

boats with consistently low success. Owners with mechanical skills may take care of many repairs themselves and save on labor costs. Repair by the owner is more frequent on smaller boats, family-owned boats, and owner-manned boats.

Because of the large amount of new equipment on converted boats, repair costs will not be typical for the first years after conversion. This point should be borne in mind in the use of the adjusted baitboat regression for predicting costs. It will be necessary to analyze current operating costs of many purse seiners over a period of several years before an accurate idea of their repair costs will be available.

2. Gear and Net Repairs

The types of gear maintained, their costs, and the methods of accounting differ between baitboats and purse seiners.

In baitboats, the gear cost consists of repairs and replacements of pole-and-line tackle, and bait nets. This cost was charged to trip expense prior to about 1958, when most owners began to bear the cost of the bait-net repairs, except for labor furnished by the crew. The 1952-57 baitboat[1] data show that the cost of gear increased with increasing use (total catch) and was $4.09 per ton of fish landed.

In purse seiners, the only fishing gear is the large purse seine, which may exceed a length of 500 fathoms and a depth of 50 fathoms. The original cost of this net may exceed $50,000. A purse seine is not worn out and replaced at 1 time, but it is continually being maintained by replacement of worn and torn panels and strips that result from damage by sharks, wear in handling, the strains from loads of fish, and occasional contact with rough bottoms. The cost of its maintenance is borne by the owner, but the crew furnishes much of the labor of repair. Very few data on net maintenance have come to light so far. This cost has only recently begun to level off since the mass conversion of the baitboats to purse seiners. An allowance of $5.00 per ton of fish landed for net repairs was reported for 26 vessel-years by 1 small group of seiners. This figure is used as an approximation in this paper.

3. Depreciation

Annual depreciation claimed for tuna vessels has greatly increased since the studies by the United States Tariff Commission and the American Tunaboat Association. The increased depreciation of the tuna fleet over these years may be largely due to 2 causes: (1) increases in the capital investments caused by the conversions from baitboats to purse seiners and (2) newer methods of accounting, which allow the accelerated depreciation of the vessels over shorter periods of time.

The United States Tariff Commission's data gave consistently low estimates of depreciation in comparison with current depreciation costs claimed by purse seiners; and rather than attempt to modify these data, we have estimated depreciation of purse seiners in Table 3 by applying straight-line depreciation over 15 years, to the replacement values of Figure 7 ($t_b = 180$, $p < 0.001$, $t_b \log X = 7.5$, $p < 0.001$), retaining 15 percent salvage value. The points in Figure 7 are from the survey data of 56 purse seiners, prepared since 1960 by a private concern for an insurance company. An abnormally low replacement cost of $86,000 for 100-ton boats results from the failure of the regression of Figure 7 to fit the data at this extreme. The average replacement value for this group is, therefore, substituted in Table 3.

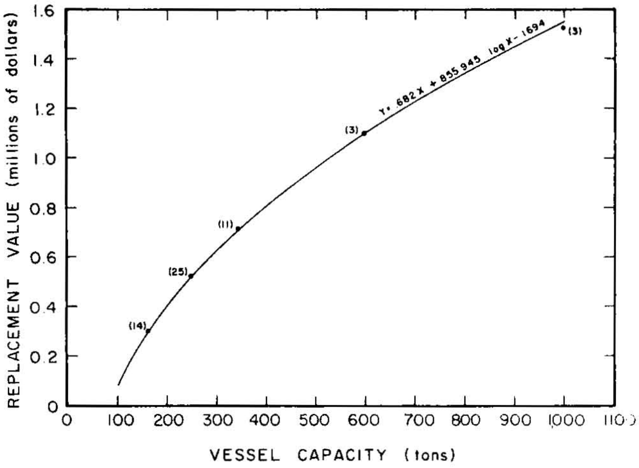

Figure 7.—Relation between replacement value of purse seiners and vessel capacity, 1960-63.

Table 3.—Annual depreciation of purse seiners by vessel capacity based on replacement value

Vessel capacity	Replacement value	Depreciation
Tons	*Dollars*	*Dollars*
100	171,000	9,691
150	271,000	15,358
200	412,000	23,348
250	529,000	29,978
300	631,000	35,759
350	723,000	40,972
400	806,000	45,676
450	884,000	50,096
500	957,000	54,233

Note: Based on straight-line depreciation over a 15-year life, leaving 15 percent salvage value.

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[1] Source: Unpublished data of the American Tunaboat Association.

4. Insurance

Several types of insurance collectively make up 1 of the boat owner's major expense items. The most substantial portion in this category is the coverage known as Hull and Machinery Insurance, which covers total loss of the vessel as well as damage caused by such things as fire, stranding, and collision. The yearly cost of this coverage may range from over 7.0 percent of the boat's value for older wooden boats to less than 3.5 percent for the newer large steel-hulled boats. These policies are subject to a deductible amount averaging $3,000 per accident, which does not apply to total loss. Whereas ocean marine policies normally provide for a return of premium for each 30-day period spent in port, the practice of most boat owners has been to waive such "layup returns" in consideration of an appropriate reduction in the initial premium.

Additional types of coverage include: skiff and net insurance for purse-seiners; war-risk coverage; cargo insurance on the catch, which is charged by the trip (included in other trip expenses); and protection and indemnity insurance, which covers illness and injuries of crew members and a broad range of possible liability to other parties. Premiums for these coverages are based on value of insured items, size of crew, and amount of protection and indemnity coverage.

Insurance companies have indirect influence on the operations of tuna vessels. To qualify for insurance, the vessel must pass an annual inspection in dry dock and be kept in repair according to the specifications of the insuring company. Area of operation is also specified, and boats that operate outside of prescribed limits in the Eastern Pacific Ocean must pay additional premiums. Vessels that have recently operated in East Coast and African waters have paid additional premiums of approximately 1 percent per year, prorated for the time actually spent in those waters. If vessels are constructed specifically for operation in such areas, the normal annual premium would permit such operation without additional charge.[2]

The total cost of insurance is a function of value and depends mainly on vessel size. Figure 8 ($t_b = 10.4$, $p < 0.001$) shows the regression of insurance costs, reported since 1963, by vessel size. The standard deviation from regression of Figure 8 is $2,730. Variation in the kinds and amount of insurance purchased cause most of the scatter in Figure 8. Hull and Machinery Insurance, for instance, may be purchased with deductibles ranging from $400 to $5,000; premiums are smaller for the larger deductibles.

5. Property Tax

The yearly cost of property tax as a function of vessel size is shown in Figure 9 ($t_b = 14.4$, $p < 0.001$). The property tax on fishing vessels varies widely with the port of registry. It is a personal property tax collected by city or county governments on the assessed valuation of the tuna boat. No data were obtained on the various tax rates and assessment practices of different ports, but a check of the *Merchant Vessels of the United States* (United States Treasury Department, Bureau of Customs, 1962) reveals that 36 percent of the purse seiners fishing out of San Diego are registered outside of California. This registration takes advantage of the lower property tax in these ports. Recent action by tax assessors may make this practice impossible in the future.[3]

6. Social Security

The social security contribution consists of tax paid by employers on the first $4,800 of each employee's wages. The rate at time of writing is 3.625 percent. Turnover of crewmen has the effect of increasing the employer contributions of this tax.

7. Other Owner Expenses

Owner's expenses such as rent on equipment, interest on boat mortgage, business telephone calls from sea, accounting fees for bookkeeping, association dues, and legal fees not chargeable to other categories, are included in other owner's expenses (Figure 10, $t_b = 5.05$, $p < 0.001$).

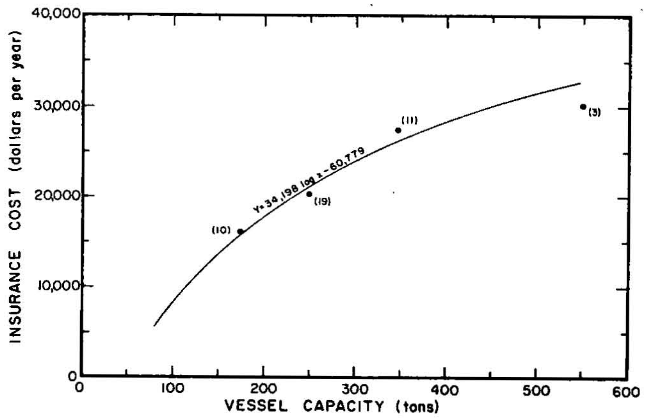

Figure 8.—Relation between annual insurance costs and vessel capacity for purse seiners, 1963-64.

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[2] A. L. Brosio of the A. L. Brosio Co., San Diego, California; personal communication.

[3] The personal property tax on tuna vessels is now under study by an interim committee of the California Assembly under House Resolution No. 399 (August Felando, Manager, American Tunaboat Association, San Diega, California).

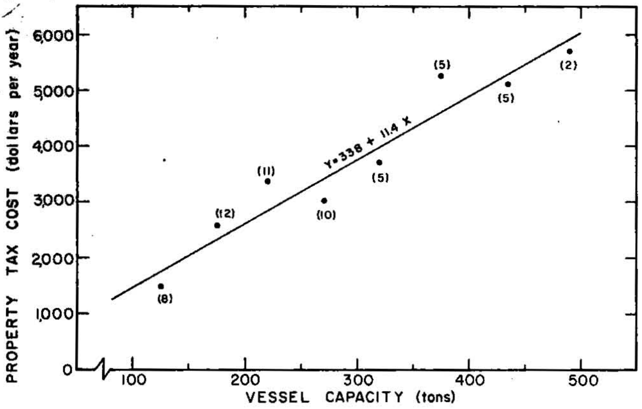

Figure 9.—Relation between annual property tax cost and vessel capacity for baitboats, 1952-57.

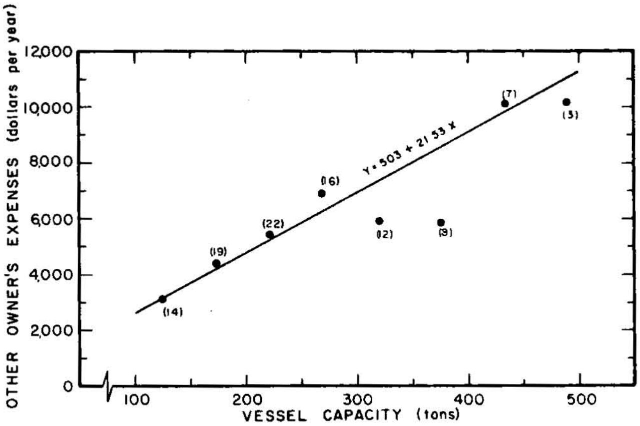

Figure 10.—Relation between other owner's costs per year and vessel capacity for baitboats, 1952-57.

III. GROSS REVENUE

In this section we present a method of computing annual gross revenue as a function of tuna price and annual catch. Vessel size modifies these 2 factors because tonnage landed and species composition of catch are related to vessel size.

A. AVERAGE PRICE

The average price received annually is influenced not only by fluctuations in price, but also by the percentage composition of the 2 species in the boat's catch. The price of skipjack tuna averaged $40 to $60 per ton less than that of yellowfin tuna. The distant grounds provide, in general, the best catch rates for skipjack, and these areas can be fished most successfully by the larger vessels.

Figure 11 shows the percentage composition of yellowfin and skipjack tuna in the catch according to vessel capacity for each of the 4 years, 1960-63. Yearly fluctuations in the percentage composition of species are related to variations in the abundance of yellowfin tuna and the response of the fishing fleet in shifting its effort toward or away from skipjack tuna. At the levels of fishing effort expended so far, no relation has been demonstrated between fishing effort and the abundance of skipjack, and the population of this species appears capable of sustaining an increased fishery (Schaefer, 1963). The curve for 1962 is used as our best estimate of the 4 years for future trends in the composition of catch by vessel size groups.

To calculate an average price received by a particular size of boat, the price for skipjack tuna is adjusted by adding to it the product of the percentage of yellowfin tuna in the catch and the difference between yellowfin and skipjack prices, usually $40 to $60 per ton. For example, a 450-ton vessel catches 44.5 percent yellowfin tuna (Figure 11, 1962 curve); the average price per ton, at $40 difference between species (assuming a skipjack price of $210 per ton), is then $210 + (.445 x $40) = $210 + $17.80 = $227.80. The fourth and fifth columns of Table 4 provide the amount to be added to the price of skipjack tuna to provide the average price received according to vessel size for differences of $40 and $60.

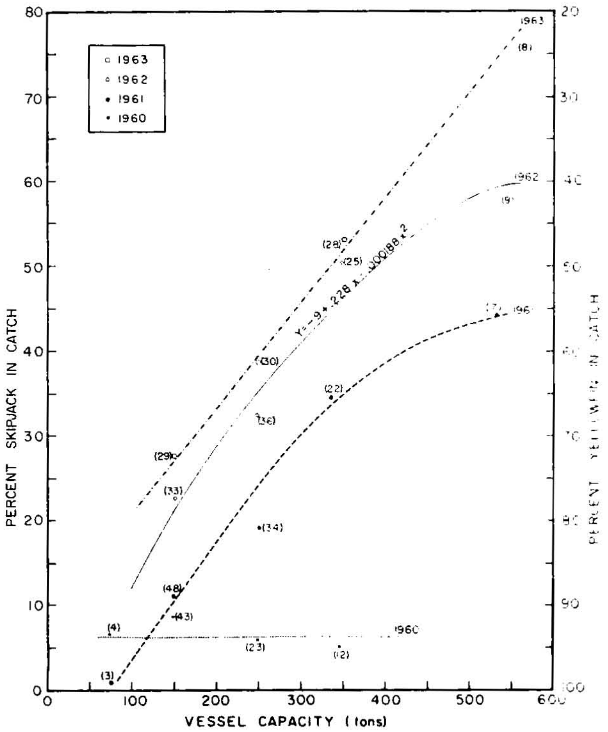

Figure 11.—Relation between percentage composition of yellowfin and skipjack in catch and vessel capacity for purse seiners, 1960-63. The points represent the average boat sizes by groups.

Table 4.—Composition of species in catch by vessel capacity, 1962, with price differentials at $40 and $60 per ton between species

Vessel capacity	Catch composition		Add to skipjack price per ton	
	Skipjack tuna	Yellowfin tuna	At $40 difference between species	At $60 difference between species
Tons	*Percent*	*Percent*	*Dollars per ton*	*Dollars per ton*
100	11.9	88.1	35.24	52.86
150	21.0	79.0	31.60	47.40
200	29.1	70.9	28.36	42.54
250	36.2	63.8	25.52	38.28
300	42.5	57.5	23.00	34.50
350	47.8	52.2	20.85	31.32
400	52.1	47.9	19.16	28.74
450	55.5	44.5	17.80	26.70
500	58.0	42.0	16.80	25.20

Because the proportion of skipjack tuna in the catch appears to vary considerably, individual boat owners may wish to substitute their own experience for composition of catch when making estimations of gross revenue. Also, it is well known among tuna-boat owners that an average of 5 to 10 percent more skipjack than yellowfin tuna may be packed in the same holds, since the skipjack tuna are generally smaller and pack better.

Ranges of annual prices as reported by canneries are shown for 1957-63 in Table 5 (Pacific Fisherman, 1964).

Table 5.—Ex-vessel prices for yellowfin and skipjack tuna, 1957-64

Year	Price per ton by species of tuna	
	Yellowfin	Skipjack
	Dollars per ton	*Dollars per ton*
1957	230-270	190-230
1958	263-283	223-235
1959	240-270	200-230
1960	250	210
1961	240-290	210-260
1962	290-300	250-260
1963	240-290	200-250
1964[1]	260-275	200-215

[1] Further complicated by fish size differentials (which change price structure somewhat) and variable results of auctions.

Sources: 1963 Pacific Fisherman Yearbook (1964), and recent auction results.

B. YEARLY CATCH

To estimate yearly catch for different sizes of boats, we use the product of 2 readily available statistics: the catch rate (in tons per day absent) and the average number of days at sea.

1. Number of Days at Sea

1 of the inherent efficiencies of large vessels is their ability to spend long periods of time at sea. This fact is shown in Figure 12, where average days at sea are shown for various sizes of vessels. The data in Figure 12 include all trips made by the California fleet in 1961 and 1962. The standard deviation from regression of Figure 12 is 33.45 days.

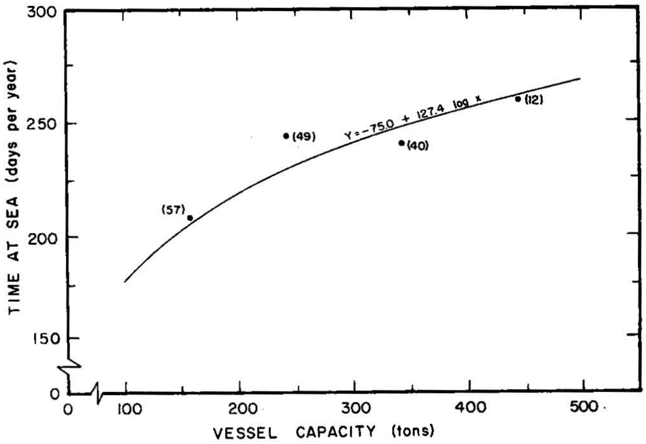

Figure 12.—Relation between average number of days at sea per year and vessel capacity for purse seiners, 1960-62.

2. Catch Rate

Condition of the stocks of tuna in the Eastern Pacific is expressed, for biological purposes, in terms of the amount that purse seiners of 101- to 200-ton capacity catch per fishing day (a standardized catch rate). The relative success each year of larger or smaller vessels is shown by a series of efficiency factors. The efficiency factors calculated by Broadhead (1962) for biological research are not useful for economic studies because time spent at sea is more closely related to vessel costs than time spent fishing. Efficiency factors are needed that are related to fish-landing capabilities of the various sizes of vessels, based on statistics on catch per day absent. Therefore, we have calculated ratios of average annual catch rates (per day absent) for various sizes of purse seiners to catch rates of the standard size for 1960-63. These efficiency factors have been plotted in Figure 13 by 50-ton size groups (with the exception of the last interval, which consists of all vessels with more than 450-ton capacity). The regression fitted to these points is our best estimator of efficiency factor in this size range but is subject to error introduced by the small size of the samples for the last 2 points. Incomplete data for 1964 conform closely to the regression of Figure 13.

Catch rates published in the bulletins and annual reports of the Inter-American Tropical Tuna Commission give good indications as to the condition of tuna stocks in the Eastern Tropical Pacific but are usually expressed as catch per day of fishing. To convert these rates to catch per day absent, the regression of catch per day absent on catch per day of fishing is shown in Figure 14. The data of this figure are from the Tuna Commission's bimonthly progress reports (1960-63), which have limited distribution, but include statistics of catch on the basis of both days absent and days fishing by size class of vessel. The failure of this regression to pass through the origin does not affect normal estimates above 2 tons per day of fishing.

Table 6 provides information on recent conditions of the fishery by presenting catch rates both by days of fishing and days absent for purse-seiners in 1959-63. These catch rates are standardized to 101- to 200-ton vessels so that efficiency factors (Figure 13) may be applied to obtain comparative catch rates for all sizes of vessels.

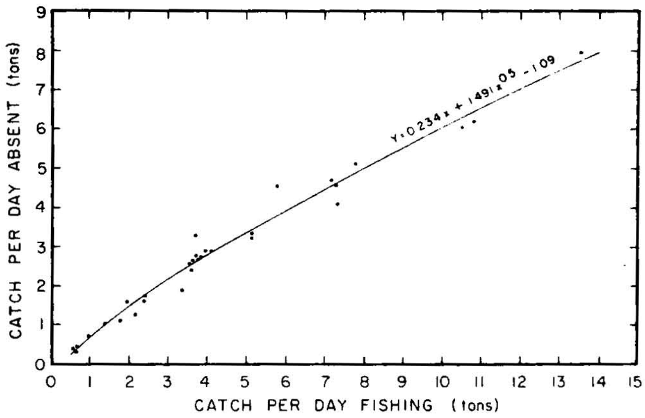

Figure 14.—Relation between catch per day of fishing and catch per day absent for purse seiners, 1959-63.

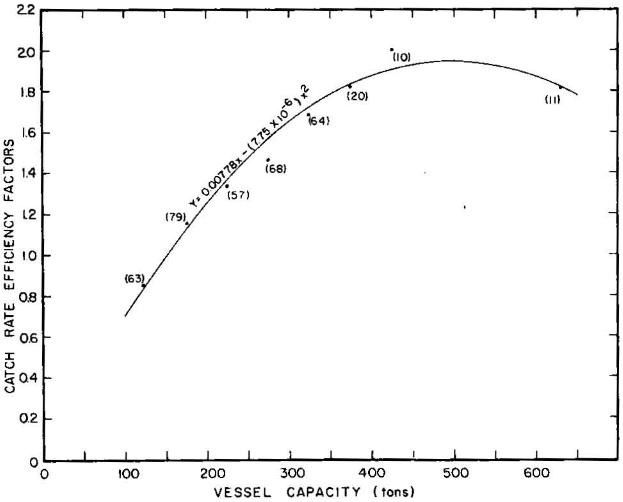

Figure 13.—Relation between catch rate efficiency and vessel capacity for purse seiners, 1960-63.

Table 6.—Standardized catch rates for yellowfin and skipjack tuna combined on both days fishing and days absent for United States-based purse seiners, 1959-63

(Converted from catch per day of fishing to catch per day absent)

Year	Catch rates, yellowfin tuna and skipjack tuna combined	
	Tons per day of fishing[1]	*Tons per day absent*[2]
1959	8.71	5.35
1960	8.60	5.30
1961	6.94	4.46
1962	5.74	3.82
1963	6.86	4.42

[1] Inter-American Tropical Tuna Commission Annual Reports, 1962 and 1963.

[2] Calculated from Figure 14.

IV. EARNINGS FOR VARYING CONDITIONS OF CATCH RATE AND PRICE FOR TUNA

In this section we illustrate how estimates of earnings for various-sized vessels may be made by combining the data on operation costs and gross revenue. We use a series of selected fishery conditions, described by standardized catch rates and prices.

8 items need special treatment before they may be estimated as annual costs according to vessel size:

1. A tabulation of trip record over a number of years has shown that about 2 percent of the fish landed are rejected at the canneries. This amount should thus be subtracted in calculation of gross revenue.
2. License fees are shown in Figure 1 as cost per trip. The number of trips per year is obtained by dividing the number of days at sea (Figure 12) by average length of trip. The trip length is estimated as the time required, at the catch rate for a particular size of purse seiner, to fill 91 percent of the boat's capacity. (This was the average percentage of capacity filled in the California-based purse-seiner fleet in 1960-62.)

3. Fuel cost is reported in Figure 2 as cost per day and is converted to annual cost by multiplying the number of days at sea (Figure 12) by fuel cost per day (Figure 2). The horsepower of the main engine may be estimated from Figure 3.
4. Other trip costs are reported as cost per trip and should be multiplied by trips per year to obtain annual cost.
5. The percentages for crew share are taken from Table 1. In the vessel-size interval, 251 to 300 tons, the columns for 12-man and 13-man crews overlap. The mean of 12.5 is used for boats in this size range.
6. The cost of provisions per man per day ($4.40) is multiplied by the number of days at sea (Figure 12) to obtain estimates of annual cost of provisions per man.
7. Net repairs are estimated by multiplying yearly catch in tons by $5.00.
8. Social security contributions by owner are 3.625 percent of the first $4,800 of each crewman's wages, including any bonus payments.

The remaining costs of operation (Figures 5, 8, 9, 10, and Table 3) are reported directly as annual costs according to vessel size.

A. SAMPLE COMPUTATIONS OF VESSEL EARNINGS

Table 7 is presented as a guide to illustrate the method used to estimate vessel earnings. The 2 basic assumptions that must be made in any estimation of vessel earnings concern price and catch rate. In Table 7, we have arbitrarily selected prices of $260 and $220 per ton for yellowfin and skipjack tuna, and a standardized catch rate of 3 tons per day absent.

The following example, which is keyed to Table 7 by column numbers, illustrates the details of computations:

Given: Vessel size = 300 tons capacity
Standardized catch rate = 3 tons per day absent
Prices = $260 per ton for yellowfin and $220 per ton for skipjack

Then: Column in Table 7

1. Individual catch rate = efficiency factor (Column 1) x standardized catch rate = 1.636 x 3 tons per day absent = 4.91 tons per day absent ---------------- [2]
2. Annual catch = individual catch rate (Column 2) x days at sea (Column 3) = 4.91 tons per day x 240 days = 1,178.4 tons ------------------------------ [4]
3. Average price of mixed catch = skipjack price + (percentage of yellowfin x $40) = $220 + $23 (Table 4) = $243 per ton ------------------------- [6]
4. Gross revenue (less an average of 2 percent damaged fish rejected by cannery) = yearly catch (Column 4) x average price of mixed catch (Column 6) x 0.98 = 1,178.4 x $243 x 0.98 = $280,624 [7]
5. Average capacity filled = 91 percent x vessel capacity = 0.91 x 300 = 273.0 [8]
6. Average trip length = average capacity filled (Column 9) ÷ individual catch rate (Column 2) = 273 ÷ 4.91 = 55.6 days [9]
7. Average number of trips per year = number of days at sea (Column 3) ÷ average trip length (Column 9) = 240 ÷ 55.6 = 4.32 trips per year ------ [10]
8. License cost per year = license cost per trip (Figure 1) x trips per year (Column 10) = $724 x 4.32 = $3,128 ------ [11]
9. Fuel cost per year = fuel cost per day (Figure 2) for 785.8 hp. (Figure 3) x days at sea per year (Column 3) = $121.34 x 240 = $29,122 ----------------- [12]
10. Other trip expenses = other trip expenses per trip (Figure 4) x trips per year (Column 10) = $2,550 x 4.32 = $11,016 [13]
11. Total trip expenses = license costs (Column 11) + fuel costs (Column 12) + other trip costs (Column 13) = $3,128 + $29,122 + $11,016 = $43,266 ------ [14]
12. Proceeds to share = gross revenue (Column 7) - trip expenses (Column 14) = $280,624 - $43,266 = $237,358 ----- [15]
13. Percentage to crew = 50.96 -------- [16]
14. Gross crew share = percentgae to crew (Column 16) x proceeds to share (Column 15) = 50.96 percent x $237,358 = $120,958 ------------------------ [17]
15. Gross individual crew share = gross crew share (Column 17) ÷ total number of shares paid (including bonus shares) =$120,958 ÷ 14 = $8,640 -------- [18]
16. Provisions per man = provisions per day, per man x days at sea per year (Column 3) = $4.40 x 240 = $1,056 [19]
17. Net individual crew share = gross individual crew share (Column 18) - provisions (Column 19) = $8,640 - $1,056 = $7,584 ---------------------- [20]

Table 7.—Sample computations of purse seiner earnings by vessel size.

[Computations based on selected standardized catch rate of 3 tons per day's absence and tuna prices of $260 and $220 per ton of yellowfin and skipjack. The numbers in parentheses at head of columns are used in discussion in text]

Vessel size	[1] Efficiency factor (Figure 13)	[2] Individual catch rate	[3] Average days at sea/year (Figure 12)	[4] Annual catch	[5] Yellowfin catch (Table 4)	[6] Price (average of mixed catch)	[7] Gross revenue (less 2 percent rejects)	[8] Average capacity filled	[9] Average trip length	[10] Average trips/year
Tons		*Tons/day absent*	*Number*	*Tons*	*Percent*	*Dollars*	*Dollars*	*Tons*	*Days*	*Number*
100	.700	2.10	180	378.0	88.1	255.24	94,551	91.0	43.3	4.16
150	.993	2.98	202	602.0	79.0	251.60	148,434	136.5	45.8	4.41
200	1.246	3.74	218	815.3	70.9	248.36	198,438	182.0	48.7	4.47
250	1.461	4.38	230	1,007.4	63.8	245.52	242,390	227.5	51.9	4.43
300	1.636	4.91	240	1,178.4	57.5	243.00	280,624	273.0	55.6	4.32
350	1.774	5.32	249	1,324.7	52.2	240.88	312,712	318.5	59.9	4.16
400	1.872	5.62	256	1,438.7	47.9	239.16	337,197	364.0	64.8	3.95
450	1.932	5.80	263	1,525.4	44.5	237.80	355,485	409.5	70.6	3.73
500	1.952	5.86	269	1,576.3	42.0	236.80	365,803	455.0	77.6	3.47

	[11] License fees	[12] Fuel cost	[13] Other trip expenses	[14] Total trip expenses	[15] Proceeds to share	[16] Percentage to crew (Table 1)	[17] Gross crew share	[18] Gross individual crew share	[19] Provisions per man	[20] Individual net crew share
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Percent*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
100	0	11,867	2,210	14,077	80,474	57.38	46,476	3,443	792	2,651
150	101	16,116	4,569	20,786	127,648	56.25	71,802	5,319	889	4,430
200	1,404	20,411	6,896	28,711	169,727	52.88	89,752	6,648	959	5,689
250	2,392	24,723	9,069	36,184	206,206	51.75	106,712	7,904	1,012	6,892
300	3,128	29,122	11,016	43,266	237,358	50.96	120,958	8,640	1,056	7,584
350	3,661	33,662	12,692	50,015	262,697	50.19	131,848	9,093	1,096	7,997
400	4,009	38,154	14,062	56,225	280,972	49.07	137,873	9,508	1,126	8,382
450	4,230	42,843	15,098	62,171	293,314	47.96	140,673	9,702	1,157	8,545
500	4,306	47,546	15,823	67,634	298,169	46.85	139,693	9,634	1,184	8,450

	[21] Owner's share	[22] Vessel repairs (Figure 5)	[23] Net repairs	[24] Depreciation (Table 3)	[25] Insurance (Figure 8)	[26] Property tax (Figure 9)	[27] Social security	[28] Other owner's expense (Figure 10)	[29] Total owner's expense	[30] Net profit or loss
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
100	33,998	15,982	1,890	9,691	7,617	1,478	1,279	2,656	40,593	- 6,595
150	55,846	20,563	3,010	15,358	13,639	2,048	1,954	3,732	60,304	- 4,458
200	79,975	23,811	4,076	23,348	17,911	2,618	2,088	4,809	78,661	1,314
250	99,494	26,332	5,037	29,978	21,224	3,188	2,088	5,886	93,733	5,761
300	116,400	28,392	5,892	35,759	23,933	3,758	2,175	6,962	106,871	9,529
350	130,849	30,135	6,624	40,972	26,221	4,328	2,262	8,038	118,580	12,269
400	143,099	31,643	7,194	45,676	28,208	4,898	2,262	9,115	128,996	14,103
450	152,641	32,972	7,627	50,096	29,955	5,468	2,262	10,192	138,572	14,069
500	158,476	34,164	7,882	54,233	31,521	6,038	2,262	11,268	147,368	11,108

18. Owner's share = proceeds to share (Column 15) - gross crew share (Column 17) = $237,358 - $120,958 = $116,400 [21]

19. Vessel repairs = $28,392 ___________ [22]

20. Net repairs = $5.00 per ton x yearly catch (Column 4) = $5.00 x 1,178.4 = $5,892 ___________________________ [23]

21. Depreciation = $35,759 ____________ [24]

22. Insurance = $23,933 ______________ [25]

23. Property tax = $3,758 _____________ [26]

24. Social security = $2,175 ___________ [27]

25. Other owner's expense = $6,962 ___ [28]

26. Total owner's expense = vessel repairs (Column 22) + net repairs (Column 23) + depreciation (Column 24) + insurance (Column 25) + property tax (Column 26) + social security (Column 27) + other (Column 28) = $28,392 + $5,892 + $35,759 + $23,933 + $3,758 + $2,175 + $6,962 = $106,871 _____________ [29]

27. Net profit = owner's share - total owner's expense = $116,400 - $106,871 = $9,529 _______________________ [30]

Table 8.—Estimations of annual purse seiner earnings based on selected standardized catch rates.

[Computations based on yellowfin prices with skipjack prices $40 less. Average mix in catch is assumed]

Standardized catch rate	Vessel size	Earnings at yellowfin price per ton											
		$200			$240			$280			$320		
		Individual crew share	Profit or loss	Return on investment	Individual crew share	Profit or loss	Return on investment	Individual crew share	Profit or loss	Return on investment	Individual crew share	Profit or loss	Return on investment
Tons/day absent	*(Tons)*	*Dollars*	*Dollars*	*Percent*	*Dollars*	*Dollars*	*Percent*	*Dollars*	*Dollars*	*Percent*	*Dollars*	*Dollars*	*Percent*
3	100	1,684	-15,319	-8.96	2,313	-9,315	-5.45	2,943	-3,271	-1.91	3,573	2,800	1.64
	150	2,955	-19,379	-7.15	3,939	-9,421	-3.48	4,922	595	0.22	5,906	10,923	4.03
	200	3,811	-20,909	-5.08	5,063	-6,205	-1.51	6,315	8,857	2.15	7,568	23,919	5.81
	250	4,635	-22,582	-4.27	6,153	-3,539	-0.67	7,670	15,565	2.94	9,188	34,668	6.55
	300	5,075	-24,247	-3.84	6,760	-1,541	-0.24	8,446	21,166	3.36	10,131	43,872	6.95
	350	5,306	-26,421	-3.65	7,104	-540	-0.08	8,903	25,342	3.51	10,701	51,223	7.09
	400	5,525	-28,871	-3.58	7,436	-112	-0.01	9,347	28,648	3.55	11,258	57,407	7.12
	450	5,570	-32,712	-3.70	7,547	-1,620	-0.18	9,523	29,473	3.33	11,499	60,565	6.85
	500	5,449	-38,270	-4.00	7,444	-5,459	-0.57	9,438	27,351	2.86	11,433	60,161	6.28
4	100	2,677	-6,459	-3.78	3,516	1,626	0.95	4,356	9,738	5.69	5,195	17,994	10.52
	150	4,461	-5,132	-1.89	5,772	8,516	3.14	7,084	22,287	8.23	8,395	36,058	13.31
	200	5,668	-288	-0.07	7,338	19,795	4.80	9,007	39,878	9.68	10,677	59,961	14.56
	250	6,835	3,361	0.64	8,858	28,832	5.45	10,882	54,304	10.26	12,906	79,775	15.08
	300	7,473	6,100	0.97	9,721	36,375	5.77	11,968	66,650	10.56	14,215	96,925	15.36
	350	7,828	7,669	1.06	10,226	42,177	5.84	12,624	76,685	10.62	15,022	111,194	15.40
	400	8,174	8,595	1.07	10,722	46,940	5.82	13,270	85,286	10.51	15,818	123,632	15.34
	450	8,285	7,462	0.84	10,920	48,919	5.53	13,555	90,375	10.22	16,190	131,832	14.92
	500	8,172	3,889	0.41	10,831	47,636	4.98	13,491	91,383	9.55	16,150	135,130	14.12
5	100	3,670	2,480	1.45	4,719	12,621	7.38	5,768	23,113	13.52	6,818	33,634	19.67
	150	5,967	9,551	3.53	7,606	26,765	9.88	9,245	43,979	16.23	10,885	61,192	22.59
	200	7,525	20,692	5.02	9,612	45,796	11.12	11,699	70,900	17.21	13,786	96,003	23.30
	250	9,034	29,364	5.55	11,564	61,203	11.57	14,093	93,042	17.59	16,623	124,881	23.61
	300	9,872	36,447	5.78	12,681	74,290	11.78	15,490	112,134	17.77	18,299	149,977	23.77
	350	10,351	41,758	5.78	13,348	84,894	11.75	16,346	128,029	17.73	19,343	171,164	23.70
	400	10,823	46,060	5.71	14,008	93,993	11.66	17,193	141,925	17.61	20,378	189,857	23.56
	450	11,000	47,636	5.39	14,294	99,457	11.25	17,587	151,277	17.12	20,881	203,098	22.98
	500	10,894	46,048	4.81	14,218	100,732	10.52	17,542	155,416	16.24	20,867	210,100	21.95

Table 7 is presented only as a guide to computing vessel earnings and will, of course, need to be modified by users in regard to current catch rates and prices. Since many estimates are involved, the reader may also wish to improve upon the accuracy of his predictions by substituting, wherever possible, his own experience for our estimates, which are based on the average past experience of the fleet. For instance, many boats are fairly consistent in their numbers of trips per year and days at sea per year under the present conditions of tuna stocks. These figures could be substituted in computation of gross revenue and certain trip expenses.

B. EFFECTS OF VARYING CATCH RATES AND PRICES ON VESSEL EARNINGS

Estimates of individual crew shares and the amount of profit or loss according to vessel size are shown for purse seiners in Table 8, which presents the results of earnings computed in the manner described above. The percentages of profit or loss on original investment (replacement values of Table 3) are also shown in Table 8. Prices are varied in 4 equal steps from $200 to $320 per ton for yellowfin tuna, with corresponding skipjack tuna prices running $40 per ton less. Standardized catch rates of 3, 4, and 5 tons per day absent are used. If the standardized catch rate is unavailable for use in Table 8, the actual catch rate of a vessel may be standardized by dividing it by the appropriate vessel efficiency factor (Figure 13 or Table 7, Column 2). To illustrate standardization with an example, an individual catch rate of 5 tons per day absent made by a 200-ton seiner represents a standardized catch rate of 5 ÷ 1.246 = 4.01 tons per day absent.

Earnings for catch rates or prices intermediate between those shown in Table 8 may be estimated by linear interpolation. For example, the annual profit for a 300-ton seiner at a price of $280 per ton for yellowfin (skipjack price is assumed at $40 less in Table 8) and a standardized catch rate of 3½ tons per day absent would be halfway between $22,454 and $68,358 (Table 8), or $45,406.

V. EFFECT OF FISHERY CONDITIONS UPON OPTIMUM SIZE OF VESSEL

Several conclusions may be drawn from Table 8. The maximum individual crew share occurs on a 450-ton vessel (or between 400 and 500 tons) under all catch rates and prices considered. From the standpoint of dollar amount of profit to the owner, the optimum size varies more with catch rate and price. At a standardized catch rate of 3 tons per day absent, the optimum vessel size is 400 tons at a yellowfin price of $240 per ton, and 450 tons at prices of $280 and $320 per ton. At a standardized catch rate of 4 tons per day absent, the optimum vessel size is 400 tons at $200 per ton, 450 tons at $240 per ton, and 500 tons or over at $280 or more per ton. At a standardized catch rate of 5 tons per day absent, the optimum size for owners is 450 tons at the yellowfin price of $200 per ton and 500 tons or over when the price is higher than $200 per ton.

On the basis of percentage return on investment (replacement values from Table 3), the optimum sizes for owners are somewhat different. At 3 tons per day absent (standardized), the optimum size is 400 tons capacity at all prices. At 4 tons the optimum sizes are 400 tons at the yellowfin price of $200 per ton, and 350 tons at $280 or more per ton. At 5 tons per day the optimum size is between 300 and 350 tons at $200 per ton and 300 tons at $240 or more per ton.

Thus, for percentage return on investment, optimum size decreases under better catch rates and higher prices; but from the standpoints of both amount of profit and individual crew share, optimum size increases under better catch rates and higher prices.

Differences in percentage of profit among vessels larger than 150 tons are slight under any given condition of catch rate and price. To illustrate these maxima graphically, Figure 15 has been prepared from Table 8; it is based on the columns for percentage return on investment.

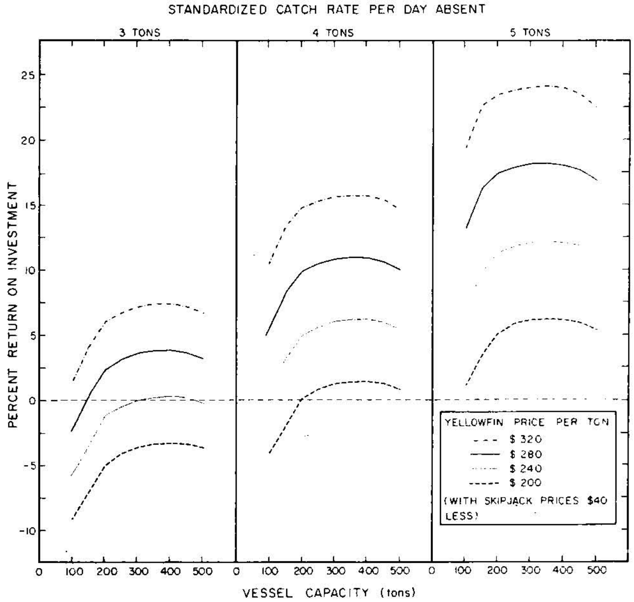

Figure 15.—Relation between percentage returns on investment and purse seiner capacity for a selected series of catch rates and prices for tuna.

Table 8 and Figure 15 illustrates the risks inherent in tuna fishing, due to variable catch rates and prices. Obviously, high catch rates and prices or both are necessary to ensure high average rates of return on investment. The catch rate of 4 tons per day absent shown in the center of Table 8 approximates conditions at the time of writing. A standardized catch rate of 5 tons per day has not been reached since 1960 (Table 6).

Earnings for the smallest vessel size seem abnormally low (Figure 15). The economic picture for this size is complicated, since these boats often fish for species other than tuna. Their costs of operation, as presented here, are probably accurate, but further studies should be made to include all of the income from sales of fish caught by vessels of this size. Seiners over 150 tons, however, fish almost exclusively for tuna.

Seiners larger than 500 tons may present an entirely different situation. Although efficiency factors (Figure 13) begin to drop off after about 500 tons, these larger boats have an advantage in being able to operate over wider areas. At present, most of these boats are operating out of Puerto Rico. We would expect that their costs of operation and the factors entering into estimations of their gross revenue would, therefore, be much different from the California-based boats, upon which this study is based.

VI. CONCLUSIONS

1. Vessel size is a factor in both (a) the cost of operation and (b) the total catch of purse seiners operating in the Eastern Tropical Pacific.
2. Estimations of purse-seiner earnings may be made on the basis of vessel size, fishing conditions, and tuna prices.
3. The optimum size of vessel from the standpoint of amount of earnings is between 450 and 500 tons capacity for crewmen, and from 400 to over 500 tons capacity for owners, depending upon conditions in the fishery and price. From the standpoint of percentage of return on investment, optimum vessel size varies from 350 tons to 400 tons capacity.

SUMMARY

The search for increased efficiency in the United States tropical tuna purse-seine fleet has led to the introduction of increasingly larger vessels. This change raises the questions as to how vessel size and other factors affect earnings, and to the optimum size. This paper attempts to answer these questions and presents a method for estimating earnings of purse seiners.

The 2 basic factors that determine earnings to boats are (1) cost of operation and (2) gross revenue. Data on cost of operation were available from most of the baitboat fleet for 1952-57. These data were modified to correspond to costs for present-day purse seiners. Data on cost of operation were divided into trip expenses and owner expenses. Subdivisions of these 2 items were examined individually with respect to vessel size. Estimates of gross revenue were based on catch rates, tuna prices, vessel size, species composition of the catch, average days at sea per year, and catch-rate efficiency. Standardized catch rates per day absent indicate fishing conditions over the entire fishery. Efficiency factors, relating actual rates to standardized catch rates, are presented for all boat sizes.

Earnings are computed by usual vessel-accounting procedures. Trip expenses are subtracted from the gross revenue; the proceeds are shared between owner and crew. The crew's net share is determined by subtracting cost of provisions from the gross crew share. The net profit or loss to the owner is determined by subtracting the owner's total expense from his share.

Different conditions of the fishery and prices were examined; assumed values ranged from 3 tons per day absent (standardized) and $200 per ton for yellowfin tuna to 5 tons per day and $320 per ton for yellowfin. Prices of skipjack tuna are assumed to be $40 per ton less than yellowfin prices.

Optimum vessel sizes vary from 350 tons capacity to over 500 tons capacity, depending upon catch rate and prices.

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MS #1512

AMINO ACID COMPOSITION OF THE ALEWIFE
(Alosa pseudoharengus)

by

Mary H. Thompson and Robert N. Farragut

ABSTRACT

The amino acid and related compound composition of alewife samples collected from Lake Michigan was determined on a seasonal basis. Significant seasonal variations in total available nitrogen, ninhydrin-positive compounds, and protein amino acids are discussed in relation to the reproductive cycle of the alewife. Results are reported in terms of the concentration of the various nitrogenous compounds present in the whole fish.

INTRODUCTION

The fresh-water alewife *(Alosa pseudoharengus)*, a schooling fish of small size, is probably most suitable for use as an industrial fish, though the somewhat larger marine form is utilized as a food fish, especially along the eastern coast of the United States. Large quantities of the species are available in Lakes Ontario, Erie, Huron, and Michigan, where for the past few years the Bureau of Commercial Fisheries research vessel ***Kaho*** has caught it in commercial quantities (U. S. Fish and Wildlife Service, 1961). Several uses have been proposed for the fish, chief among them being for fish meal or heat-processed animal foods. Because little has been known of the chemical composition of the species, the purposes of this paper are to report its amino acid composition and to record any seasonal variations in those acids. These variations will be discussed in terms of total available nitrogen, ninhydrin-positive compounds, and protein amino acid concentration.

I. AMINO ACID COMPOSITION

A. PROCEDURE

1. Sampling Methods

The sampling methods and the preparation of the materials used for analysis are described by Travis (1966); therefore, only the more important aspects are reviewed here. 6 samples of alewife were obtained over a period of a year in Lake Michigan by members of the research team aboard the exploratory fishing vessel ***Kaho***. The fish were alive when frozen whole for shipment to the Bureau of Commercial Fisheries Technological Laboratory at Pascagoula, Mississippi. Each sample of fish was divided at random into 2 subsamples, weighed, measured, and, while frozen, ground whole in a ball-mill grinder. All samples were frozen and held at 0° F. until required for analysis.

2. Chemical Methods

Each subsample was hydrolyzed separately for determination of amino acids, thereby providing duplicate values for each original sample. Tryptophan was determined in accordance with the procedure of Graham, Smith, Hier, and Klein (1947). The acid hydrolysates were prepared by placing about 0.05 grams of sample in 1 milliliter of 6N HCl, evacuating to 30 microns mercury pressure, and digesting at 110° C. for 22 hours. The hydrolysates were flash-evaporated, and the amino acids redissolved in sodium citrate buffer at pH 2.2 and stored at 0° F. until required for analysis. Duplicate subsamples of the same ground sample were also hydrolyzed for 22-hour, 48-hour, and 72-hour periods to determine (1) increased hydrolysis of the peptide bonds or (2) destruction of amino acids. The factors ob-

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Table 1.—Physical measurements and nitrogen content of the Lake Michigan alewife *(Alosa pseudoharengus)*[1]

Sample	Fish in sample	Physical measurements				Nitrogen content
		Length		Weight		
		Range	Average	Range	Average	
Date	*No.*	*Cm.*	*Cm.*	*Grams*	*Grams*	*Percent*
4/11/63	77	9.0-20.5	15.1	8.4-64.4	30.2	2.26
6/05/63	57	14.7-20.1	17.0	24.0-54.5	35.2	2.41
8/18/63	97	10.0-17.5	14.4	8.7-34.1	21.5	2.34
10/09/63	94	10.4-20.1	15.3	13.9-52.1	29.4	2.22
10/19/62	71	8.1-21.2	15.5	4.1-82.3	32.9	2.25
12/14/62	116	6.8-20.7	13.4	3.6-60.2	23.5	2.12

[1] Travis (1966).

tained were then used in subsequent calculations to relate the concentration of the amino acids to the 0-time state (Block, 1960). Amino acids (other than tryptophan were analyzed using the 30°-50° C. method with a Beckman Model 120B Amino Acid Analyzer[1]. Standard runs of each amino acid were made after each replenishment of ninhydrin.

3. Statistical Methods

The standard deviations and standard error of the various amino acid determinations were obtained by using the data for the duplicate analyses that were run throughout the experiment. Therefore, these statistical measures represent an estimation of the precision of the sampling method, the hydrolysis method, and the analysis method.

Values for each of the amino acids reported were, in effect, averages obtained from a random selection of a large number of individuals. In order that differences might be detected between samples collected at different times of the year, use was made of the standard deviation. A monthly value was said to be significantly different at the 5-percent level (*) if the 2 values differed from their average by more than ±2 standard deviations. Further, the differences were said to be significantly different at the 1-percent level (**) if the 2 values exceeded the average by ±3 standard deviations. A further criterion of smoothness in seasonal curve configuration was also required.

B. RESULTS

1. Physical Measurements and Nitrogen Content

The proximate composition and physical measurements of the fish composing the 6 samples of alewife were reported by Travis (1966). For convenience, a portion of these data is recorded in Table 1. There is considerable disparity in length and weight of the individual fish in each sample, although the mean lengths and weights of each sample differ but little from each other. As was noted by Travis, total nitrogen content decreased significantly (*) during December and increased significantly (*) during the June spawning period.

2. Amino Acid and Related Compound Composition

The amino acid and related-compound composition of the alewife is presented in Table 2 on a wet-weight and nitrogen-content basis. Subsequent discussions will, for the most part, be based on data calculated on a nitrogen-content basis, since truly significant differences in composition can be discerned by this method. Several of the amino acids differ considerably in concentration from those previously reported for an invertebrate (Thompson and Farragut, 1966). They are arginine, hydroxylysine, hydroxyproline, proline, and tyrosine. Also, the urea content was significantly (*) less in the flesh of the alewife than in the flesh of the blue crab. It has been established that fish, in general, contain less arginine than do invertebrates (Borgstrom, 1962). A greater concentration of hydroxyproline and hydroxylysine has been noted in the flesh of fresh-water fish than in marine invertebrates (Gustavson, 1956). Thus, the differences found during the present study are not surprising. Vertebrates, such as fish, have an excretory system that is more developed than that of invertebrates. Accordingly, the lesser concentration of urea in the alewife is well in line.

In the 6 samples reported here, the ninhydrin-positive compound nitrogen (with the exception of ammonia, which is not reported) ranged from 67 to 77 percent of the total nitrogen available as calculated from the total nitrogen content of the sample. The protein amino acid nitrogen ranged from 65 to 74 percent of the total available nitrogen. The amino

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[1] Trade names are used merely to simplify the description of the experimental equipment; no endorsement is implied.

Table 2.—Amino acid and related compound composition of the alewife *(Alosa pseudoharengus)*

Amino acid	Concentration on a wet-weight basis on:						Concentration on a nitrogen basis on:						Probability of difference
	4/11/63	6/5/63	8/18/63	10/9/63	10/19/62	12/14/62	4/11/63	6/5/63	8/18/63	10/9/63	10/19/62	12/14/62	
	Micromoles per gram						*Micromoles per milligram N*						*Percent*
Alanine	103.6	96.4	103.5	84.3	104.0	92.8	4.59	4.01	4.43	3.80	4.63	4.38	--
γ-Aminobutyric acid	0.4	0.8	0.4	0.2	0.3	0.4	0.01	0.03	0.02	0.01	0.01	0.01	--
Arginine	39.3	42.8	41.7	39.8	38.7	36.2	1.74	1.79	1.79	1.79	1.72	1.71	--
Aspartic acid	89.9	72.9	92.2	75.9	93.5	89.2	3.98	3.04	3.95	3.42	4.16	4.21	5.0
Cystathionine	0.3	0.1	2.9	1.4	0.2	0.3	0.01	<0.01	0.12	0.07	0.01	0.01	--
Cystine/2	11.8	10.0	11.3	9.8	12.2	12.0	0.52	0.42	0.49	0.44	0.54	0.57	--
Ethanolamine	6.5	3.3	3.5	3.5	2.7	4.2	0.29	0.14	0.15	0.16	0.12	0.20	1.0
Glutamic acid	133.6	115.7	130.6	109.6	133.8	120.6	5.92	4.82	5.59	4.95	5.95	5.69	--
Glycine	103.2	112.8	115.9	85.6	107.2	95.9	4.58	4.69	4.96	3.86	4.77	4.53	--
Histidine	14.7	14.1	17.4	19.8	15.3	15.3	0.65	0.59	0.75	0.89	0.68	0.72	--
Hydroxylysine	0.9	2.0	1.5	1.1	1.1	1.0	0.04	0.09	0.06	0.05	0.05	0.05	5.0
Hydroxyproline	6.7	13.9	10.6	7.0	9.7	6.0	0.30	0.58	0.46	0.32	0.43	0.29	5.0
Isoleucine	41.5	34.9	41.0	35.9	43.7	36.8	1.84	1.45	1.76	1.62	1.95	1.74	--
Leucine	76.8	64.2	76.2	64.8	77.8	71.0	3.40	2.67	3.26	2.92	3.46	3.35	--
Lysine	75.2	72.5	73.3	78.4	70.0	75.8	3.33	3.01	3.14	3.53	3.11	3.58	--
Methionine	24.4	20.6	25.0	18.9	23.8	24.1	1.08	0.85	1.07	0.85	1.06	1.14	--
3-Methylhistidine	0.1	0.0	0.1	0.0	0.0	0.0	<0.01	0.00	<0.01	0.00	0.00	0.00	--
Ornithine	0.7	2.4	2.9	3.2	1.8	1.6	0.03	0.10	0.13	0.15	0.08	0.08	5.0
Phenylalanine	24.7	24.6	30.6	27.0	32.4	28.8	1.32	1.02	1.31	1.22	1.44	1.36	--
Proline	49.5	54.4	50.3	38.1	48.0	41.7	2.19	2.26	2.10	1.72	2.14	1.97	--
Serine	59.3	52.2	58.6	49.4	59.8	54.6	2.63	2.17	2.51	2.23	2.66	2.58	--
Taurine	18.9	14.6	15.5	14.8	17.2	16.9	0.84	0.61	0.67	0.67	0.76	0.80	1.0
Threonine	47.5	38.8	47.1	39.8	48.1	42.8	2.11	1.61	2.02	1.80	2.14	2.02	--
Tryptophan	9.2	8.9	9.5	9.3	6.6	7.9	0.41	0.37	0.41	0.42	0.30	0.37	--
Tyrosine	21.1	17.5	21.2	18.4	21.4	20.1	0.94	0.73	0.91	0.83	0.95	0.95	--
Urea	13.3	8.0	4.3	5.6	5.7	7.3	0.59	0.33	0.18	0.25	0.26	0.34	5.0
Valine	55.3	43.2	52.4	45.6	56.2	52.7	2.45	1.80	2.25	2.06	2.50	2.49	5.0
Total μmoles of N from protein amino acids	1182	1110	1206	1067	1189	1113							
Total μmoles of N from ninhydrin-positive compounds	1236	1149	1246	1105	1225	1153							
Total μmoles of N available	1613	1720	1670	1585	1606	1513							
Percent protein amino acids N	73	65	72	67	74	74							
Percent ninhydrin-positive N	77	67	75	70	76	76							

acid analysis shows then that there is little nitrogen (2-4 percent) that is not of a protein amino acid type (Table 2).

The greatest contribution to nonprotein nitrogen was made by taurine, a constituent of the bile acids. A secondary source of nonprotein nitrogen was urea. Presumably, part of the nitrogen that was not accounted for under the present reporting scheme is that occurring as ammonia. Further contributions to the nonreported nitrogen were made from nitrogen in such compounds as vitamins, lipids, and carotenoids.

3. Protein Amino Acid Composition

Table 3 lists the protein amino acid concentrations computed on the basis of 100 grams of protein. Borgstrom (1962) lists such values for several of the more common Atlantic Ocean species of fish and for 1 fresh-water species. No marked difference is evident between the fresh-water alewife and the Atlantic species of fish in concentrations of the following amino acids: alanine, cystine/2, glycine, methionine, proline, and tryptophan. However, the arginine, aspartic acid, glutamic acid, histidine, isoleucine, leucine, lysine, phenylalanine, serine, threonine, tyrosine, and valine contents appear to be from 1/4 to 2 times as high in the Atlantic marine species as in the fresh-water alewife. Fresh-water perch is similar to fresh-water alewife in concentration of cystine/2, glutamic acid, histidine, leucine, lysine, proline, and tryptophan. The perch, however, has a greater concentration of arginine, glycine, isoleucine, methionine, phenylalanine, serine, threonine, tyrosine, and valine. On the other hand, the aspartic acid content is greater in alewife than perch. The apparently smaller concentration of amino acids in the alewife compared with the other species may be attributed to the large amount of nonninhydrin-positive nitrogen material present in the alewife which is computed as protein (when protein is assumed to be equal to 6.25 times the nitrogen content). This is also apparent when the amino acid concentration is computed on the basis of a total nitrogen content. The foregoing serves to point out the fallacy of either calculating available protein in the usual routine manner or trying to compare values expressed on this basis with others in the literature.

Table 3.—Concentrations of the protein amino acids of the alewife

Amino acid	Concentration of the indicated amino acid on:					
	4/11/63	6/5/63	8/18/63	10/9/63	10/19/62	12/14/62
	Grams per 100 grams of protein[1]					
Alanine	6.5	5.7	6.3	5.4	6.6	6.2
Arginine	4.8	5.0	5.0	5.0	4.8	4.8
Aspartic acid	8.5	6.5	8.4	7.3	8.9	9.0
Cystine/2	1.0	0.8	0.9	0.8	1.0	1.1
Glutamic acid	13.9	11.3	13.2	11.7	14.0	13.4
Glycine	5.5	5.6	6.0	4.6	5.7	5.4
Histidine	1.6	1.5	1.9	2.2	1.7	1.8
Hydroxylysine	0.1	0.2	0.2	0.1	0.1	0.1
Hydroxyproline	0.6	1.2	1.0	0.7	0.9	0.6
Isoleucine	3.9	3.0	3.7	3.4	4.1	3.7
Leucine	7.1	5.6	6.8	6.1	7.3	7.0
Lysine	7.8	7.0	7.3	8.2	7.3	8.4
Methionine	2.6	2.0	2.6	2.0	2.5	2.7
Phenylalanine	3.5	2.7	3.5	3.2	3.8	3.6
Proline	4.0	4.2	3.9	3.2	3.9	3.6
Serine	4.4	3.6	4.2	3.7	4.5	4.3
Threonine	4.0	3.1	3.9	3.4	4.1	3.9
Tryptophan	1.3	1.2	1.3	1.4	1.0	1.2
Tyrosine	2.7	2.1	2.6	2.4	2.8	2.8
Valine	4.6	3.4	4.2	3.9	4.7	4.7

[1] Nitrogen content x 6.25.

II. SEASONAL VARIATIONS

A. NITROGEN

Figure 1 shows the seasonal variation in total available nitrogen, ninhydrin-positive nitrogen, and protein amino acid nitrogen during the period of this study. As previously reported by Travis (1966), the total nitrogen showed a significant (*) increase during the spawning season. In Lakes Erie and Michigan, the alewife spawns in June or July (Trautman, 1957, and Edsall, 1964). The total nitrogen content decreased to a low in December. The ninhydrin-positive compound nitrogen and the protein amino acid nitrogen concentrations did not follow this pattern in its entirety. Whereas the total available nitrogen concentration increased during the spawning season, the ninhydrin-positive compounds decreased in concentration. Those changes are as would be expected if spawning activity depletes the protein reserves, a generally accepted theory. The increase in total protein indicated by the data of Travis (1966), thus is not a real increase, but an apparent one, caused by the assumption that the nitrogen content multiplied by 6.25 equals the protein content. Presumably, as the alewife expends considerable metabolic energy during its spawning period, excretory processes do not keep pace with metabolic destruction; thus considerable quantities of nitrogen may remain in the body. Such residual nitrogen could, in turn, lead to the false assumption that the protein content increased during the spawning period. During the spawning period, the alewife feeds, but it does not grow (Joeris[2]).

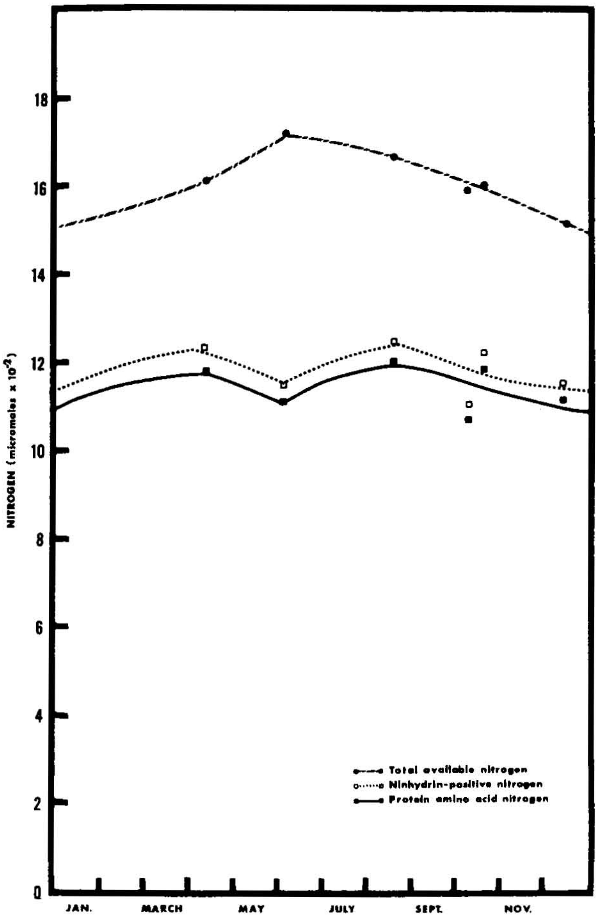

Figure 1.—The seasonal variation in total available nitrogen, ninhydrin-positive nitrogen, and protein amino acid nitrogen of the Lake Michigan alewife (1962-63).

The concentration of ninhydrin-positive compounds and protein amino acids increased after spawning, apparently a result of the general rebuilding processes. This increase then gradually dropped off during the winter but increased in the spring prior to spawning. The differences apparent (which are not significant at the 5-percent level) in the 2 samples taken during October, though a year apart, are not readily explanable. Duplicate subsamples were in good agreement, and the individual fish did not seem to differ markedly in physical measurements. The only noticeable disagreement between samples appears in the percentage composition of the nitrogen fractions. Table 2 shows that the October 9, 1963, sample was poorer both in ninhydrin-positive nitrogen and protein amino acid nitrogen than was the October 19, 1962, sample. Apparently, for an unknown reason, the October 9 fish had exhausted some of their protein reserves and were more akin to the fish taken during the spawning period than to the fish in the other 4 samples. Environmental conditions—such as lack of feed and colder waters—could have played a part in the decrease of these compounds. One must note, however, that neither the concentration of total nitrogen nor the concentration of any individual amino acid was significantly (*) different between the 2 samples. This lack of significant difference would tend to confirm the theory of metabolic action leading to a depletion of amino acid content, which is also assumed to account for the differences occurring during the spawning period. Thus, the question of the differences occurring in October of 2 different years cannot be resolved with the data obtained for this report. It is, however, worthy of note.

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[2] Leonard Joeris. The present status of our knowledge of the biology of the alewife in the Great Lakes. Unpublished report; available at the Bureau of Commercial Fisheries Technological Laboratory, Pascagoula, Mississippi.

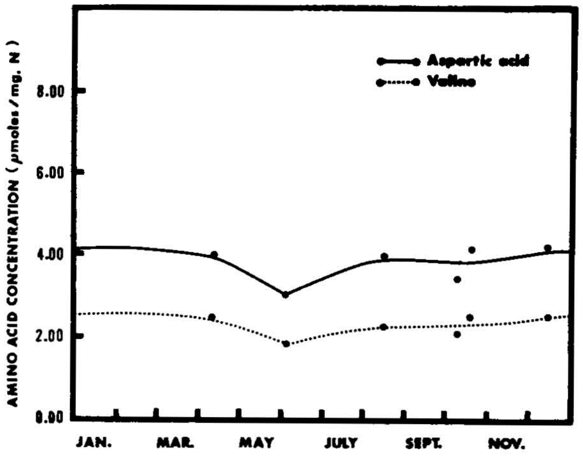

Figure 2.—The seasonal variation in aspartic acid and valine content of the Lake Michigan alewife (1962-63).

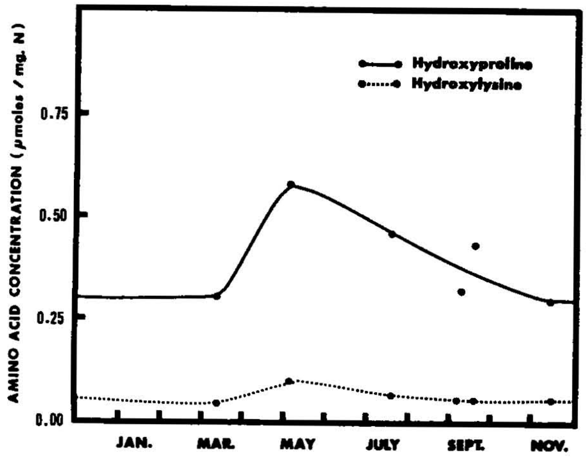

Figure 3.—The seasonal variation in hydroxyproline and hydroxylysine content of the Lake Michigan alewife (1962-63).

B. AMINO ACIDS AND NINHYDRIN-POSITIVE COMPOUNDS

Figures 2 and 3 show the significant seasonal variations in amino acids. In Figure 2, the decreases in concentration of aspartic acid and valine, which occurred simultaneously with the spawning period, are shown. These amino acids remained at a high level throughout the remainder of the year. Figure 3 shows the significant (*) increase in hydroxyproline and hydroxylysine. The increase occurs during the spawning period and would be expected if the theory of depletion of protein reserves is indeed true. These 2 amino acids are found exclusively in the connective tissue of animals. Thus, if the muscular tissue apparently was depleted during extreme activity, the relative amount of connective tissue amino acids would increase. As the fish recover from the spent condition, the concentration of the connective tissue (and thus of these 2 amino acids) returns to its proper normal balance with the muscular tissue.

Several significantly (*) different seasonal changes in nonprotein ninhydrin-positive compounds are shown in Figure 4. The compounds were taurine, urea, ethanolamine, and ornithine. Taurine and ethanolamine dropped to a seasonal low during the spawning period, further evidence of a depletion of metabolically reactive compounds during this time. Ornithine, as a byproduct of the metabolism of arginine, increased significantly during the summer. Urea was significantly (*) higher in concentration during the early spring.

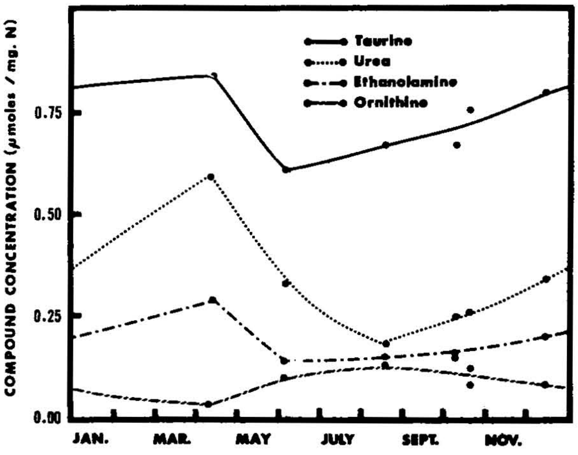

Figure 4.—The seasonal variation in taurine, urea, ethanolamine, and ornithine content of the Lake Michigan alewife (1962-63).

SUMMARY

1. The amnio acid and ninhydrin-positive compound composition of the alewife is reported on a seasonal basis for 1962-63.

2. Differences between the composition of the alewife, as a vertebrate fresh-water fish, and the blue crab, as a marine invertebrate, are pointed out. Significant (*) differences are evident in the concentrations of arginine, hydroxylysine, hydroxyproline, proline, and tyrosine.

3. The increase in total available nitrogen and the decrease in concentration of ninhydrin-positive compounds and protein amino acids were apparently related to the increased activity of the alewife during spawning; presumably, the increased metabolic activity of the fish caused the "poor," or spent, fish to undergo a loss in muscle tissue and an increase in ammonical end-products.

4. Significant (*) seasonal increases in hydroxylysine and hydroxyproline concentrations, as well as significant (*) decreases in aspartic acid and valine concentrations, occurred during June and July. The concentrations of taurine, ethanolamine, urea, and ornithine also vary in a significant (*) manner with season.

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MS #1493

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