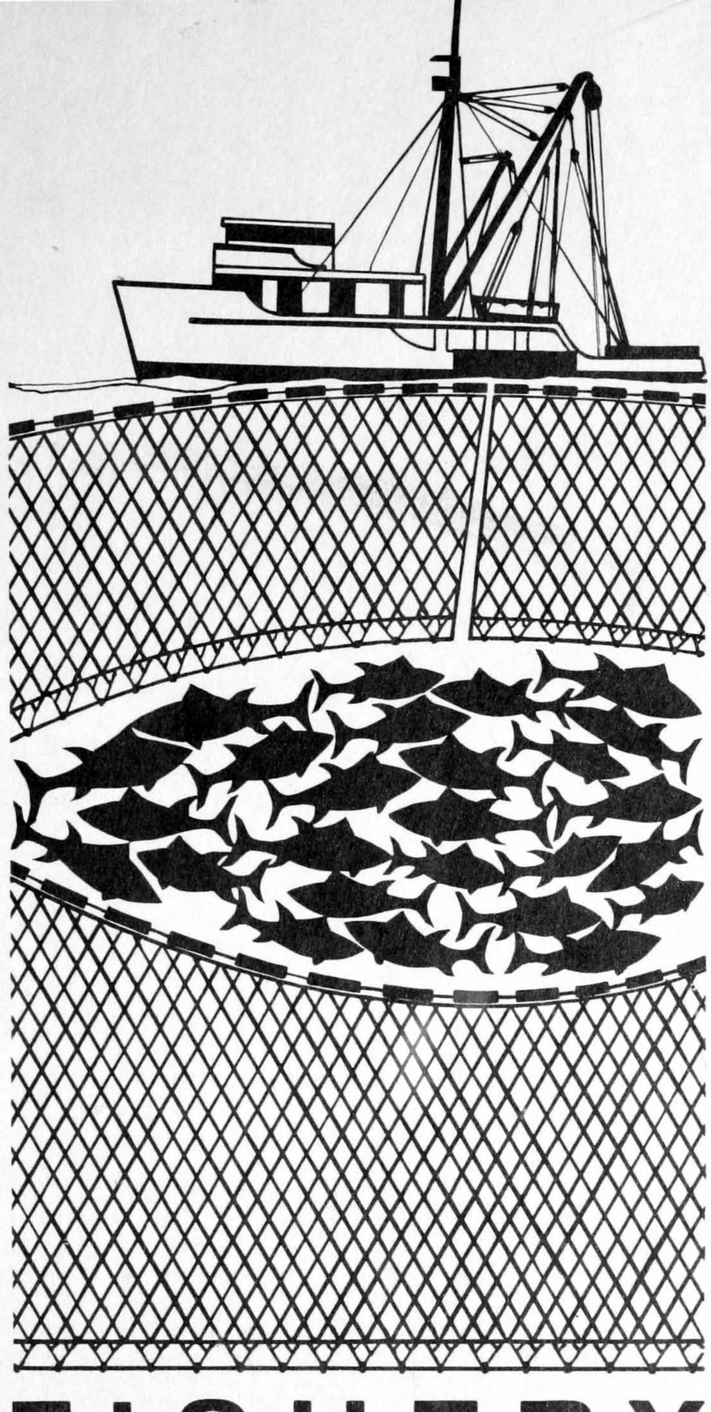

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VOLUME 3 NO. 2

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PROXIMATE COMPOSITION OF LAKE MICHIGAN ALEWIFE (*Alosa pseudoharengus*)

by

Donald R. Travis

ABSTRACT

The concentration of nitrogen, oil, ash, and moisture in alewives caught in Lake Michigan was determined on 6 bimonthly samples. The proximate composition and physical measurements are reported for the whole fish.

INTRODUCTION

The fresh-water alewife is taken in commercial quantities, largely in the Great Lakes. A marine form of alewife is found along the Atlantic Coast of the United States; however, the data reported here concern only the fresh-water form found in Lake Michigan. An average annual catch of about 5,000,000 pounds of alewives constitutes about 9 percent of the United States catch of alewives (Lyles, 1963).

The alewife is one of several species of fish in the Great Lakes not fully utilized by sport and commercial fishermen. Recent catches by exploratory fishing operations reveal that commercially significant quantities of alewife are available in Green Bay and Northern Lake Michigan (Commercial Fisheries Review, 1961). Information on these catches should be of special interest to those segments of the fishing industry looking for new ways of increasing the supply of fish for the expanding animal-food and fish-meal markets.

No data concerning the chemical composition of this species are found in the literature. Yet, a knowledge of the proximate composition and its possible seasonal variation would be valuable to anyone using this resource or contemplating its use. Several workers have reported seasonal variations in proximate composition for various species of the *Clupeidea*. The changes in oil and moisture content of these species have been related to the feeding and the spawning cycles (McBride, MacLeod, and Idler, 1959). This report, as well as others, has been reviewed recently by Thompson (1966). The purposes of this paper therefore are: (1) to report the proximate composition of the alewife on a seasonal basis and (2) to consider possible causes of any seasonal variation found in the proximate composition.

I. PROXIMATE COMPOSITION

A. PROCEDURE

1. Sampling Method

Alewives were obtained, on a bimonthly basis, using commercial methods, by members of the Bureau of Commercial Fisheries Technological Laboratory, Ann Arbor, Michigan, in cooperation with the Bureau's Exploratory Fishing and Gear Research Base in Ann Arbor. The area of sampling was dictated in part by cruise schedules, 3 samples were taken in the southern section of Lake Michigan, 2 in the central section, and 1 in the northern section. The samples were frozen aboard the vessel and shipped in dry ice to the Bureau of Commercial Fisheries Technological Laboratory, Pascagoula, Mississippi. No samples were obtained in January, February, and March because of ice on the lakes.

Author: Donald R. Travis, *Chemist*, Bureau of Commercial Fisheries Technological Laboratory, Pascagoula, Mississippi.

Table 1.—Physical dimensions of the alewife *(Alosa pseudoharengus)*, Lake Michigan, 1962-63.

Date	Fish in sample	Physical dimensions							
		Length		Width		Depth		Weight	
		Range	Average	Range	Average	Range	Average	Range	Average
	No.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Grams*	*Grams*
4/11/63	77	9.0-20.5	15.1	2.1-5.1	3.6	0.7-2.5	1.3	8.4-64.4	30.2
6/5/63	57	14.7-20.1	17.0	3.1-4.2	3.7	1.0-1.5	1.3	24.0-54.5	35.2
8/18/63	97	10.0-17.5	14.4	2.0-3.7	3.0	0.6-1.4	1.0	8.7-34.1	21.5
10/9/63	94	10.4-20.1	15.3	1.9-4.3	3.3	0.8-1.7	1.2	13.9-52.1	29.4
10/19/62	71	8.1-21.2	15.5	1.8-4.9	3.5	0.5-1.8	1.3	4.1-82.3	32.9
12/14/62	116	6.8-20.7	13.4	1.1-4.7	3.1	0.3-1.7	1.2	3.6-60.2	23.5

Table 2.—Proximate composition of the alewife *(Alosa pseudoharengus)* as percent of total weight and as mg./mg. N, Lake Michigan, 1962-63.

Date	Fish in sample	Average proximate composition						
		Protein content	Moisture content	Oil content	Ash content	Moisture content	Oil content	Ash content
	No.	*Percent*	*Percent*	*Percent*	*Percent*	*Mg./mg. N*	*Mg./mg. N*	*Mg./mg. N*
4/11/63	77	14.1	73.6	10.2	2.95	32.6	4.5	1.31
6/5/63	57	15.1	73.5	7.8	3.83	30.5	3.2	1.59
8/18/63	97	14.6	74.6	7.5	3.38	31.9	3.2	1.44
10/9/63	94	13.9	66.5	15.6	3.33	30.0	7.1	1.50
10/19/62	71	14.1	70.9	13.0	2.46	31.5	5.8	1.09
12/14/62	116	13.2	71.4	14.1	2.43	33.7	6.7	1.15

At the Laboratory, each sample was divided randomly into 2 groups. The weight to the nearest 0.1 gram and the overall length to the nearest 0.1 centimeter were determined for each fish. Each group of whole fish was then homogenized in a stoneware ball-mill grinder. Each sample was placed in a polyethylene bag, sealed, and put in a sealed glass container. To minimize dehydration and other changes in the sample during storage, we placed a cube of ice in each glass container. The sample was held at 0° F. until analyzed.

2. Chemical Methods

The methods for determining nitrogen, oil, ash, and moisture were substantially those of the Association of Official Agricultural Chemists (1960). The only deviation was the substitution of reagent-grade ottawa sand in place of asbestos in the determination of moisture. Protein was calculated by multiplying the total nitrogen content by 6.25. The data are reported as the average of 4 determinations (duplicate determinations of duplicate samples).

B. RESULTS

The physical measurements and proximate composition of the alewives are reported in Tables 1 and 2.

The fish were quite small, weighing only about 1 ounce each, and ranging in length from 3 to 8 inches.

As Farragut (1965) found in his work, the proximate data proved more meaningful on a per-milligram-of-nitrogen basis than on a wet-weight basis. For convenience, however, the data are listed on both bases. When the wet-weight basis is used in the discussions, it is so specified. Table 3 shows the standard deviation for each method of reporting.

Table 3.—Standard deviation for proximate composition method as applied in analyses of the Lake Michigan alewife *(Alosa pseudoharengus)*, 1962-63.

Component	Standard deviation on the:	
	Wet-weight basis	Nitrogen-content basis
	Percent	*Mg./mg. N*
Nitrogen	.035	---
Oil	.734	.339
Ash	.247	.115
Moisture	.746	.684

The concentrations of protein and oil in the alewife on a wet-weight basis are equal to, and in some cases higher than, that of menhaden and other species generally used for fish meal. Thompson (1966) reports that whole menhaden, analyzed over a 1-year period, had a maximum protein concentration of 16.4 percent, oil concentration of 17.8 percent, ash concentration of 4.8 percent, and moisture concentration of 79.3 percent. In the present study, alewife had maximum protein, oil, ash, and moisture concentrations of 15.1, 15.6, 3.8, and 74.6 percent, respectively. The foregoing results indicate that fish meal made from alewife should compare favorably in nutritive value with the fish meal normally on the market.

II. POSSIBLE CAUSES OF SEASONAL VARIATIONS

Spawning occurs in June or July in Lakes Erie and Michigan (Trautman, 1957; Edsall, 1964) and probably during the same months in the other lakes. Spawning in the different lakes, or in different areas within the same lake, may also occur at somewhat different times during the same year. Spawning may occur at somewhat different times from year to year although within the months of June, July, and August (Edsall, 1964).

Oil concentration varied from a high of 7.1 milligrams per milligram of nitrogen in October to a low of 3.2 milligrams per milligram of nitrogen in August (Figure 1). This decrease in the oil content in the summer coincided with the spawning season, as would be expected during a period of great activity. The oil increased sharply during the fall to a record high for the year and remained high with only a small decrease during the winter, a period of extreme cold and low metabolism.

During the period of the present study, the concentration of moisture was fairly constant, except for a minor increase to a maximum value in December and minor decreases to minimum values in June and October (Figure 2). The slight variation in the moisture content coincided with the spawning season.

A statistically significant inverse relation between moisture and oil did not appear when the data were calculated on a nitrogen-content basis, although this relation was significant at the 1-percent level on a wet-weight basis. The oil content did tend to increase (Figures 1 and 2), however, when the moisture content decreased slightly, and vice versa. This lack of significant correlation on a nitrogen-content basis is sometimes observed in oily species in which fat is deposited in "pockets," since there is not necessarily an exchange of oil and moisture as the fluid medium in the tissue.

On a wet-weight basis, there was a correlation at the 1-percent level or better between protein and oil as well as between protein and ash. The relation between protein and ash was positive, as would be expected with the simple growth of the animal (weight and length are closely correlated in this species). The protein-oil relation was indirect, again indicating the deposition of fatty layers in this fish.

Changes in the proximate composition of various species of fish have been related to various other conditions (reviewed by Thompson, 1966), among them being the reproductive cycle.

"Spawning alewives can be seen regularly during June and July from the dock of the Bureau of Commercial Fisheries Research Vessel on the Kalamazoo River in Saugatuck, about 2 miles above the river mouth," according to Edsall (1964). The protein content of this species reached a high of 15.1 percent in June, the first month of the spawning season, and dropped to a low of 13.2 percent in December

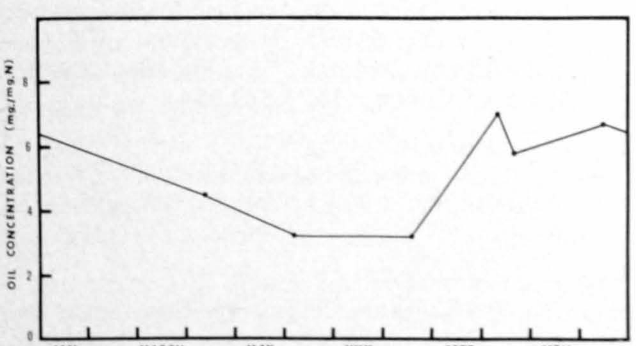

Figure 1.—The seasonal variation (1962-63) in the concentration of oil in the alewife ***(Alosa pseudoharengus).***

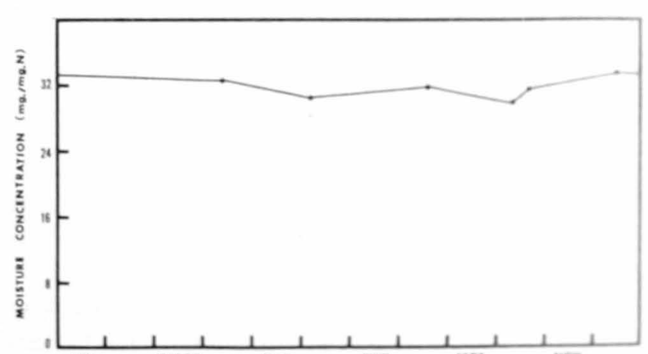

Figure 2.—The seasonal variation (1962-63) in the concentration of moisture in the alewife ***(Alosa pseudoharengus).***

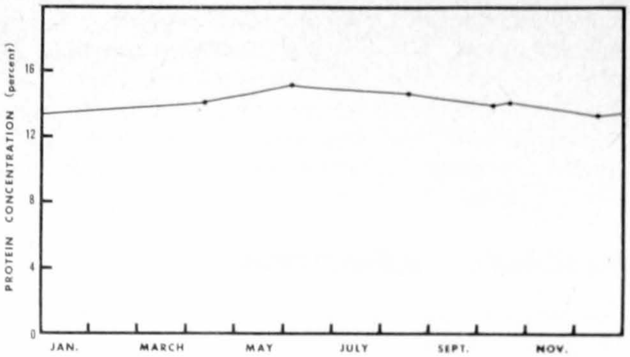

Figure 3.—The seasonal variation (1962-63) in the concentration of protein in the alewife *(Alosa pseudoharengus)*.

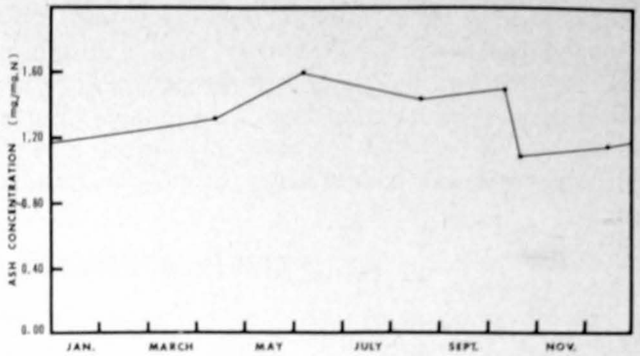

Figure 4.—The seasonal variation (1962-63) in the concentration of ash in the alewife *(Alosa pseudoharengus)*.

(Figure 3). The increase in protein during the first week in June may have been necessary for the increase of activity during spawning.

In October, the ash content reached a low of 1.1 milligram per milligram of nitrogen (Figure 4). It is interesting to note that a sharp decrease occurred between the 2 samples obtained in October. This decrease is not significant, however, at the 5 percent level. The difference between these 2 samples is not explained by the data on spawning habits. It is quite possible that the lapse of 1 year between the samples could be a factor in this discrepancy. Other causes to be considered are change of temperature, different location of catch, and difference in food due to fluctuations in weather conditions.

SUMMARY

In 1962-63, the proximate composition of the Lake Michigan alewife varied with the season. This variation generally coincided with the spawning habits of the fish. The concentration of proteins increased during the summer and decreased during colder months. The concentration of oil decreased in June (the first month for spawning) and increased in October. The concentration of moisture increased to a maximum value in December and to a minimum in June and October. The concentration of ash increased to a maximum in June and decreased to a minimum in October.

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ACCUMULATION OF ORGANIC ACIDS DURING COLD STORAGE OF SHUCKED SOFT CLAMS, *Mya arenaria* (L.), IN RELATION TO QUALITY

by

Baruch Rosen

ABSTRACT

During the cold storage of soft clams in plug-top metal cans, the content of glycogen decreased; that of glucose at first increased and then stabilized; that of lactic acid increased continuously; and that of acetic, propionic, and pyruvic acids increased at diminishing rates. The bacterial count increased at an exponential rate. Except in the cases of extreme freshness and extreme spoilage, organoleptic quality was related neither to the chemical changes nor to the bacterial count.

INTRODUCTION

Traditionally, the soft clam has been a local product in New England. In recent years, however, a decline in the production of soft clams in New England and the almost simultaneous development of this resource in Maryland have resulted in soft clams being transported from Maryland to New England. Soft clams with a dockside value exceeding $2,000,000 were produced in Maryland in 1964. More than half of this production was shipped to New England.

Bacteriological studies (Cox, 1965; Nickerson and Goldblith, 1964) indicate that the quality may decline during holding and transport. In 1961, Fieger and Novak reviewed the literature on the microbiology of shellfish deterioration and discussed in much detail the spoilage changes that occur in oysters. Investigations by Gardner and Watts (1957a), Piskur (1947), Pottinger (1951), and Simidu and Hibiki (1957) demonstrated that acids were produced during the storage and spoilage of bivalves.

The causative agents of the increase in acidity are endogenous enzymes and microorganisms. By irradiating oysters until the bacterial flora were destroyed, Gardner and Watts (1957b) showed that acidity would increase even in the absence of bacteria. The role of endogenous enzymes was also supported by the fact (Collip, 1920; Martin, 1961) that, under anaerobic conditions, living soft clams produced and excreted acids. Colwell and Liston (1960) have called attention to the presence of a fermentative bacterial population in living Japanese oysters, *Crassostrea gigas*, and to the possible role of this population in commercial handling.

Studies of post mortem, specific, quantitative chemical changes that are related to the present study of commercial bivalves have shown that glycogen in oysters (*Ostrea* sp.) and New England scallops (*Placopecten magellanicus*) is consumed at a slower rate than it is in vertebrates (Humphrey, 1944, 1950; Power, Fraser, Neal, Dyer, Castell, Freeman, and Idler, 1964). The free amino acids that are contained within the tissues of marine bivalves (Allen, 1961) are reduced during the cold storage of soft clams (Brooke, Ravesi, Gadbois, and Steinberg, 1964).

Little else has been reported, however, on the chemical changes that occur during the commercial handling, storage, and spoilage of shucked soft clams.

Author: Baruch Rosen, *Faculty Research Assistant*, Natural Resources Institute, University of Maryland, Crisfield, Maryland.

Natural Resources Institute Contribution Number 295.

The purpose of this investigation was to study the increase of acidity that occurs during cold storage of shucked soft clams—specifically, the relation between quality and pH and the formation of lactic, acetic, propionic, and α-keto acids. Chemical, bacteriological, and organoleptic studies were made.

I. INITIAL PROCEDURE

A. ACQUISITION

Shucked clams harvested in the summer of 1964 were obtained directly from the shucking tables of commercial clam-packing houses in Talbot County, Maryland. The clams were packed in pint-size, plug-top cans (the can commonly used by commercial vendors of clams) and were transported in ice to the laboratory within 2 hours after being shucked.

B. COLD STORAGE

The pint cans were stored in melting crushed ice in a refrigerated room held at a temperature between 1° and +3° C. The temperature of 1 can, recorded daily, was found to vary between 0° C. and 1° C. during all experiments.

C. SAMPLING

The first sample was taken on the day of collection, which was designated as Day 1. For each sample, the contents of 2 1-pint cans were combined, ground in a meat grinder (in the cold room), and well mixed. Several 20-gram portions were weighed into laminated plastic bags. The bags were heat sealed, frozen, and held at -30° C. for chemical analysis.

II. METHODS OF STUDY

A. CHEMICAL STUDY

Absorption spectra and optimal wave length for colorimetric analysis were obtained with a Beckman Model DB Spectrophotometer[1]. Colorimetric analyses were made with a B&L Spectronic-20 colorimeter. All reagents were analytical reagent grade.

pH was measured after the method of Gardner and Watts (1957a) with a Beckman model H2 pH meter calibrated with standard buffer. The measurements were made before the ground clams were frozen.

Glycogen was estimated by the anthrone method. 20 grams of frozen ground clams was blended in a Waring Blendor with 80 milliliters of ice-cold distilled water. 5 milliliters of the foamy slurry was pipetted into a preweighed centrifuge test tube containing 5 milliliters of 60-percent KOH. The tissue was digested, and the process was followed as described previously by Seifter, Dayton, Novic, and Muntwyler (1950). Glucose was used as the standard.

Protein-free extract was obtained by blending a frozen sample of 20 grams with 20 milliliters of ice-cold distilled water in a monel-metal Waring Blendor. 25 milliliters of 25-percent $ZnSO_4 \cdot 5H_2O$ was added during blending. The slurry was then titrated to pH 7.5 with NaOH solution, the concentration of which had been previously adjusted so that about 25 milliliters was required. The volume was then brought up to 100 milliliters with distilled water, and the slurry was filtered or centrifuged.

Basic zinc was used as a protein precipitant in preference to the common acidic protein precipitants (perchloric acid and trichloroacetic acid) because these latter reagents extract much glycogen from the tissue. The glycogen interferes with subsequent analyses.

Alcohol-soluble carbohydrates were estimated on the protein-free extract. An aliquot of the protein-free extract was slurried in a beaker with an excess (4-5 times the estimated total ionic strength) of ion-exchange resin. The ion-exchange resin was made from a mixture of equal volumes of previously water-washed Amberlite IR-4B and Amberlite CG-50. The mixture was stirred with a glass rod and allowed to settle, and the effluent was decanted. The ion-exchange resin was twice washed with equal volumes of distilled water, and the wash water was combined with the effluent. The resulting solution was adjusted to 55-percent ethanol and centrifuged, and the supernatant was dried under vacuum. The residue was then diluted to the desired volume with distilled water, and carbohydrates were estimated by the anthrone reagent with glucose as a standard (Seifter and associates, 1950). Carbohydrates in the dried supernatant were identified by paper chromatography on

[1] Use of trade names is merely to facilitate the description of the experimental equipment and materials; no endorsement is implied.

Whatman No. 1 paper with the solvents system: butanol, water ethanol, and NH_3 (Block, Durrum, and Zweig, 1958).

α-keto acids were determined and identified spectrophotometrically by the dinitrophenylhydrazone method (Koepsell and Sharpe, 1952). Redistilled pyruvic acid was used as a standard.

Lactic acid was determined by the method of Hullin and Noble (1953) except that the number of precipitations with $Ca(OH)_2$+$CuSO_4$ was reduced to 2. Twice-crystallized lithium lactate was used as a standard.

Lactic acid was identified as follows: 10 grams of the frozen ground clams was ground with 25 grams of celite acidified to a pH of 2 with a few drops of diluted (1:1) reagent-grade sulfuric acid. The ground material was packed as a column, and ethyl ether was passed under pressure until no acids could be detected by titration. The ether was evaporated, and the ammonium salts of the acids were identified by paper chromatography with 2 solvent systems: n-butanol, NH_3; and ethanol, NH_3, water (Block and associates, 1958).

Volatile acids were estimated by steam distillation of a 20-milliliter portion (acidified with H_2SO_4; acid to congo red) of protein-free extract. An electrically heated Sellier still was used. Distillate (5 volumes of distilled solution were collected) was titrated with 0.01N NaOH in a CO_2-free atmosphere and reported as milliequivalents of acids. The volatile acids were resolved on a celite column with a gradient of butanol and chloroform by the method described by Wiseman and Irvin (1957), except that no internal indicator was used in the column. 10-milliliter portions of the eluate were collected and titrated with 0.01N NaOH in a CO_2-free atmosphere.

B. BACTERIOLOGICAL STUDY

Bacteria were plated on tryptone glucose yeast extract agar (Cox, 1965). After the bacteria had been incubated 72 hours at room temperature (25° C.), the colonies were counted.

C. ORGANOLEPTIC STUDY

Laboratory personnel made organoleptic determinations. Clams were grouped into 3 classes. Class I consisted of the strictly fresh clams, with strong sea odor and taste. The free liquor in the can was clear with slight, white opalescence. This class of clams exists for only about 3 days. It is rarely available to the consumer and, indeed, may be treated suspiciously by him. Class II consisted of the common clams of commerce, with a typically sweet odor and taste, sometime with a slight (though not objectionable) sourness. The free liquor was somewhat off-white in color. Clams stay in this class from the 3d day until about the 15th day of storage. The clams of Class III were darker and had a definitely sour-rancid, unpleasant taste and odor. Slight sliminess and loss of rigidity of the tissues were noticed occasionally. The free liquor in the can was definitely dark brown.

III. RESULTS

The results reported were derived from 3 sets of experiments. Information presented in the figures show mean and range of the results, except for bacterial counts, both within and between samples.

A. CHEMICAL STUDY

The rate of decrease of glycogen was slow (Figure 1); yet almost 1 gram of glycogen per 100 grams of tissue was consumed in 17 days. No major change in the rate of consumption was noted.

Alcohol-soluble carbohydrates (Figure 2) increased during the first 3-6 days and then remained at practically the same level. The only alcohol-soluble carbohydrates identified was glucose. Other alcohol-soluble carbohydrates, if present, were in lesser amounts than glucose. Ribose and maltose were not detected by the method used.

Production of α-keto acids (Figure 3) first increased and then decreased. The only α-keto acid identified was pyruvic acid.

Lactic acid (Figure 4), initially at a very low concentration, increased continuously.

Volatile acids (Figure 5) increased but at a diminishing rate. On resolution of volatile acids, recovery was as low as 50-60 percent, possibly owing to the distillation of lactic acid or other carbonyl compounds that added to the total volatile acidity. Acetic acid was identified as a major component; propionic acid, as a minor component. Aldehydes were also present in the distillate. This was confirmed by the Fehling test and by the iodoform reaction.

The average pH (Figure 6) decreased from 6.7 to 5.8 in the first 5 days. Then it decreased at a slower rate to 5.2 after 17 days.

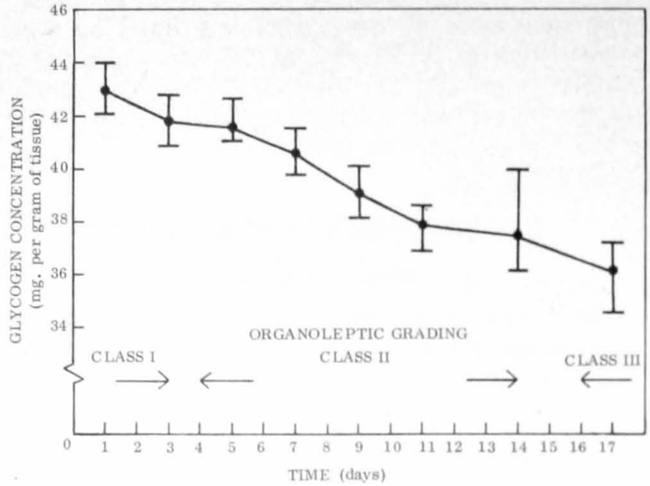

Figure 1.—Changes in the concentration of glycogen in shucked clams during cold storage.

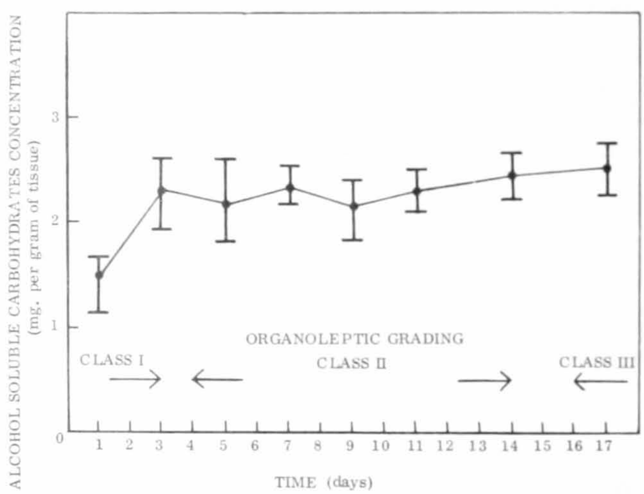

Figure 2.—Change in the concentration of alcohol-soluble carbohydrates in shucked clams during cold storage.

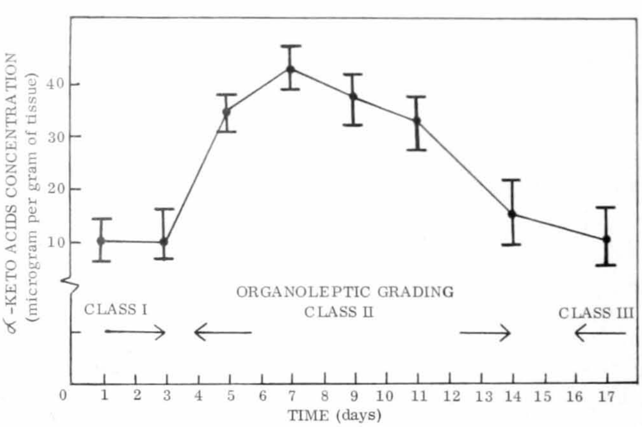

Figure 3.—Change in the concentration of α-keto acids in shucked clams during cold storage.

B. BACTERIOLOGICAL STUDY

The aerobic bacterial population (Figure 7) increased exponentially during the whole storage period.

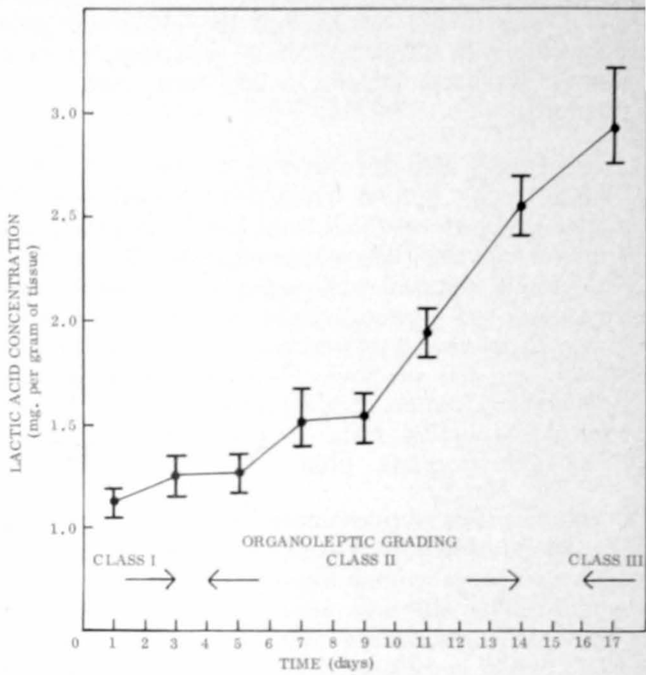

Figure 4.—Change in concentration of lactic acid in shucked clams during cold storage.

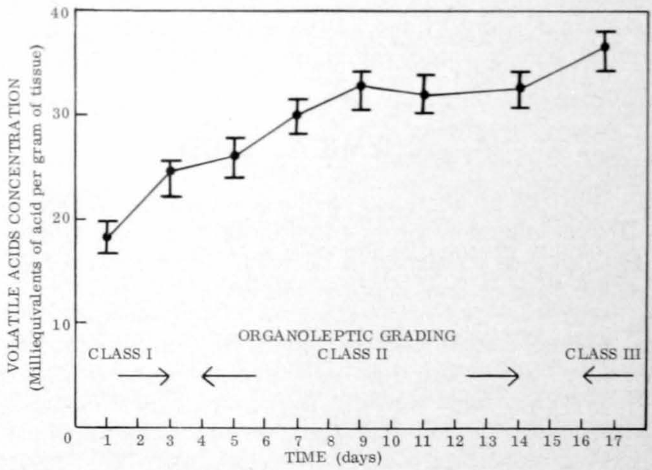

Figure 5.—Change in the concentration of volatile acids in shucked clams during cold storage.

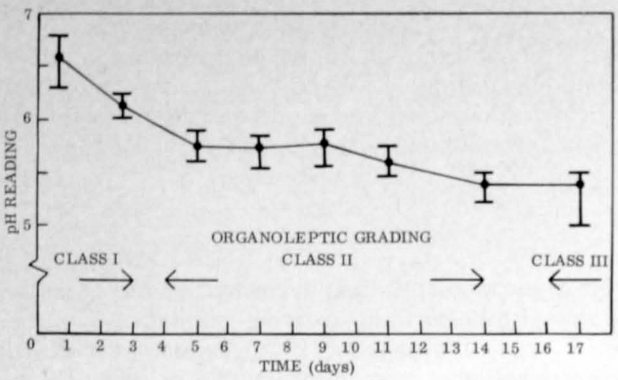

Figure 6.—Change in the pH of shucked soft clams during cold storage.

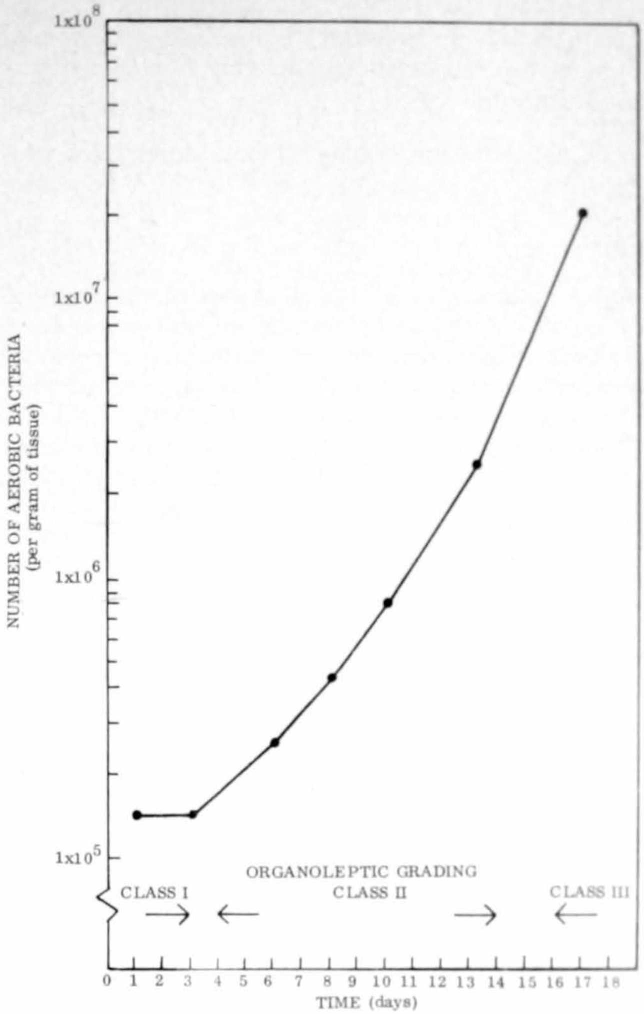

Figure 7.—Changes in numbers (plate count) of bacteria in shucked clams during cold storage.

C. ORGANOLEPTIC STUDY

The relation between organoleptic quality and measurable acids in shucked soft clams was definite only when the clams were strictly fresh or actually spoiled. Though the total storage time was 17 days, the clams were judged unfit for human consumption after 15 days.

Bacterial counts were not predictive of organoleptic quality.

IV. DISCUSSION AND CONCLUSION

Clams, as well as other commercial bivalves, are among the most chemically complex food consumed by Americans. As marketed, soft clams contain the whole animal, including muscle, glands, gills, and digestive tract with its content and accompanying bacteria. Accordingly, variations in the chemical makeup should be expected. As has been found in this laboratory (Rosen, 1964[2]), season and geographical locations of catch will slightly alter the spoilage pattern described in this report. Yet the basic pattern remains essentially the same.

The major source of the various acids is probably glycogen via well-described metabolic pathways. Glycogen seems to be split into carbohydrates of low molecular weight, and these appear to be catabolized by well-known pathways to lactic, acetic, and propionic acids, with pyruvic acid as an intermediate (White, Handler, Smith, and Stetten, 1954). Free amino acids may also contribute to the pool of acids.

The significance of the volatile aldehydes in relation to the degradation of carbohydrates is not clear. But production of acetaldehyde in place of, or concurrently with, lactic acid under fermentative conditions has been shown to be caused by certain microorganisms (Holzer and Beaucamp, 1961).

This study does not elucidate the relative importance of bacteria versus endogenous enzymes as causative agents for this pattern of deterioration.

[2] Baruch Rosen. 1964. Unpublished data.

But the similarity between the increase in acids and the increase in bacterial population indicates a possible bacterial role.

To delineate the quality of soft clams more precisely, we need additional objective methods. The relation of season and geographic location to quality requires investigation. Analysis of the microbial flora in fresh and stored clams should produce important information.

SUMMARY

The pattern and probable causes of the increase in acidity during cold storage of soft clams were studied. Conditions in the common, commercial container were fermentative. Glycogen, and possibly amino acids, contributed to an increasing acid pool. At early stages of storage, glycogen was consumed while glucose, pyruvic acid, volatile acids, and lactic acid were accumulated. At later stages of storage, glycogen was still being consumed; but the rate of accumulation of glucose, pyruvic acid, and volatile acids decreased, and the rate of accumulation of lactic acid increased rapidly.

None of the chemical changes was explicitly related to organoleptic quality except in the cases of extreme freshness and extreme spoilage. In the former case, the amount of glycogen was at its highest level, the amount of volatile acids was low, and both pyruvic and lactic acid were at the threshold of detection. In the latter case, lactic acid had become the single major acid, glycogen had diminished to its lowest level, and volatile acids increased but were practically at a steady level.

Similarly, the bacterial count was not related to organoleptic quality other than that the count increased exponentially with time. The longer the clams were held, the poorer the quality.

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MS #1516

VALUE OF MENHADEN FISH MEAL AS A PROTEIN SUPPLEMENT TO COTTONSEED MEAL-CORN DIETS FED TO RATS

by

Robert R. Kifer, Edgar P. Young, and Kam C. Leong

ABSTRACT

Menhaden fish meal was evaluated as a protein supplement to cottonseed meal-corn diets by means of a rat-feeding study. Rats were randomly allotted to 9 treatment groups and fed diets containing cottonseed meal-corn with 0-, 2-, or 4-percent levels of fish-meal protein, at 16-, 15-, or 14-percent levels of total protein. A significant improvement in rates of gain and utilization of feed resulted from supplementation by the menhaden fish meal. These differences in growth response and utilization of feed were not significantly related to the 16-, 15-, or 14-percent dietary levels of protein.

INTRODUCTION

Cottonseed meal-corn diets fed to rats have been shown to be deficient in the amino acid lysine. For instance, Cabell and Earle [quoted by Phelps (1962)] reported a marked increase in gains of weight when 0.2 percent L-lysine was added as a supplement to a cottonseed meal-corn diet.

Fish meal has been reported to be an excellent source of lysine (Snyder, Ousterhout, Titus, Morgareidge, and Kellenbarger, 1962; Ousterhout and Snyder, 1962). If fish meal is truly so, when used as a low-level supplement to cottonseed meal-corn diets, it should improve the protein quality. This hypothesis, however, can be verified only by actual animal-feeding experiments using cottonseed meal-corn diets supplemented with and without fish meal at low levels.

The object of this study, therefore, was to verify the value of fish meal as a source of lysine by conducting a rat study to test the value of low levels of protein from fish meal as supplements to diets formed from cottonseed meal-corn.

I. PROCEDURE

A. SAMPLES

Menhaden *(Brevoortia tyrannus)* fish meal (64.7 percent protein) was obtained from a commercial source, and corn (7.8 percent protein) was obtained from a local feed mill. Cottonseed meal (41.5 percent protein) also was obtained from a commercial source. This sample of cottonseed meal was used because of its low levels of bound (0.91 percent) and free gossypol (0.03 percent) and high content of lysine (3.5 grams per 16 grams of meal nitrogen) with free epsilon amino groups[1].

B. DIETS

Total protein levels of 16, 15, and 14 percent were used because these levels represent values near or just below those considered as being optimal

[1] Vernon E. Frampton of the Oilseed Crops Laboratory, Agricultural Research Service, U. S. Department of Agriculture, New Orleans, Louisiana, analyzed the cottonseed meal.

Authors: Robert R. Kifer, *Animal Husbandman*, and Kam C. Leong, *Research Chemist*, Bureau of Commercial Fisheries Technological Laboratory, College Park, Maryland; and Edgar P. Young, *Associate Professor*, Department of Animal Science, University of Maryland, College Park, Maryland.

with a good source of protein. Diets were formulated with these total protein levels from corn and cottonseed meal with 0, 2, and 4 percent of protein from fish meal to make a total of 9 dietary treatments (Table 1). The remaining parts of the diets were formulated to be equivalent and to be nutritionally adequate in all other known nutrients (Table 2).

C. RATS

16 weanling black-hooded rats, 8 males and 8 females, weighing 55 ± 5 grams, were randomly allotted to each of the 9 treatment groups for 4 weeks.

Each animal was placed in an individual wire cage with wire-screen floor. The cages were kept in a room held at a temperature of 80° ± 2° F. and a relative humidity of 50 ± 5 percent. The animals were permitted water and feed ad libitum. Weights and food consumption of each animal were measured weekly.

Table 1.—Experimental design of a study to determine the value of menhaden fish meal (FM) as a protein supplement to cottonseed meal-corn diets (CC) fed to rats

Treatment designation	Relative amount of protein supplied by:		
	CC[1]	FM[2]	Total
	Percent	*Percent*	*Percent*
CC16-FMO	16	0	16
CC15-FMO	15	0	15
CC14-FMO	14	0	14
CC14-FM2	14	2	16
CC13-FM2	13	2	15
CC12-FM2	12	2	14
CC12-FM4	12	4	16
CC11-FM4	11	4	15
CC10-FM4	10	4	14

[1] Amount of crude protein derived from cottonseed meal-corn.
[2] Amount of crude protein derived from fish meal.

Table 2.—Diet formulations in a study to determine the value of menhaden fish meal (FM) as a protein supplement to cottonseed meal-corn diets (CC) fed to rats

Ingredient	Concentration of the ingredients in:								
	CC16-FMO	CC15-FMO	CC14-FMO	CC14-FM2	CC13-FM2	CC12-FM2	CC12-FM4	CC11-FM4	CC10-FM4
	Parts per hundred								
Corn (Yellow U. S. #2)	69.42	72.37	75.52	72.28	75.23	78.28	74.81	77.77	81.03
Cottonseed meal	25.00	22.00	18.85	19.50	16.40	13.45	14.25	11.25	8.00
Fish meal (menhaden)	—	—	—	3.12	3.12	3.12	6.24	6.24	6.24
Rock phosphate (defluorinated)[1]	1.58	1.50	1.57	1.02	1.20	1.37	.85	1.10	1.20
Limestone[2]	.50	.63	.56	.58	.55	.28	.35	.14	.03
Salt (trace mineralized)[3]	.50	.50	.50	.50	.50	.50	.50	.50	.50
Vitamin premix[4]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00

[1] Calcium, 31-34 percent; phosphorus, 18 percent (guaranteed analysis).
[2] Calcium, 38 percent.
[3] The trace minerals as percent of salt mixture were: Mn, 0.600 as manganese oxide; S, 0.250, sodium sulfate; Fe, 0.200, ferrous carbonate; Cu, 0.060, cuprous oxide; I, 0.016, calcium iodide; Zn, 0.010, zinc oxide; and Co, 0.015, cobalt carbonate.
[4] The vitamins as grams/pound of vitamin mix were: riboflavin, 0.45; calcium pantothenate, 1.36; niacin, 2.05; choline chloride, 34.10; thiamine, 0.45; pyridoxine, 0.45; paraminobenzoic acid, 2.27; menadione, 1.02; inositol, 2.27; ascorbic acid, 20.5; alpha tocopherol, 2.27; Vitamin D concentrate (400,000 units per gram), 0.11; Vitamin A (200,000 units per gram), 2.05 grams; milligrams/pound: biotin, 9.09; folic acid, 40.9; Vitamin B_{12}, 0.61.

II. RESULTS

A. EFFECT OF FISH-MEAL SUPPLEMENTATION ON GROWTH AND UTILIZATION OF FEED

Results of the rat-feeding study are shown in Table 3. Statistical analysis (t-test) of these data indicate that dietary treatment differences exist at the 5-percent level of significance.

Rats fed the diets with either 2 or 4 percent protein from fish meal gained weight at a greater rate than did those fed the cottonseed meal-corn control diets (CC16-FMO, CC15-FMO, and CC14-FMO). Greater rates of gain were obtained from

Table 3.—Weight gain and feed utilization of rats fed cottonseed meal-corn basal diets with and without fish-meal supplementation

Treatment designation	Average total gain in weight (28 days)	Average feed/gain
	Grams	
CC16-FMO	69.25	5.34
CC15-FMO	66.18	6.11
CC14-FMO	63.56	5.72
CC14-FM2	87.25[1]	4.26[1]
CC13-FM2	86.93[1]	4.53[1]
CC12-FM2	81.43[1]	4.45[1]
CC12-FM4	103.75[2]	3.67[2]
CC11-FM4	96.37[1]	4.05[1]
CC10-FM4	100.56[1]	4.03[1]

[1] t-test $P < .01$.
[2] t-test $P < .05$.

rats fed the CC12-FM4 and CC10-FM4 diets when the level of fish-meal supplement was increased from 2 to 4 percent. Also, the rats fed the diets with fish meal contributing 2 or 4 percent protein utilized the feed more efficiently than did those fed the 3 cottonseed meal-corn control diets. Even more efficient utilization of feed was obtained from the rats fed the 16-percent-protein diet (CC12-FM4) when the protein from fish meal was increased from 2 to 4 percent.

There were no significant differences in gain in weight or utilization of feed with respect to the 16-percent vs. 15-percent vs. 14-percent-protein diets either with or without the 2 or 4 percent protein from fish meal.

III. DISCUSSION

The results indicate that fish-meal supplementation improved the growth and the feed utilization of rats; hence the amino acid balance of the cottonseed meal-corn diet doubtlessly was improved, probably owing to the high content of lysine in the fish meal.

Cottonseed meal, however, contains gossypol (a toxic substance) in various quantities. The possibility of gossypol toxicity therefore cannot be excluded, although no gross pathological symptoms were observed in this experiment. Nevertheless, it could be that the lower gain in weight and poorer utilization of feed by the rats fed the cottonseed meal-corn control diets are caused by a nonapparent pathological gossypol toxicity.

It has been shown with swine that the quantity of good-quality protein in the diet alters the toxic effects of gossypol and that fish meal is particularly effective in this function (Lyman and Hale, 1963). The mechanism is postulated to be the reaction of the gossypol with an amino group of the protein and the formation of an insoluble indigestible complex (Baliga and Lyman, 1957). The increased rates of gain and utilization of feed indicate that in addition to the postulation of a better amino acid balance, fish meal could also have functioned, in this experiment, to block the deletrious effects of gossypol.

SUMMARY

A rat-feeding study was conducted to determine the supplementary value of 2 and 4 percent protein from fish meal to cottonseed meal-corn diets at total protein levels of 16, 15, and 14 percent.

This study indicates that significantly increased rates of gain and better utilization of feed resulted when 2 percent protein from fish meal was added to the cottonseed meal-corn diets and that, in general, a further improvement was obtained when the level of protein was increased from 2 to 4 percent. There were no significant differences in rates of gain or utilization of feed that were related to the 16-, 15-, and 14-percent dietary levels of total protein either with or without the 2 or 4 percent protein from fish meal.

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MS #1510

VALUE OF MENHADEN FISH MEAL AS A PROTEIN SUPPLEMENT TO MEAT-AND-BONE MEAL-CORN DIETS FED TO RATS

by

Robert R. Kifer, Edgar P. Young, and Kam C. Leong

ABSTRACT

To evaluate menhaden fish meal as a protein supplement to meat-and-bone meal-corn diets, we allotted rats randomly to 9 treatment groups and fed them diets containing meat-and-bone meal-corn, with 0, 2, and 4 percent fish meal protein, at 16-, 15-, and 14-percent levels of total protein. Rates of gain and utilization of feed were significantly improved by adding fish meal. The rates of gain and utilization of feed decreased, however, as the dietary levels of protein were lowered, whether fish meal was used as a supplement or not.

INTRODUCTION

Methionine, tryptophan, or a combination of these amino acids are indicated to be limiting for rats fed meat-and-bone meal-corn diets at a 15-percent level of protein (Kraybill and Wilder, 1947; March, Stupick, and Biely, 1949).

Fish meal is a good source of methionine (Ousterhout and Snyder, 1962) and, according to chemical analysis, usually contains a greater content of tryptophan than does meat-and-bone meal. If this finding by chemical analysis is valid, a diet containing meat-and-bone meal-corn with low levels of fish meal should be better balanced and have a more favorable level of amino acids than does meat-and-bone meal-corn alone.

Testing this hypothetically better balance of meat-and-bone meal-corn diets supplemented by fish meal, however, requires biological evidence. The object of this study, therefore, was to verify this balancing effect of fish meal by conducting a rat-feeding study that would reveal the supplemental value of low levels of protein derived from fish meal and added to meat-and-bone meal-corn diets.

I. PROCEDURE

The meat-and-bone meal-corn diets were supplemented with menhaden *(Brevoortia tyrannus)* fish meal—the fish meal produced in largest quantity in the United States. They then were evaluated by means of a rat-feeding study that provided data on rates of gain and utilization of feed. The amino acid content of the diets was compared with the amino acid requirements of the rat.

A. SAMPLES

The menhaden fish meal and the meat-and-bone meal used were from commercial sources. Corn was purchased from a local feed mill and subsequently ground and added to the meat-and-bone meal in a manner that would give a homogeneous product.

Authors: Robert R. Kifer, *Animal Husbandman*, and Kam C. Leong, *Research Chemist*, Bureau of Commercial Fisheries Technological Laboratory, College Park, Maryland; and Edgar P. Young, *Associate Professor*, Department of Animal Science, University of Maryland, College Park, Maryland.

B. ANALYSES

All feedstuff samples were analyzed for protein by the Kjeldahl method (Association of Official Agricultural Chemists, 1955), and the amino acid content was determined by the method of Spackman, Stein, and Moore (1958). The analysis for tryptophan was by the Spies and Chambers method (1949). The analysis of the fish meal and the meat-and-bone meal for calcium and phosphorus content was by the AOAC method (1955).

Table 1.—Experimental design of the rat study to determine the value of fish meal as a protein supplement to meat-and-bone meal-corn diets

Diet	Protein concentration		
	Meat-and-bone meal-corn	Fish meal	Total
	Percent	*Percent*	*Percent*
MB16-FMO[1]	16	0	16
MB15-FMO	15	0	15
MB14-FMO	14	0	14
MB14-FM2	14	2	16
MB13-FM2	13	2	15
MB12-FM2	12	2	14
MB12-FM4	12	4	16
MB11-FM4	11	4	15
MB10-FM4	10	4	14

[1] MB—abbreviation for meat-and-bone meal-corn; FM—abbreviation for fish meal.

The numerical suffixes indicate the percent protein of the diet supplied by the MB mixture and the FM mixture.

The dietary variables tested were total protein levels at, or just below, optimum levels for rats (16, 15, and 14 percent) with different low levels of protein derived from fish meal (0, 2, and 4 percent; Table 1). The diets used were formulated on a crude-protein basis and were balanced to be nutritionally equal and adequate in all other known nutrients (Table 2); however, as a result of the diets being formulated for protein content and owing to the high content of calcium and phosphorus in meat-and-bone meals, the levels of calcium and phosphorus in some of the diets were above the rats' requirement. Therefore, the dietary levels of calcium and phosphorus were increased to a standard level in all diets to equalize a possible growth depression that might occur as the result of an excess or imbalance of these minerals (National Research Council, 1962).

C. RATS

10 weanling albino male rats weighing 55 ± 5 grams were randomly allotted to each of 9 dietary treatments for an experimental period of 4 weeks.

Each animal was housed in an individual wire cage with a wire-screen floor. The room was maintained at 80° ± 2° F., and the relative humidity was maintained at 50 ± 5 percent. The animals were permitted water and were fed ad libitum. Individual weights of animals and the consumption of food were measured weekly.

Table 2.—Ingredients of diets used in evaluation of menhaden fish meal as a protein supplement to meat-and-bone meal-corn diets

Ingredients	Relative amounts of the various ingredients in:								
	MB16-FMO	MB15-FMO	MB14-FMO	MB14-FM2	MB13-FM2	MB12-FM2	MB12-FM4	MB11-FM4	MB10-FM4
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Corn (yellow U. S. #2)	79.50	81.21	82.75	79.87	81.59	83.17	80.06	81.86	83.61
Meat-and-bone meal	17.00	14.70	12.40	12.85	10.60	8.35	8.80	6.45	4.10
Fish meal (menhaden)	--	--	--	3.07	3.07	3.07	6.14	6.14	6.14
Defluorinated rock phosphate[1]	--	0.59	1.35	0.71	1.24	1.91	1.50	2.05	2.65
Salt trace mineralized[2]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
N. B. C. vitamin mix[3]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00

[1] Calcium, 31-34 percent; phosphorus, 18 percent (guaranteed analysis).

[2] The trace minerals as percent of salt mixture were: Mn, 0.600 as manganese oxide; Na, 0.250 sodium sulfate; Fe, 0.200, ferrous carbonate; Cu, 0.060, cuprous oxide; I, 0.016, calcium iodide; Zn, 0.010, zinc oxide; and Co., 0,.015, cobalt carbonate.

[3] The vitamins as grams/pound of vitamin mix were: riboflavin, 0.45; calcium pantothenate, 1.36; niacin, 2.05; choline chloride, 34.10; thiamine, 0.45; pyridoxine, 0.45; paraminobenzoic acid, 2.27; menadione, 1.02; inositol, 2.27; ascorbic acid, 20.5; alpha tocopherol, 2.27; vitamin D concentrate (400,000 units per gram), 0.11; vitamin A (200,000 units per gram), 2.05 grams; milligrams/pound: biotin, 9.09; folic acid, 40.9; vitamin B_{12}, 0.61. N.B.C. Nutritional Biochemical Corporation. (Use of trade names does not imply endorsement of commercial products.)

Note: MB is meat-and-bone meal-corn; FM is fish meal; the numerical suffixes indicate the percent protein supplied to the diet by the mixture.

II. RESULTS

A. CHEMICAL ANALYSIS

Data from a chemical analysis of the feedstuffs used are shown in Table 3. Results of the calculation of the amino acid content of the diets on the basis of analyses of individual components are shown in Tables 4 and 5. Profile diagrams graphically indicating the dietary amino acid content in relation to the requirement of the rat are shown in Figures 1-9.

Table 3.—Analysis of feedstuffs

Feedstuffs	Protein	Calcium	Phosphorus
	Percent	*Percent*	*Percent*
Fish meal (menhaden)	65.32	4.94	2.86
Meat-and-bone meal	49.75	8.50	4.27
Corn	9.49	0.01	0.25

spective of the total dietary protein levels. The exception was the 16-percent-protein diet with 0-percent level of protein from fish meal (MB16-FMO). Even though the gain in weight by animals fed the MB16-FMO diet was numerically poorer than that of those fed the fish-meal diets, it was only significantly poorer than the other 16-percent-protein diets with fish-meal components (MB14-FM2 and MB12-FM4).

No statistically significant differences were observed among protein levels without fish meal, although marked numerical differences existed. Rates of gain of the animals in relation to total protein and fish-meal substitutions varied within the fish-meal protein groups. When 2 percent protein from fish

Table 4.—Calculated amino acid content of the experimental diets

Amino acid	Amount recommended by National Research Council	Amount of amino acid contributed by:								
		MB16-FMO	MB15-FMO	MB14-FMO	MB14-FM2	MB13-FM2	MB12-FM2	MB12-FM4	MB11-FM4	MB10-FM4
	Percent of diet									
Tryptophan[1] ..	.15	.17	.16	.15	.17	.15	.14	.16	.15	.13
Methionine ...	.60	.37	.35	.32	.38	.36	.33	.39	.36	.34
Lysine	.90	.62	.57	.51	.67	.62	.56	.72	.66	.61
Leucine	.80	1.48	1.43	1.38	1.50	1.46	1.41	1.53	1.48	1.43
Isoleucine	.50	.58	.55	.52	.60	.57	.53	.62	.59	.56
Phenylalanine .	.90	.64	.61	.57	.65	.61	.58	.65	.63	.58
Histidine	.30	.31	.29	.27	.32	.31	.29	.34	.33	.31
Threonine	.50	.53	.49	.46	.54	.51	.46	.55	.52	.48
Valine	.70	.75	.71	.66	.76	.71	.67	.76	.72	.67
Arginine	.20	.90	.83	.75	.88	.81	.77	.88	.79	.71
Cystine[2]	--	.19	.18	.17	.18	.17	.16	.17	.15	.14
Tyrosine[3]	--	.62	.59	.56	.63	.60	.57	.60	.58	.53

[1] Calculation based on analysis of feedstuffs by the method of Spackman, Stein, and Moore, except crystine, which was analyzed by microbiological procedure, and tryptophan, which was analyzed by a modification of Spies and Chambers method.

[2] Cystine can supply up to 1/3 of the methionine requirement.

[3] Tyrosine can supply up to 1/3 of the phenylalanine requirement.

Note: MB is meat-and-bone meal-corn; FM is fish meal; the numerical suffixes indicate the percent protein supplied to the diet by the mixture.

B. EFFECT OF FISH-MEAL SUPPLEMENTATION ON RATE OF GAIN AND UTILIZATION OF FEED

Statistical analyses (t-test) indicate that certain differences in dietary treatment exist at the 5-percent level of significance (Table 6). In general, rates of gain and utilization of feed improved with the inclusion of fish meal.

1. Rate of Gain

Rats fed diets with 2 or 4 percent of protein from fish meal, with 1 exception, gained weight at a significantly greater rate than did those fed the meat-and-bone meal-corn diets without fish meal, irre-

Table 5.—Relation of the amino acid lysine and of the methionine plus cystine dietary content to the average total gain

Diet	Amount of amino acid in the diet: Lysine	Methionine plus cystine	Total gain
	Percentage of requirement		*Grams*
MB16-FMO	69	93	116.8
MB15-FMO	63	88	98.9
MB14-FMO	57	82	88.5
MB14-FM2	74	93	149.5
MB13-FM2	69	88	131.7
MB12-FM2	62	82	124.9
MB12-FM4	80	93	166.8
MB11-FM4	73	85	137.5
MB10-FM4	68	80	132.1

Note: MB is meat-and-bone meal-corn; FM is fish meal; the numerical suffixes indicate the percent protein supplied to the diet by the mixture.

Table 6.—Weight gain and utilization of feed by rats fed meat-and-bone meal-corn diets with and without fish-meal supplementation

Identifying coefficient	Diet	Average total gain	Feed/gain
		Grams	*Ratio*
a	MB16-FMO	116.8	3.6 c
b	MB15-FMO	98.9	4.1
c	MB14-FMO	88.5	4.3
Average		101.4	4.0
d	MB14-FM2	149.5 a, b, c, f	3.2 a, b, c, f
e	MB13-FM2	131.7 b, c	3.6
f	MB12-FM2	124.9 b, c	3.6 c
Average		135.3	3.5
g	MB12-FM4	166.8 a, b, c, e, f, h, i	3.0 a, b, c, f
h	MB11-FM4	137.5 b c	3.2 a, b, c
i	MB10-FM4	132.1 b, c	3.6
Average		148.8	3.3

Note: The lower-case letters following the numbers indicate significant difference ($P = < .05$)—that is, that the gain and/or feed/gain values of the diet preceding the letter is better than the value of the diet indicated by the letter: for example, 131.7 grams is significantly better than 98.9 grams and 88.5 grams.

meal was substituted in the diets, the rate of gain was greater than the 16-percent-protein diet (MB14-FM2) than with the 14-percent-protein diet (MB12-FM2).

Increasing the fish-meal protein protein in the diets from 2 to 4 percent resulted in a rate of gain significantly greater in animals fed the 16-percent-protein diet (MB12-FM4) than in those fed the 15- and 14-percent-protein diets (MB13-FM2 and MB12-FM2).

2. Utilization of Feed

Rats fed diet MB14-FM2 and diets MB12-FM4 and MB11-FM4 utilized their food more efficiently than did the rats fed the 3 meat-and-bone meal-corn diets (MB16-FMO, MB15-FMO, and MB14-FMO). Utilization of feed was improved when the fish-meal protein was increased from 2 to 4 percent—that is, MB12-FM4 was utilized more efficiently than was MB12-FM2.

In the utilization of feed, differences that are related to the 3 total dietary levels of protein, either

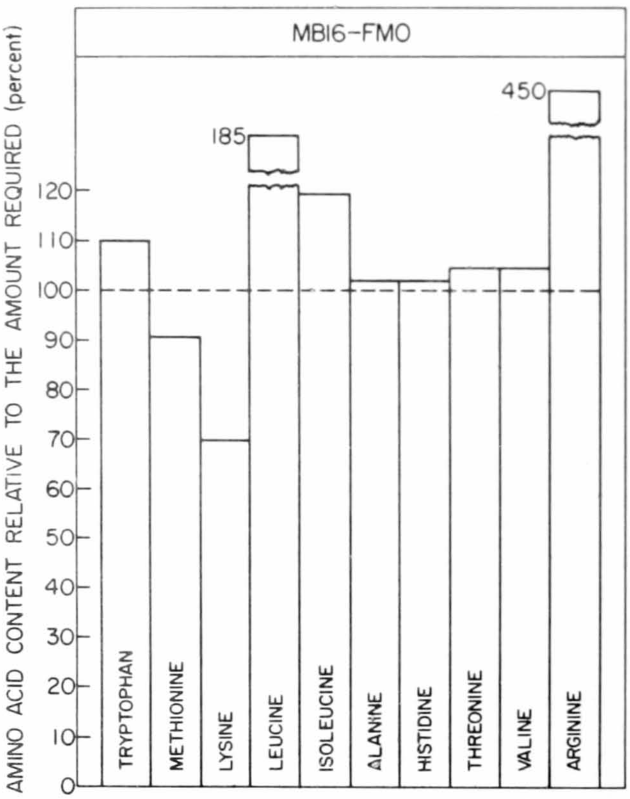

Figure 1.—Amino acid profile of the relative content of amino acids of diet MB16-FMO to the required amino acid level of the rat.

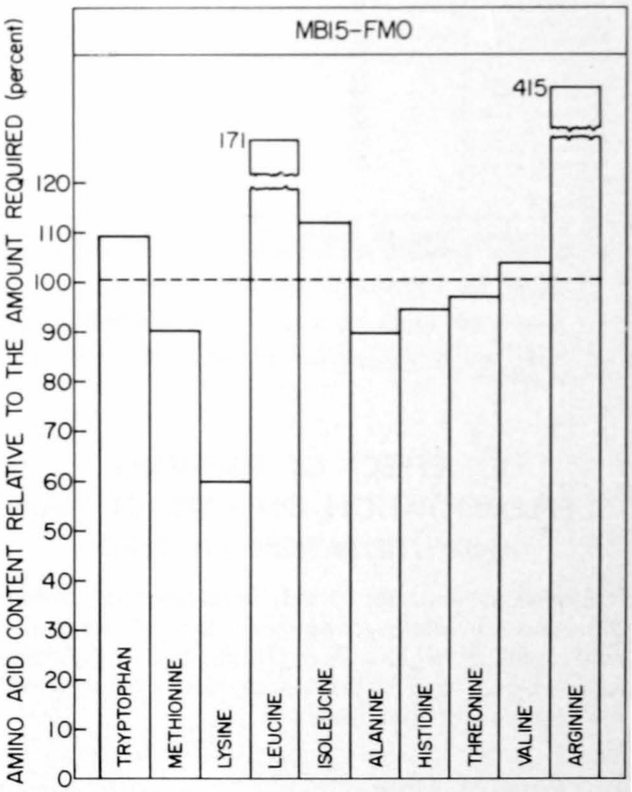

Figure 2.—Amino acid profile of the relative content of amino acids of diet MB15-FMO to the required amino acid level of the rat.

with or without 2 or 4 percent protein from fish meal, were not uniform. At the 0-percent level of protein from fish meal, more efficient utilization of feed was obtained at the 16-percent-protein level (MB16-FMO) than at the 15- and 14-percent levels (MB15-FMO and MB14-FMO). Similarly, when the percent protein from fish meal was increased from 0 to 2, the rats utilized the feed more efficiently when fed at the 16-percent-protein level (MB14-FM2) than when fed at the 15- and 14-percent levels (MB13-FM2 and MB12-FM2). No difference in utilization of feed was observed among the protein levels when the percent protein from fish meal was increased to 4 percent.

III. DISCUSSION

The results of the fish-meal-evaluation experiment suggest that a fish-meal supplement will improve the amino acid balance of meat-and-bone meal-corn diets. Calculated values of the amino acid content of the experimental diets indicate that each diet is deficient in 1 or more of the amino acids required for optimum growth (Tables 4 and 5). These calculations and the amino acid profiles (Figures 1-9) suggest that lysine and methionine are the first and second limiting amino acids in all the diets. Further, the data indicate that a direct relation exists between the lysine content of the diets (as a percent of the requirement) and the rates of gain. However, 1 exception was noted in that diets MB15-FMO and MB12-FM2 both contained the same content of lysine but did not support the same gain in weight. No relation was indicated between the percent methionine plus cystine and the rates of gain.

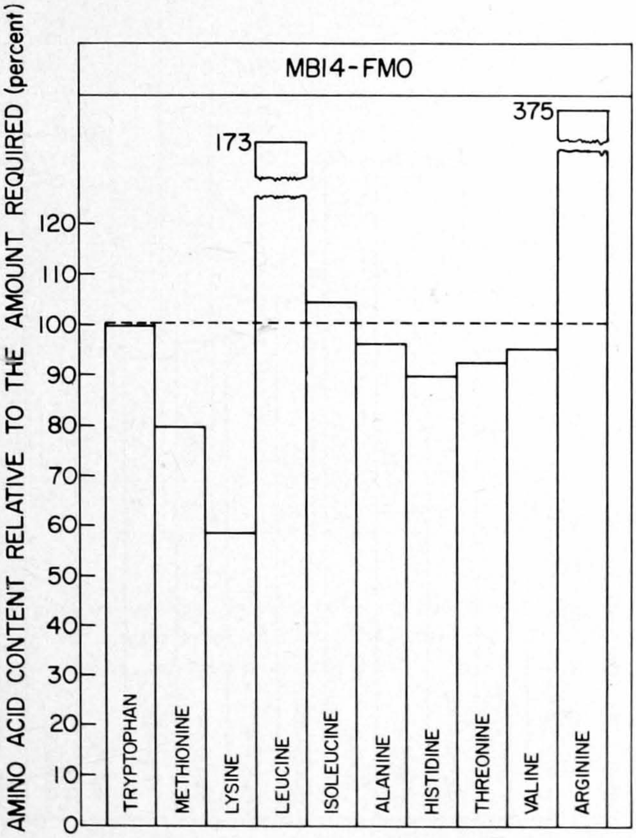

Figure 3.—Amino acid profile of the relative content of amino acids of diet MB14-FMO to the required amino acid level of the rat.

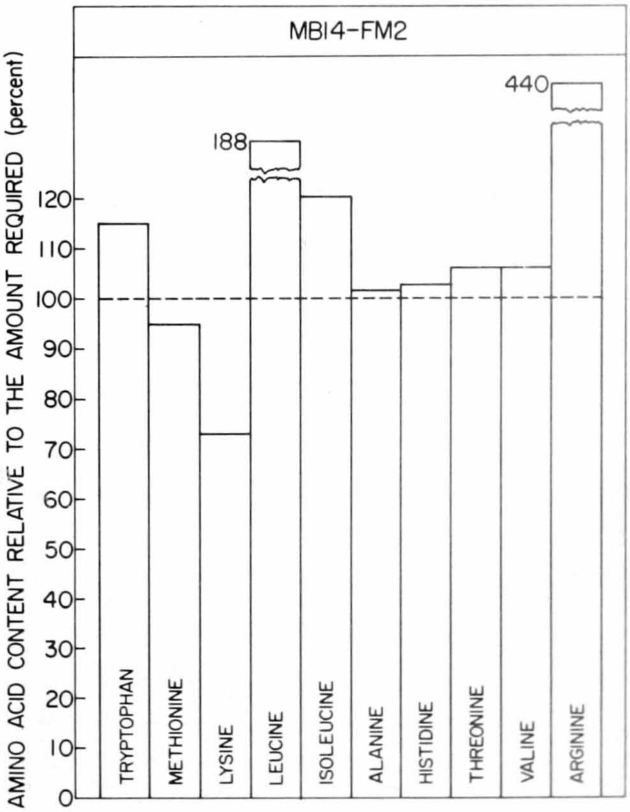

Figure 4.—Amino acid profile of the relative content of amino acids of diet MB14-FM2 to the required amino acid level of the rat.

SUMMARY

Statistical analyses of the data obtained from a study of the value of supplementing meat-and-bone meal-corn diets with menhaden fish meal indicated that certain dietary treatments will promote difference at the 5-percent level of significance in the growth of rats.

Rates of gain increased and utilization of feed was more efficient when 2 and 4 percent protein obtained from fish meal was added to the meat-and-bone meal-corn diets.

Differences in rates of gain and utilization of feed—both of which are related to the 3 dietary levels of protein, either with or without 2 or 4 percent protein from fish meal—were variable.

The calculated ratios of dietary amino acid indicate that lysine was the limiting amino acid in all the diets fed.

Rates of gain, with 1 exception, were directly related to the calculated dietary lysine content (expressed as percent of requirement).

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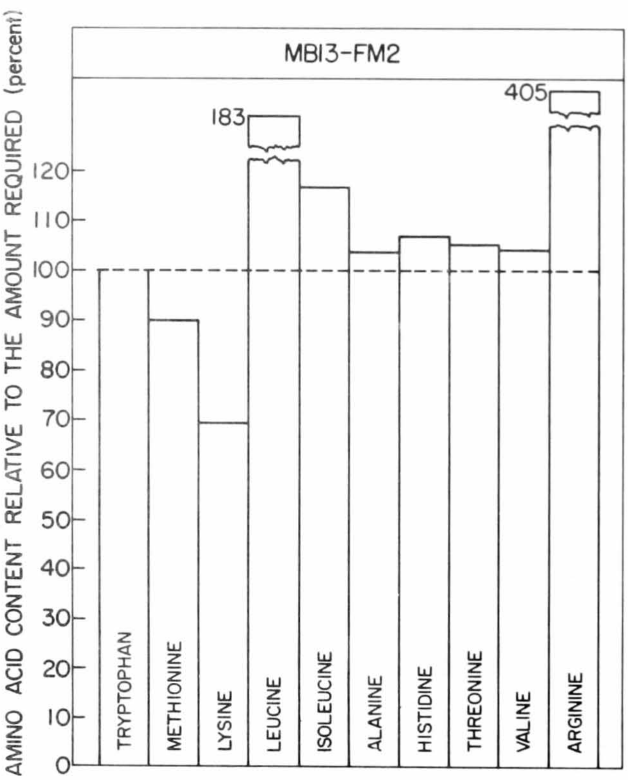

Figure 5.—Amino acid profile of the relative content of amino acids of diet HM13-FM2 to the required amino acid level of the rat.

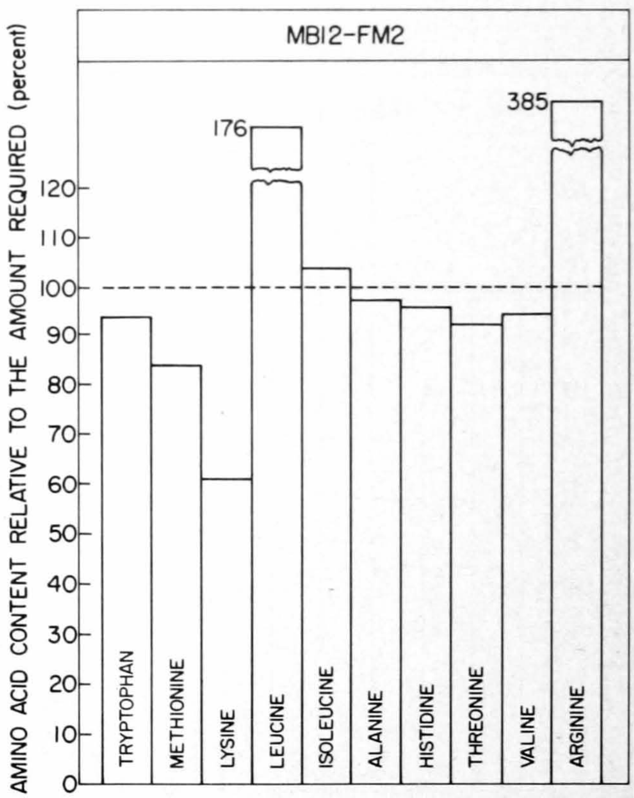

Figure 6.—Amino acid profile of the relative content of amino acids of diet MB12-FM2 to the required amino acid level of the rat.

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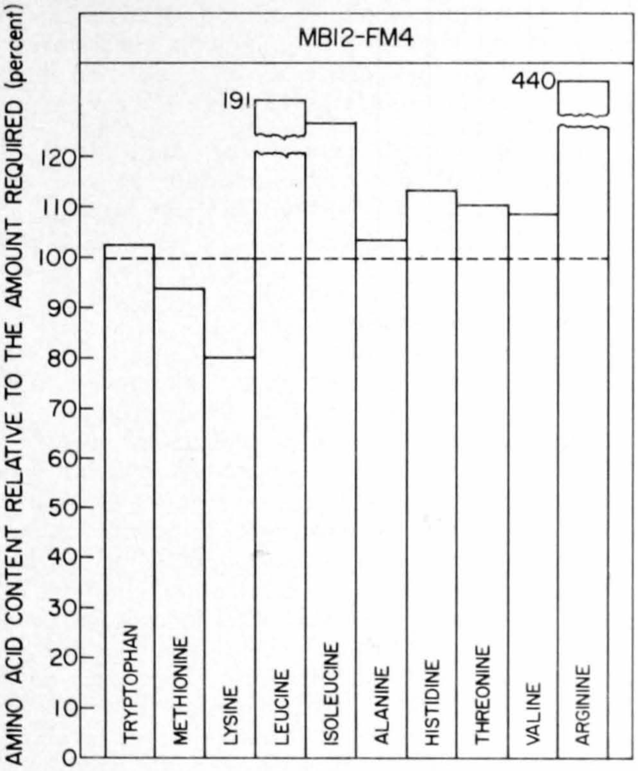

Figure 7.—Amino acid profile of the relative content of amino acids of diet MB12-FM4 to the required amino acid level of the rat.

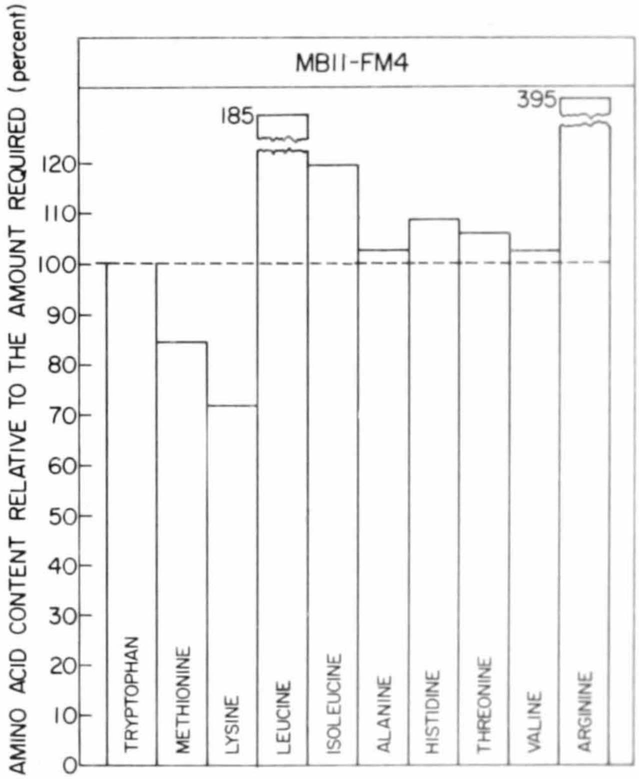

Figure 8.—Amino acid profile of the relative content of amino acids of diet MB11-FM4 to the required amino acid level of the rat.

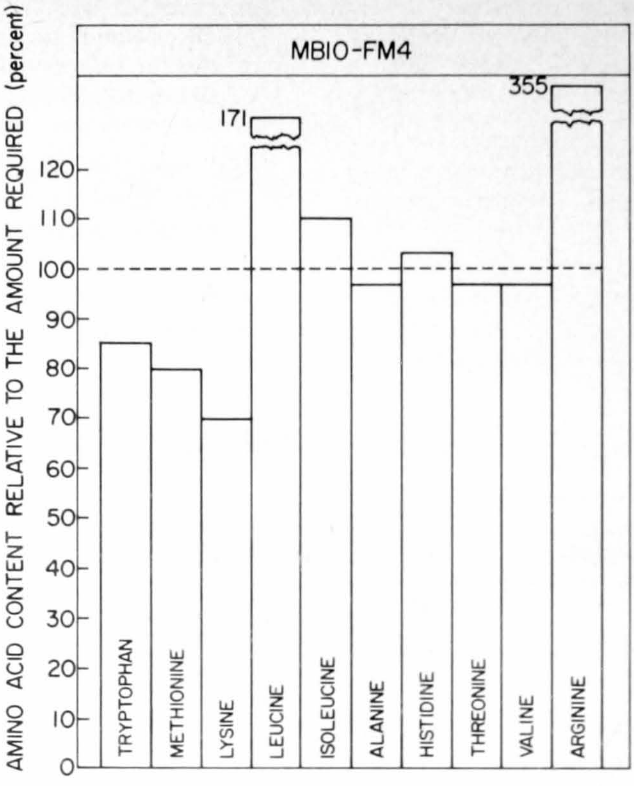

Figure 9.—Amino acid profile of the relative content of amino acids of diet MB10-FM4 to the required amino acid level of the rat.

MS #1517

VALUE OF MENHADEN FISH MEAL AS A PROTEIN SUPPLEMENT IN SOYBEAN MEAL-CORN DIETS FED TO RATS

by

Robert R. Kifer, Edgar P. Young, and Kam C. Leong

ABSTRACT

2 consecutive rat-feeding studies were conducted so that menhaden fish meal could be evaluated as a protein supplement in soybean meal-corn diets. Animals weighing 50 $\pm$ 5 grams were randomly allotted to 5 treatment groups in Experiment I and to 9 treatment groups in Experiment II and fed diets containing soybean meal-corn, with and without fish meal, at various levels of total protein (16 and 14 percent in Experiment I and 16, 15, and 14 percent in Experiment II).

In both experiments, response to fish-meal supplementation varied somewhat, as indicated by rates of gain and utilization of feed. It was indicated, however, that fish-meal supplementations in general did not improve the amino acid balance of the soybean meal-corn diets.

INTRODUCTION

Throughout the world, soybean meal is one of the most extensively used sources of protein supplementation for both animal and human diets. Its protein quality apparently is not adequate, however, for maximum rate of growth of certain animals. Based on a calculation of average amino acid values (Block and Weiss, 1956) and on experimental evidence (Jones and Pond, 1963; Borchers, 1962; Barnes, Fiala, and Kwong, 1962; Hayward and Hafner, 1941), soybean meal-corn diets, for example, are deficient in the amount of methionine and lysine required by rats (National Research Council, 1962). In contrast, fish meal is an excellent source of lysine (Snyder, Ousterhout, Titus, Morgareidge, and Kellenbarger, 1962) and a good source of methionine (Snyder and associates, 1962).

It thus should follow that a diet of soybean-corn in which fish meal replaces some of the soybean meal should contain a better balance and level of amino acids, owing to the high content of lysine and methionine in the fish meal. Because of this better content of amino acids, an increased rate of gain and more efficient utilization of feed should be obtained. We therefore conducted rat-feeding experiments to see if, by adding the protein from fish meal to soybean meal-corn, we could obtain in practice this balancing effect.

The results of our first experiment were not what we expected. Accordingly, we made a second experiment to verify our initial findings.

I. EXPERIMENT I

Soybean meal-corn diets supplemented by various amounts of menhaden fish meal were evaluated by rat-feeding experiments. Data collected were on rates of gain, both in weight and in utilization of feed.

Authors: Robert R. Kifer, *Animal Husbandman*, and Kam C. Leong, *Research Biochemist*, Bureau of Commercial Fisheries Techological Laboratory, College Park, Maryland; and Edgar P. Young, *Associate Professor*, Department of Animal Science, University of Maryland, College Park, Maryland.

A. EXPERIMENTAL PROCEDURE

1. SAMPLES

The menhaden *(Brevoortia tyrannus)* fish meal used was of commercial production. The soybean meal and corn were purchased from a local feed store. All samples were analyzed for protein by the Kjeldahl method (Association of Official Agricultural Chemists, 1955).

2. Diets

The dietary variables (Table 1) were total protein levels (16 and 14 percent) and different protein levels from fish meal (0, 2, and 4 percent). The diets were formulated on a protein (N x 6.25) basis and were calculated to be nutritionally adequate in all other nutrients (Table 2).

3. Rats

4 weanling black-hooded rats, 2 males and 2 females, weighing 50 ± 2 grams each were randomly allotted to each of 5 dietary treatments for an experimental period of 4 weeks.

Table 1.—Experimental design of rat study to determine the value of menhaden fish meal as a protein supplement in soybean meal-corn diets (Experiment I)

Treatment	Relative amount of protein contributed by:		Total protein
	Corn and soybean meal	Fish meal	
	Percent	*Percent*	*Percent*
CS16-FMO[1]	16	0	16
CS14-FM2	14	2	16
CS12-FM2	12	2	14
CS12-FM4	12	4	16
CS10-FM4	10	4	14

[1] CS is the symbol for corn and soybean meal; FM, for fish meal; numerical values indicate percent protein contributed by the ingredient.

All animals were housed in a room maintained at 80 ± 2° F., and the relative humidity was maintained at 50 ± 5 percent. The animals were permitted water and feed ad libitum. Individual animal weight and feed consumption were measured weekly.

B. RESULTS

1. Chemical Analyses

Chemical analyses of the feedstuffs are given in Table 3.

2. Effect of Fish-Meal Supplementation on Growth and Utilizatian of Feed

Results of the study on growth and feed utilization are given in Table 4. Statistical analysis (t-test) of the data obtained for rates of gain and utilization of feed indicates that differences exist (at the 5-percent level of significance) between certain of the dietary treatments.

Similar rates of gain were obtained only with rats fed diets CS16-FMO[2] and CS14-FM2. The rats fed diet CS14-FM2 utilized the feed more efficiently, however, than did those animals fed the control diet CS16-FMO. Reducing the total protein level, irrespective of fish-meal level or amount of protein in the diets (for example, CS12-FM2 and CS10-FM4), resulted in poorer rates of gain and utilization of

[2] CS is the symbol for corn and soybean meal; FM, for fish meal; numerical values indicate percent protein contributed by the ingredient.

Table 2.—Diet formulations for a rat-feeding study to determine the value of menhaden fish meal as a protein supplement to soybean meal-corn diets (Experiment I)

Ingredient	Relative amounts of the various ingredients in:				
	CS16-FMO	CS14-FM2	CS12-FM2	CS12-FM4	CS10-FM4
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Corn (yellow, U. S. #2)	75.63	76.46	81.27	78.34	83.15
Soybean meal	18.55	14.60	9.80	10.30	5.50
Menhaden meal	—	3.12	3.12	6.24	6.24
Rock phosphate (defluorinated)[1]	2.34	2.32	2.31	1.62	1.61
Salt (trace mineralized)[2]	0.50	0.50	0.50	0.50	0.50
Vitamin premix (NBC)[3]	3.00	3.00	3.00	3.00	3.00
Total	100.00	100.00	100.00	100.00	100.00

[1] Calcium, 31-34 percent; phosphorus, 18 percent (guaranteed analysis).

[2] The trace minerals as percent of salt mixture were: Mn, 0.600 as manganese oxide; S, 0.250 sodium sulfate; Fe, 0.200 ferrous carbonate; Cu, 0.060 cuprous oxide; I, 0.016 calcium idoide; Zn, 0.10 zinc oxide; and Co, 0.015 cobalt carbonate.

[3] The vitamins as grams/pound of vitamin mix were: riboflavin, 0.45; calcium pantothenate, 1.36; niacin, 2.05; choline chloride, 34.10; thiamine, 0.45; pyridoxine, 0.45; paraminobenzoic acid, 2.27; menadione, 1.02; inositol, 2.27; ascorbic acid, 20.5; alpha tocopherol, 2.27; Vitamin D concentrate (400,000 units per gram), 0.11; Vitamin A (200,000 units per gram), 2.05 grams; as milligrams/pound: biotin, 9.09; folic acid, 40.9; Vitamin B_{12}, 0.61. NBC—Nutritional Biochemical Corporation. (Use of trade names does not imply endorsement of commercial products.)

Table 3.—Protein analyses of feedstuffs used in Experiment I

Ingredient	Concentration of protein
	Percent
Fish meal I (menhaden)	64.08
Corn I (yellow, U. S. #2)	8.49
Soybean meal I	50.08

feed. The rats fed diets with 4 percent fish meal (CS12-FM4 and CS10-FM4) utilized the feed less efficiently than did those rats fed either the control diet (CS16-FMO) or diet CS14-FM2.

Table 4.—Weight gain and utilization of feed of rats fed soybean meal-corn diets with and without fish meal supplementation (Experiment I)

Treatment	Average total weight gain[1]	Feed/gain[1]
	Grams	
CS16-FMO[2]	151.0 a	2.97 b
CS14-FM2	152.0 a	2.71 a
CS12-FM2	122.5 b	3.11 c
CS12-FM4	130.0 b	3.13 c
CS10-FM4	101.3 b	3.50 c

[1] Treatments with a common letter are not significantly different from each other. Treatments without a common letter are significantly different (t-test P = < .05).

[2] CS is the symbol for corn and soybean meal; FM, for fish meal; numerical values indicate percent protein contributed by the ingredient.

II. EXPERIMENT II

Experiment II had different menhaden fish meal, corn, and soybean meal from those used in Experiment I and includes 4 more treatments than in Experiment I—that is, 2 additional controls and 2 additional diets containing fish meal were used.

A. EXPERIMENTAL PROCEDURE

1. Samples

The samples were obtained from the same sources and analyzed in the same way as in Experiment I.

2. Diets

The dietary variables (Table 5) were total protein level (16, 15, and 14 percent) and the proportion of protein from fish meal (0, 2, and 4 percent). Formulations of the diets are shown in Table 6.

3. Rats

10 weanling male albino rats weighing 55 ± 5 grams were randomly allotted to each of 9 treatments for an experimental period of 4 weeks. Feeding procedure, housing, and weighing were the same as for Experiment I.

Table 5.—Experimental design of rat study to determine the value of menhaden fish meal as a protein supplement in soybean meal-corn diets (Experiment II)

Treatment	Relative amount of protein contributed by:		Total protein
	Corn and soybean meal	Fish meal	
	Percent	*Percent*	*Percent*
CS16-FMO[1]	16	0	16
CS15-FMO	15	0	15
CS14-FMO	14	0	14
CS14-FM2	14	2	16
CS13-FM2	13	2	15
CS12-FM2	12	2	14
CS12-FM4	12	4	16
CS11-FM4	11	4	15
CS10-FM4	10	4	14

[1] CS is the symbol for corn and soybean meal; FM, for fish meal; numerical values indicate percent contributed by the ingredient.

Table 6.—Diet formulations for rat Experiment II to determine the value of menhaden fish meal as a protein supplement in soybean meal-corn diets

Ingredient	Relative amounts of the various ingredients in:								
	CS16-FMO	CS15-FMO	CS14-FMO	CS14-FM2	CS13-FM2	CS12-FM2	CS12-FM4	CS11-FM4	CS10-FM4
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Corn (yellow, U. S. #2)	76.37	78.75	81.13	77.95	80.33	82.71	79.59	81.99	84.37
Soybean meal	18.23	15.85	13.47	14.03	11.65	9.27	9.77	7.37	4.99
Menhaden meal	—	—	—	3.07	3.07	3.07	6.14	6.14	6.14
Rock phosphate (defluorinated)[1] ...	1.90	1.90	1.90	1.45	1.45	1.45	1.00	1.00	1.00
Salt (trace mineralized)[2]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin premix (NBC)[3]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1] Calcium, 31-34 percent, phosphorus, 18 percent (guaranteed analysis).

[2] The trace minerals as percent of salt mixture were: Mn, 0.600 as manganese oxide; S, 0.250 sodium sulfate; Fe, 0.200 ferrous carbonate; Cu, 0.060 cuprous oxide; I, 0.016 calcium iodide; Zn, 0.010 zinc oxide; and Co, 0.015 cobalt carbonate.

[3] The vitamins as grams/pound of vitamin mix were: riboflavin, 0.45; calcium pantothenate, 1.36; niacin, 2.05; choline chloride, 34.10 thiamine, 0.45; pyridoxine, 0.45; paraminobenzoic acid, 2.27; menadione, 1.02; inositol, 2.27; ascorbic acid, 20.5; alpha tocopherol, 2.27; Vitamin D concentrate (400,000 units per gram), 0.11; Vitamin A (200,000 units per gram), 2.05 grams; as milligrams/pound; biotin, 9.09; folic acid, 40.9; Vitamin B_{12}, 0.61. NBC—Nutritional Biochemical Corporation. (Use of trade names does not imply endorsement of commercial products.)

B. RESULTS

1. Chemical Analyses

Chemical analyses of the feedstuffs are given in Table 7.

Table 7.—Protein concentration and feedstuffs used in Experiment II

Ingredient	Concentration of protein
	Percent
Menhaden meal II	64.24
Corn II (yellow, U. S. #2)	8.76
Soybean meal II	50.74

2. Effect of Fish-Meal Supplementation on Growth and Utilization of Feed

Rates of gain were not significantly improved by the inclusion of 2-percent or 4-percent protein from fish meal in the soybean meal-corn diets at all 3 levels (16, 15, or 14 percent) of total protein (Table 8). The animals fed diet CS12-FM4 utilized the feed significantly better, however, than did those animals fed diets CS16-FMO, CS14-FMO, CS14-FM2, CS12-FM2, CS11-FM4, and CS10-FM4.

In diets containing 4-percent protein from fish meal, a greater rate of gain and utilization of feed were obtained from animals fed the 16-percent-protein diet (CS12-FM4) than from those fed the diets containing 15- and 14-percent protein (CS11-FM4 and CS10-FM4).

Table 8.—Weight gain and utilization of feed of rats fed soybean meal-corn diets with and without fish meal supplementation (Experiment II)

Treatment	Average total weight gain[1]	Feed/gain[1]
	Grams	
CS16-FMO[1]	185.4 ab	2.44 ab
CS15-FMO	196.2 ab	2.34 ab
CS14-FMO	195.6 ab	2.42 ab
CS14-FM2	187.0 ab	2.56 c
CS13-FM2	189.4 ab	2.38 ab
CS12-FM2	189.2 ab	2.55 ab
CS12-FM4	203.5 a	2.24 ab
CS11-FM4	181.1 b	2.49 b
CS10-FM4	180.5 b	2.68 c

[1] Treatments with a common letter are not significantly different from each other. Treatments without a common letter are significantly different (t-test P = < .05).

[2] CS is the symbol for corn and soybean meal; FM, for fish meal; numerical values indicate percent protein contributed by the ingredient.

III. CONCLUSIONS

Contrary to our premise, the results obtained indicate that fish-meal supplementation in general did not improve the amino-acid balance of the soybean meal-corn diets. However, 1 exception was noted in that the rats fed diet CS12-FM4 in Experiment II, although gaining weight at a similar rate, utilized the feed more efficiently than did those receiving 6 other treatments. Possibly, at this level of total protein (16 percent), the amino acid requirements of the rats were met quantitatively, whereas the decreases obtained from fish-meal supplementation at the lower protein levels (15 and 14 percent) may have been due to an amino acid imbalance.

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MS #1518

PROXIMATE COMPOSITION OF GULF OF MEXICO INDUSTRIAL FISH

by

Mary H. Thompson

ABSTRACT

Variations in physical measurements and proximate composition of 17 Gulf of Mexico industrial fish over several years are delineated on a monthly basis. Scattered data for several other species are also presented. Analysis of variation in proximate composition and the influence of (1) geographic location of catch, (2) yearly variation, (3) reproductive cycle, (4) sex, (5) food, (6) size, (7) activity, and (8) species are discussed. The fishery is described, and data are given on fluctuations in bottom temperature and types of bottom encountered. Changes in moisture and oil content are shown, and an equation for estimating the oil content of a lot, composed of mixed species, from its known moisture content is presented. The equation (Y = 65.3 — 0.8X) can be used to predict the oil content with a statistically estimated error of ± 0.6 percent oil. A series of actual samples showed the average deviation to be −0.1 percent.

CONTENTS

INTRODUCTION

Much has been written about the proximate composition of various species of fish, particularly those species used for human food. Several recent books have included reviews of the subject (Vinogradov, 1953; Heen and Kreuzer, 1962; and Stansby, 1963); they may be consulted for further information, in-

Author: Mary H. Thompson, *Supervisory Research Chemist*, Bureau of Commercial Fisheries Technological Laboratory, Pascagoula, Mississippi.

cluding partial bibliographies. In consideration of the large amount of published research, it would seem that the subject of variations in composition would have been exhaustively treated. This, however, is far from the case.

Certain of the commercially important species — particularly those species whose oil content is valued commercially — have been studied on a seasonal basis (Hart, Tester, Beall, and Tully, 1940; Black and Schwartz, 1950; Venkataraman and Chari, 1951; Chidambaram, Krishnamurthy, Venkataraman, and Chari, 1952; Brasmaes, Mogensen, and Birno, 1954; Flood, 1958; McBride, MacLeod, and Idler, 1959; Sohn, Carver, and Mangan, 1961). Seasonal changes in the proximate composition of fish have been attributed to: (1) differences in the amount of food or the type of food available, or to both the amount and the type (Venkataraman and Chari, 1953; Stansby, 1963); (2) feeding habits of the species in relation to the reproductive cycle (Chidambaram and associates, 1952); (3) size and maturity of the fish (Chidambaram and associates, 1952; Flood, 1958); (4) geographic location of catch (Venkataraman and Chari, 1951); (5) reproductive cycle of the species (Hart and associates, 1940; Venkataraman and Chari, 1951); and (6) sex (Chidambaram and associates, 1952). On the other hand, certain investigators find so much variation from 1 fish to another that the seasonal variation becomes meaningless (Stansby, 1953), and others find neither seasonal nor species variation (Thurston, 1961).

1 of the fastest growing fisheries in the world is the relatively new Gulf of Mexico industrial fishery. The fishery has grown from a production of 3,000 tons in 1952 to 41,000 tons in 1962. The catch is utilized in the production of pet food and fish meal and as mink food. Over 170 species have been recorded in the catch, although of these 170 only 18 species comprise over 1 percent of the catch throughout the year (Haskell, 1961). To date, only a limited study of these 18 species has been made (Thompson, 1959a, 1959b, 1959c), and no interpretation of changes occurring with respect to seasonal variations in proximate composition has been attempted. The particular purposes for which these species are utilized render such composition data not only desirable, but mandatory. In the manufacture of pet foods, a certain level of oil and protein must be present in the finished product to meet the requirements of various State codes. In the production of fish meal in which oil is not removed during manufacture, the production of a desirable meal necessitates regulation of the oil content of the incoming raw material. The dietary requirements of mink during the reproductive cycle, as well as during the pelt-producing season, are quite well defined as to high oil and low oil requirements.

The purpose of this paper, therefore, is to report on the proximate composition of the common Gulf of Mexico industrial fish with particular emphasis on variations to be expected throughout a single year, and also from year to year. In order that a frame of reference be provided, the fishery will be described; then with that background to provide insight, the proximate composition will be reported.

I. THE GULF OF MEXICO INDUSTRIAL FISHERY

A. PRODUCTION

The fishery was started in 1952 to use the "trash" fish recovered during shrimping operations. In that year, a plant was established in Pascagoula, Mississippi, to process these species into a pet food. During its first year, the fishery produced 3,000 tons. In 1954, a fleet of vessels devoted to fishing for industrial species was established (Illustration 1). By 1962, the catch had increased to 41,000 tons, and the fish meal and mink food had been added to the products being marketed.

Although the industrial fish are not intended for use in human nutrition, they are treated with care. In general, the fishing vessel remains at sea for only 2 to 3 days; none of the landing sites is more than 1-1/2 days running time from the farthest fishing point. The fish are caught in a flat shrimp trawl, usually 65 feet in width, and are brought onto deck, where unusable items are culled and the rest of the catch is iced. The catch is kept well iced for the remainder of the cruise, as any deleterious change in the fish makes them unusable in the production of pet food or mink food. At dock-site, the fish are unloaded with a "fish pump". This pump has attached to it a flexible hose of large diameter to which a slight vacuum is supplied (Illustration 2). The fish are directed to it by means of 2 high-pressure water streams and are then further carried with their accompanying stream of water through the suction pumps into a large washing tank. During this process, the catch is cleaned of any adhering ice and bits of extraneous material. From the washing tank, the fish are spread onto a continuous conveyor and carried past inspectors who cull the unutilizable species.

It is at this point that the catch was sampled.

Illustration 1.—Vessels typical of those used in the fishery for industrial species in the Gulf of Mexico.

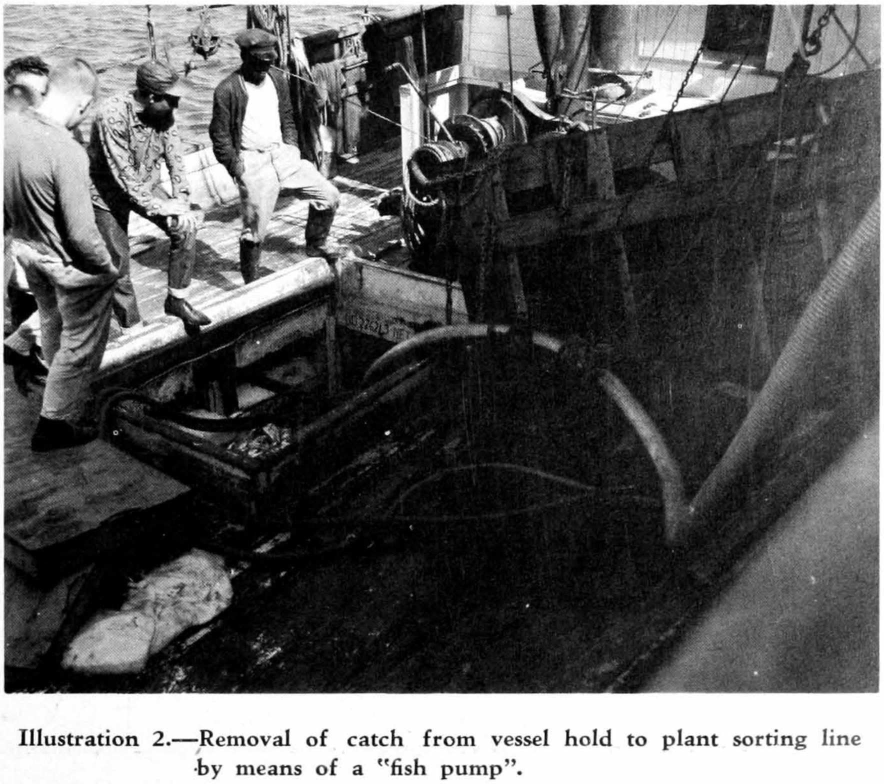

Illustration 2.—Removal of catch from vessel hold to plant sorting line by means of a "fish pump".

B. FISHING GROUNDS

The definition of this particular fishing ground as an environment is of significance to the intent of this study. At the present time few, if any, other fishing grounds are so well-defined geographically and are as productive both in terms of quantity of fish landed and in terms of diversity of species. A study of the composition and variations in composition of the separate species is, therefore, a worthwhile and informative project.

The geographic range of the fishery extends from Ship Shoal or Vermillion Bay, Louisiana, on the west to Cape St. George, Florida, on the east (Figure 1). The greatest portion of the catch is taken between 2 and 20 fathoms, but occasional fishing is done as deep as 30 fathoms. Although the fishery does extend some 7 degrees of longitude, or about 420 miles, it does not exceed 2 degrees of latitude and is seldom farther than 30 miles from the nearest coastal point. The shallow shelf extends along the coast for many miles and outward to the 100-fathom curve some 60 miles offshore, forming an environment with many common characteristics.

Figure 2 shows the changes in bottom temperature for 4 longitudinal sections of the area throughout the year as recorded by personnel of the research vessel *Oregon* over a 5-year period. Although there is a variation of 20 to 30 degrees in bottom temperature throughout the year, there appears to be no great change in temperatures from east to west, nor is there an apparent difference due to depth within the range considered. The summer fishing grounds are inshore (Figure 1) in depths of 2 to 7 fathoms, whereas the winter grounds are farther offshore in depths of 8 to 20 or, occasionally, 30 fathoms.

Within the area fished, the bottom has been found to be almost entirely mud, sand, or mixtures of both, and the organisms associated with it are thus apt to be uniform as to type and distribution. There apparently is an abundance of food during the entire year in these shallow-water areas (Coker, 1949). The species of fish normally obtained in this fishery throughout the year in greatest abundance are bottomfish. For the most part, they ingest various worms and shrimps and other small crustaceans, all of which are numerous.

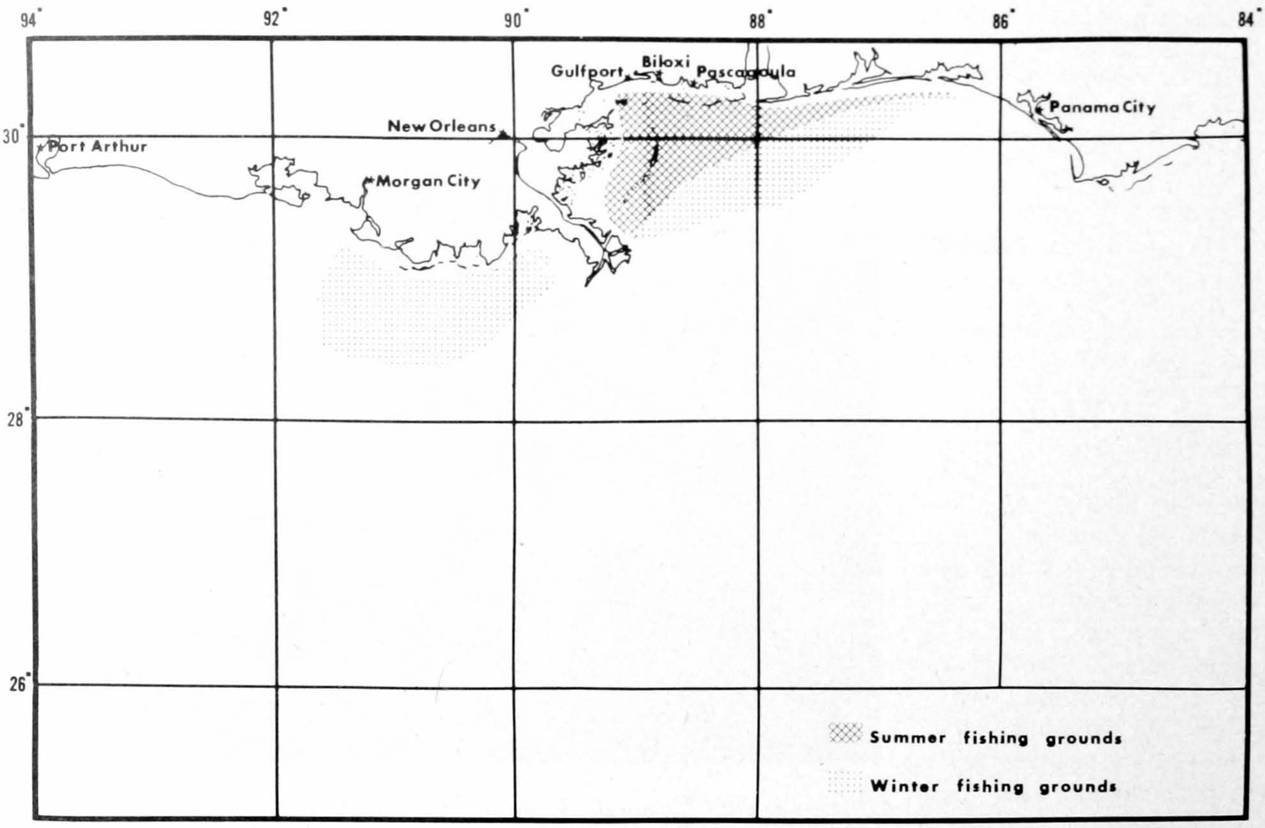

Figure 1.—The summer and winter industrial fishing grounds in the Northern Gulf of Mexico.

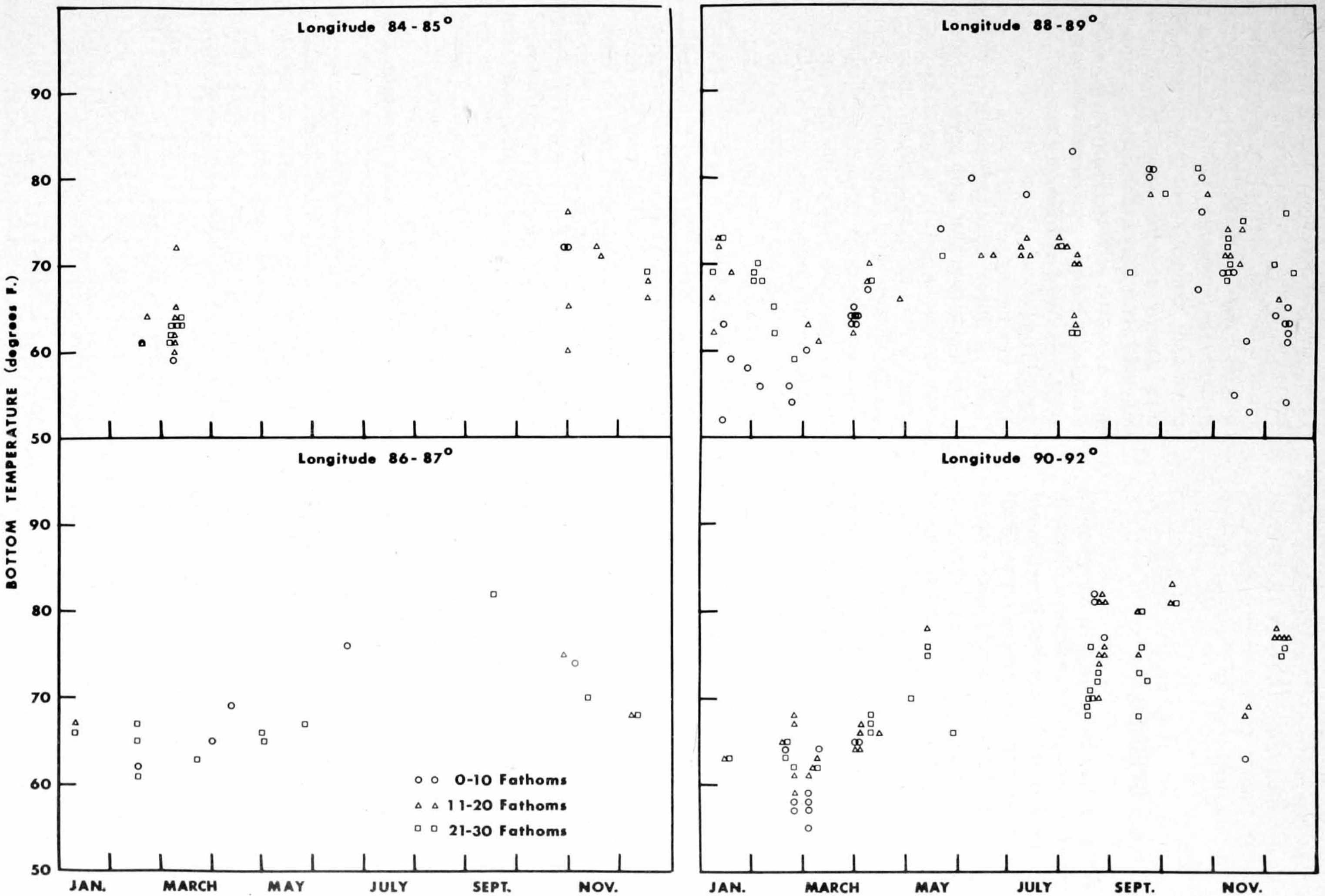

Figure 2.—Seasonal variation in bottom temperatures in the study area.

When taken together, the characteristics of the environment available to the fishery seem remarkably stable and uniform throughout the geographic area fished (even in their variations). The possibility therefore exists that the numerous species taken here might have some common characteristics as to composition and, further, that a unique opportunity presents itself to study the influence of the environment upon composition.

C. SPECIES

Over 170 species of fish belonging to 65 families have been recorded as present in the fishery (Haskell, 1961). Of these, only a small number are present throughout the year in a proportion greater than 1 percent of the total catch. A few additional species enter the catch in measurable amounts during a few-months period (Table 1). According to the annual report of the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas, fiscal year 1963 (1964), croaker *(Micropogan undulatus)* accounted for 58 percent of the total production in 1962. In the same year, spots *(Leiostomus xanthurus)*, sand and white seatrouts *(Cynoscion arenarius* and *C. nothus)*, and silver eels *(Trichiurus lepturus)* accounted collectively for 23 percent of the catch. The remaining 19 percent was made up of relatively few of the remaining species—particularly those included in this study.

The menhaden *(Brevoortia patronus)* included in this study cannot be considered as representative of the fish normally associated with that fishery. The samples taken were caught in bottom trawls (probably as the trawls were let out and retrieved) and were not schooling as do the menhaden of the normal fishery. For the most part, these menhaden are smaller and are peculiar to the industrial fishery.

To avoid confusion, it should be clear that the common names of the species used frequently in this report are not the only ones applied to particular species. For instance, silver eels are also known as Atlantic cutlassfish, white trout are perhaps more commonly called silver trout, and hardheads are also known as sea catfish. The scientific names, however, can be used to find a more familiar common name in such publications as ***Check List of the Florida Game and Commercial Marine Fishes*** (Robins, 1958), or ***Food and Game Fishes of the Texas Coast*** (Pew, 1954).

The 3 most common fishes—croaker, spot, and white trout—together with several others that appear more or less regularly in the catch (banded croaker, silver perch, and star drum), belong to the same family *(Sciaenidae)*. The fourth common fish, the silver eel, belongs to family ***Trichiuridae***. These species are all bottomfish and feed commonly on smaller crustaceans and worms. Other species belonging to this group are hardhead (family ***Ariidae***), threadfin (family ***Polynemidae***), porgy (family ***Sparidae***), and grunt and pigfish (family ***Pomadasyidae***).

The most common pelagic (or mid-water) species taken belong to family ***Clupeidae*** and include menhaden, razorbelly, and thread herring. These species are plankton eaters and for the most part do not congregate on the bottom. Other pelagic fishes frequently found in the catch are anchovy (family ***Engraulidae***), bumper (family ***Carangidae***), harvestfish, and butterfish (family ***Stromateidae***).

Table 1.—Species composition of Gulf of Mexico industrial trawl fishery catches by weight, 1959

Species		Concentrations during:											
Common name	Scientific name	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
		Percent by weight											
Anchovy	*Anchoa* sp. (2 species)	--	1.18	1.62	2.72	1.44	1.92	2.05	1.73	2.18	--	--	--
Butterfish	*Porontus triacanthus*	--	--	--	--	1.24	--	--	--	--	2.75	--	--
Catfish, sea	*Galeichthys felis*	2.41	1.79	3.34	3.03	5.76	4.35	4.71	3.86	4.73	1.65	1.25	--
Croaker	*Micropogon undulatus*	41.41	62.98	49.81	53.65	51.74	55.65	46.02	44.02	41.04	40.20	54.97	55.17
Croaker, banded	*Larimus fasciatus*	2.19	1.50	--	2.60	--	--	--	--	1.17	2.12	--	--
Flounder	*Paralichthys* sp. (2 species)	--	--	--	--	--	--	--	--	--	--	--	1.30
Lizardfish	*Synodus foetens*	--	--	--	--	1.12	--	--	--	--	2.06	5.76	3.82
Menhaden	*Brevoortia* sp. (3 species)	3.28	--	1.69	2.54	2.21	4.27	1.12	--	--	4.32	6.13	1.00
Porgy	*Stenotomus* sp.	--	3.72	3.48	2.28	6.99	--	--	--	--	--	--	1.65
Razorbelly	*Harengula pensacolae*	--	--	--	2.13	3.50	10.24	3.26	2.64	3.79	5.01	1.77	--
Sea robin	*Prionotus* sp. (2 species)	--	--	1.26	--	--	--	--	--	--	--	--	1.25
Silver eel	*Trichiurus lepturus*	--	--	--	1.62	3.42	4.13	6.11	4.08	7.23	7.66	1.05	--
Spot	*Leiostomus xanthurus*	29.34	9.03	5.80	10.95	9.00	12.81	17.35	11.89	16.70	9.48	4.96	20.99
Star drum	*Stellifer lanceolatus*	--	--	--	2.36	2.11	--	--	--	--	--	--	--
Threadfin	*Polydactylus octonemus*	--	--	--	--	--	1.19	1.94	1.90	--	--	--	--
Trout, silver	*Cynoscion nothus*	12.45	13.23	24.91	10.13	3.18	2.31	5.55	8.26	11.32	13.50	6.51	2.66
Whiting	*Menticirrhus* sp. (2 species)	1.65	2.15	--	--	1.82	--	1.52	1.28	1.86	1.71	3.46	3.78
Miscellaneous (less than 1 percent each)		7.27	4.42	8.09	5.99	6.47	3.13	10.37	20.34	9.98	9.54	14.14	8.38

Source: Haskell (1961)

II. PROXIMATE COMPOSITION

In this section, variation in proximate composition is considered first, and predictability of the compositional factors is considered second.

A. VARIATION

1. Procedure

a. Samples.—Samples of the species of industrial fish that could be obtained throughout the year on a more-or-less regular basis were taken at random from the sorting belt of a production line. Species falling into this category were: anchovy, *Anchoa hepsetus;* bumper, *Chloroscombrus chrysurus;* butterfish; croaker; banded croaker; hardhead, *Galeichthys felis;* harvestfish, *Peprilus alepidotus;* menhaden, *Brevoortia patronus;* pigfish, *Orthopristis chrysopterus;* porgy, *Stenotomus caprinus;* razorbelly; silver eel; spot; threadfin; thread herring, *Opisthonema oglinum;* and white trout, *Cynoscion nothus.* In addition, samples of the following species were obtained at irregular intervals: grunt, *Haemulon* sp.; scad, *Trachurus lathami;* silver perch, *Bairdiella chrysura;* silverside, *Menidia* sp.; and star drum, *Stellifer lanceolatus.* These samples were identified and then placed in a polyethylene bag, frozen, and held at 0° F. until prepared for analysis. Detailed histories of prior handling procedures were recorded. No specimen was held over 4 days in ice prior to its being obtained from the sorting line; for the most part, the fish were only 2 days old. The samples were taken, identified, and frozen within 3 hours. Additional samples of mixed fish were taken from the exit line of an industrial food chopper located at a pet-food plant. These additional samples were used for analysis in a second experiment to determine the correctness of fit of an equation for the prediction of oil content.

The samples were identified by personnel of the Exploratory Fishing and Gear Research Base at Pascagoula, Mississippi. The sex and the reproductive state of later collections of spot and croaker were identified by personnel of the Biological Field Station at the Bureau of Commercial Fisheries laboratory in Pascagoula.

b. Physical measurements.—Prior to preparation of the sample for analysis, the fish were thawed and drained thoroughly. Each fish was measured to the nearest millimeter with a meter stick and weighed to the nearest 0.1 gram on a direct-reading pan balance or on a double-beam balance. For very small fish, such as anchovy, a random sample was used as the criterion of the whole lot. "Forktail" length measurements were taken for those species having well-defined forked tails, and "overall" length measurements were taken for those species having more-or-less blunt tails. The forktail measurement is from the tip of the mouth to the apex of the angle formed by the 2 sides of the tail. The overall measurement is from the tip of the mouth to the farthest end of the tail.

c. Proximate-composition analysis.—After the physical measurements were taken, the lot of fish was divided into 4 subsamples containing, if possible, not less than 4 fish each. Each subsample was ground 3 times in a food grinder having 3/16-inch plates and was placed in a glass container. The samples were then frozen and held at 0° F. until analyzed. This procedure afforded a spread of values for each species, giving an approximation of the variation to be expected at any given time of the year. The mean of the 4 samples prepared in this manner is equivalent to the mean obtained from a single large sample (Thompson, 1959c).

The methods of analysis used were those of the Association of Official Agricultural Chemists (1955) modified as follows:

1. Moisture: 20 grams of white sand was measured into aluminum dishes, replacing asbestos fiber in gooch crucibles.

2. Ash: Vycor[1] crucibles replaced platinum ones; moistening the ash with water and re-ashing was not necessary.

3. Protein: Selenium granules replaced HgO or metallic Hg as the catalyst; therefore, sulfide or thiosulfate solution was not needed to precipitate the Hg.

Samples were analyzed as single determinations; however, determinations seemingly questionable because of large variations from the mean were rerun to check the accuracy of the data. Thus, values reported that vary widely from the expected norm are averages of duplicate analyses.

2. Results

Variations in the environment, the fish, and the season are examined in the following discussion of the results:

a. Variations in the environment.—the following factors are considered: (1) geographical and annual variations, (2) water temperature, and (3) food.

(1) Geographical and annual variations.—Several authors (for example, Venkataraman and Chari,

[1] Trade names referred to in this publication do not imply endorsement of commercial products.

1951; Stansby, 1953; and Karrick, Clegg, and Stansby, 1956) have commented on the changes in composition for a given species caught at different localities at the same time and during different years in the same locality. In general, some authors have suggested that such variations are so great that comparisons are invalidated. It thus is necessary first to consider the possibility of variation in composition (a) from one end of the geographic area sampled to the other and (b) from year to year. Only then can the data gathered be evaluated in a valid manner.

Table 2 shows the average measurements and average proximate composition of various sample pairs taken from different localities at the same time of the year. A test of significance of the difference between the means applied to these sample pairs should show whether the means actually represent means from 2 different populations or 2 different means from the same population. There is no significant difference in the protein content of the various pairs. With the exception of the porgy sample, the ash content does not differ significantly in any of the sample pairs.

The same type of data but for pairs associated by dates of catch is shown in Table 3. These samples are paired to each other as representative of the same time if they were obtained within 7 days of each other, although 1 or more calendar years apart. 3 of the 25 pairs show significant differences between the means of the protein pairs as do 2 of the ash-content pairs. In a group of pairs of this size, this number of significant differences does not assume a large proportion. It can then be said that the protein and ash content of these species does not vary significantly from year to year. When a variation in time of more than 7 days between samples, whether in the same year or different years, has elapsed, there are significant differences between sample pairs. Perhaps this has contributed to the statements that such extreme variations exist that no prediction can be made from year to year, since samples have seldom been taken within such a short time-lapse in previous studies.

7 of the 13 geographic pairs show a significant difference in oil content, as do 5 of the moisture-content pairs (Table 2). 11 of the year pairs vary

Table 2.—Comparison of physical measurements and proximate composition of samples of industrial fish obtained from different parts of the sampling area

Species	Location[1] of catch	Date of catch	Average size		Protein content		Oil content		Ash content		Moisture content	
			Length	Weight	Average	D²	Average	D²	Average	D²	Average	D²
			Cm.	*Gram*	*Percent*		*Percent*		*Percent*		*Percent*	
Anchovy	18 9	2/15/59 2/15/60	11.1 11.9	11.5 16.9	18.9 18.7	None	3.8 4.6	None	3.27 2.61	None	74.2 74.3	None
Croaker	20 6	1/10/58 1/14/59	17.1 19.1	49.8 65.2	17.0 16.4	None	2.6 1.4	*	4.53 5.74	None	76.0 76.9	None
	7 9	4/7/59 4/12/60	18.9 18.1	65.6 64.4	15.9 16.4	None	1.6 3.2	*	6.41 5.42	None	76.3 74.9	*
	10 9	6/30/60 7/6/60	13.9 17.9	30.5 69.8	16.7 16.3	None	4.6 7.4	*	4.29 4.73	None	74.4 72.1	*
	7 6	8/19/59 8/19/59	15.2 15.3	36.5 36.9	17.5 17.4	None	4.3 2.6	*	4.58 5.18	None	74.5 75.4	None
	6 7	9/22/59 9/24/58	15.3 20.7	36.1 94.7	17.2 16.5	None	3.0 3.6	None	4.80 3.96	None	75.0 76.0	None
Croaker, banded	8 9	11/22/58 11/30/60	19.5 17.7	103.1 88.0	17.8 17.1	None	2.3 3.3	None	4.03 3.12	None	75.6 76.2	None
Hardhead	8 9	8/12/59 8/16/60	15.4 20.6	43.3 106.0	17.3 15.2	None	4.2 8.7	*	6.65 5.68	None	72.1 70.9	None
	7 15	10/7/60 10/13/59	15.6 12.9	52.5 31.1	15.2 14.7	None	7.5 5.0	*	5.26 4.05	None	72.0 75.9	*
Porgy	7 17	4/7/59 4/12/60	13.7 11.6	58.1 41.2	17.4 17.0	None	3.0 3.5	None	8.49 5.67	*	71.1 73.6	*
Silver eel	5 9	1/14/59 1/21/60	44.9 45.7	38.8 39.7	17.2 17.2	None	3.2 3.9	None	2.77 2.27	None	77.0 76.4	None
	12 9	4/6/59 4/12/60	45.3 43.5	43.4 43.2	17.0 15.9	None	3.1 4.9	*	2.62 2.00	None	77.2 76.7	None
Spot	7 9	2/16/60 2/16/60	13.3 17.7	31.9 72.8	15.9 16.2	None	4.3 2.2	None	3.55 3.87	None	76.0 78.5	*

[1] See Appendix A, Table 1A and Figure 1A, for numerical identification.
D = Significant difference: None = not significantly different.
* = significantly different at the 99.7-percent level.

significantly in oil content, and 7 in moisture content (Table 3). The number of pairs varying significantly from one another represents about 1/2 of the geographic pairs and 1/2 of the year pairs. Thus, there is no greater probability of significant differences' appearing in those samples differing in year of collection or in area of collection than there is of significant differences' not appearing. There are

Table 3.—Comparison of physical measurements and proximate composition of samples of industrial fish obtained during the same 7-day period in different calendar years

Species	Date of catch	Average size		Protein content		Oil content		Ash content		Moisture content	
		Length	Weight	Average	D[1]	Average	D[1]	Average	D[1]	Average	D[1]
		Cm.	*Gram*	*Percent*		*Percent*		*Percent*		*Percent*	
Anchovy	2/15/59 2/15/60	11.1 11.9	11.5 16.9	18.9 18.7	None	3.8 4.6	None	3.27 2.61	None	74.2 74.3	None
	6/9/58 6/10/60	10.8 13.0	12.3 15.0	17.2 17.7	None	2.6 2.2	None	3.29 2.97	None	77.3 77.3	None
Bumper	9/24/58 9/22/60	19.2 15.8	80.3 58.8	18.6 17.1	*	5.1 4.5	None	3.91 4.34	None	72.2 74.0	None
	10/19/59 10/12/60	7.1 12.0	5.4 23.4	17.8 17.7	None	3.7 3.3	None	4.31 4.19	None	75.3 74.8	None
Butterfish	10/13/59 10/12/60	13.1 12.9	59.9 51.4	17.2 17.2	None	4.7 1.3	*	2.55 2.96	None	75.7 78.1	*
	11/12/58 11/11/59	13.0 13.9	76.4 65.8	16.6 17.4	None	2.6 3.3	None	2.37 2.93	None	78.5 76.2	None
Croaker	1/10/58 1/14/59	17.1 19.1	49.8 65.2	17.0 16.4	None	2.6 1.4	*	4.53 5.74	None	76.0 76.9	None
	4/7/59 4/12/60	18.9 18.1	65.6 64.4	15.9 16.4	None	1.6 3.2	*	6.41 5.42	None	76.3 74.9	*
	9/24/58 9/22/59	20.7 15.3	94.7 36.1	16.5 17.2	None	3.6 3.0	None	3.96 4.80	None	76.0 75.0	None
	10/19/59 10/13/61	13.6 17.0	25.9 55.5	16.3 16.7	None	2.1 5.7	*	4.83 1.45	*	76.5 76.1	None
Hardhead	6/9/58 6/10/60	23.3 13.0	182.6 30.1	17.0 17.0	None	6.7 5.1	*	4.14 5.60	None	71.0 72.3	None
	8/12/59 8/16/60	15.4 20.6	43.3 106.0	17.3 15.2	None	4.2 8.7	*	6.65 5.68	None	72.1 70.9	None
	10/13/59 10/7/60	12.9 15.6	31.1 52.5	14.7 15.2	None	5.0 7.5	*	4.05 5.26	None	75.9 72.0	*
Harvestfish	7/20/58 7/20/60	14.8 14.1	111.2 142.2	16.4 17.2	None	7.5 7.5	None	2.31 2.30	None	73.0 73.5	None
	10/13/59 10/13/60	7.2 7.3	14.3 17.9	15.7 14.4	*	2.5 0.5	*	2.67 3.14	None	78.8 81.9	*
Porgy	4/7/59 4/12/60	13.7 11.6	58.1 41.2	17.4 17.0	None	3.0 3.5	None	8.49 5.67	*	71.1 73.6	*
	10/13/59 10/7/60	8.8 9.7	19.6 33.3	17.9 17.0	None	2.0 3.3	None	6.59 6.13	None	73.7 73.5	None
Razorbelly	5/14/59 5/12/60	11.2 11.3	25.0 31.1	19.4 19.0	None	4.7 10.3	*	4.31 3.42	None	72.7 67.3	*
Silver eel	1/14/59 1/21/60	44.9 45.7	38.8 39.7	17.2 17.2	None	3.2 3.9	None	2.77 2.27	None	77.0 76.4	None
	4/6/59 4/12/60	45.3 43.5	43.4 43.2	17.0 15.9	None	3.1 4.9	*	2.62 2.00	None	77.2 76.7	None
	9/24/58 9/22/60	67.4 30.1	179.5 15.1	17.8 17.6	None	2.7 2.2	None	3.51 2.30	None	76.4 78.6	*
	10/13/59 10/13/60	56.1 46.3	104.1 71.5	17.9 17.3	None	1.9 2.3	None	2.62 2.40	None	78.1 78.1	None
Spot	1/14/59 1/21/60	18.8 16.8	74.2 64.2	15.9 16.7	None	1.8 1.2	None	3.71 3.70	None	80.1 78.8	None
	10/13/59 10/13/60	15.3 15.8	57.5 65.3	16.8 15.2	*	3.8 7.9	*	4.17 3.59	None	75.0 72.9	None
White trout	10/21/58 10/19/59	22.4 18.6	120.0 60.5	17.7 16.7	None	6.2 6.5	None	2.93 2.25	None	73.1 74.4	None

[1] Significant difference: None = not significantly different
* = signifiantly different at the 99.7-percent level

9 matching geographic pairs (that is, 9 pairs altogether from the East, the East and the West, and the West) that do not differ significantly in oil or moisture content in different years and 3 East-and-West pairs that do not differ significantly. Of those pairs that do differ significantly in oil content in different years, 7 are matching geographic pairs, and 4 are not. Of those pairs that differ significantly in moisture content in different years, 4 are matching pairs, and 2 are not. Apparently then, one must look to other factors contributing heavily to variation in sample composition. Should this factor not be readily explainable in terms of environment, then it can be assumed that the variation does occur due to chance—indeed, that it is intrinsic to the study.

That there are variations in both oil and moisture content—with oil content having the greater degree of variation—is not surprising. As will be shown later, oil and moisture are strongly correlated in an inverse manner. Thus, if by some means the oil content of a sample is increased to a great degree, the moisture content will be decreased proportionately. These 2 factors can be changed without affecting the protein and ash content to any great degree, thus accounting for the relative constancy of the protein and ash factors throughout the sampling area.

In summary, ash and protein content seem to be little affected from year to year or by geographic influences within the area studied; however, oil and moisture content do vary in a random manner, indicating the influence of another factor or factors. Although these variations do exist, a thorough sampling of the species should provide data indicative of yearly trends and also data that are useful to study third-factor influences.

(2) Water temperature.—An examination of Figure 2 shows that the bottom temperature does not fluctuate throughout the year from the eastern end to the western end of the area studied. Surprisingly, depth up to 30 fathoms does not seem to play an extremely important part in the temperature variation. The scatter of temperatures at any 1 time is as great as any difference apparent between figures for any given range in depth. The general trend seems, however, to be toward warmer temperatures starting in June and continuing through November. Figures 2A through 17A reveal that 4 species have oil-content peaks during winter (December, January, and February), 7 during spring (March, April, and May), 3 during summer (June, July, and August), and 4 during fall (September, October, and November). The greater number of species tend to peak in the spring, a time when the bottom temperatures seem to change very little. Thus the temperature of the environment cannot be said to play a primary role in conditioning all of the species, although it may well "trigger" the event in combination with other factors.

(3) Food.—Another conditioning factor may be the quantity and type of food available to each species. The species associated with the industrial fishery are all inhabitants of the "littoral" zone about which Coker (1949) says:

> Richest in number of individual animals visible to the naked eye, and in diversity of kinds, is the littoral zone, which, as previously defined extends from the upper tide line to a depth of some 100-200 fathoms—or as far out as there is light enough at the bottom to permit the growth of benthonic plants. There are several reasons for the relative populousness of this region. The shallowness and the illumination of the bottom favor the growth of photosynthetic organisms, the "producers", from top to bottom. Mixing by waves and tides is here more active and complete. Better vertical circulation promotes turnover of the nutritive substances, bringing them back from the less well lighted bottom into the uppermost and better illuminated waters, where they are most effectively used. Drainage from land comes first into the littoral region.

That there is a great abundance of food for both the benthic and pelagic species of industrial fish in the Northern Gulf of Mexico seems to be a point all can agree on. Therefore, cyclical changes in oil and moisture, as well as paired differences, can hardly be due to lack of available food. That the type of food available may vary from the eastern end of the study zone to the western end is possible, although not extremely likely. The bottom conditions are the same throughout the region—sand, mud, or both. Other environmental factors—temperature, amount of light, etc.—are much the same. The whole region is one of excellent land drainage, there being a number of large river systems emptying into the Northern Gulf of Mexico. It is probable, therefore, that the same types of organisms are distributed throughout the study area, although not necessarily the same species. It seems unlikely then that types of available food have any great influence on the differences in paired oil and moisture content.

Thus, of the 6 possible contributory factors, only 1—the reproductive cycle—seems likely to influence difference between the means of oil and moisture content. The influence of the changes occurring in the population at the inception of the reproductive cycle is a difficult one to assess as being wholly the cause. The chance nature of the incidence of significant differences of the means of the paired values, as well as the lack of information about the reproductive-cycle periods of most of the species, makes it impossible to arrive at a final conclusion. For the purposes of this paper, however, one may conclude that (1) the populations have the same compositional characteristics within certain limits, (2) the significant increases in oil content will take place at about the same time from year to year, and (3) the study area can be treated as a geographic unit.

b. Variations in the fish.—The following factors are considered here: (1) size, (2) maturity, (3) sex, and (4) reproductive cycle.

(1) Size.—Taking only the variations in oil and moisture into account in Tables 2 and 3, we see that the size of the fish in the paired samples has little to do with significant differences in composition. Of those samples that do vary significantly, there are 3 pairs of the same size and 6 of different sizes listed in Table 2; and 6 and 8 of each, respectively, in Table 3. Of those samples that do not vary significantly, there is 1 pair of the same size and 3 of different sizes listed in Table 2, with 3 and 8 of each respectively enumerated in Table 3. A more graphic example may be had by comparing the sample pair of April croaker (average weight difference of 1.2 grams) with the sample pair of September croaker (the 1959 sample being about 1/3 the weight of the 1958 sample). The former pair differs significantly in oil and moisture content; whereas the latter pair does not differ significantly. A further comparison of the samples of January and April silver eel in the same table shows the variation present in the April oil content and not in the January, although in this case, the sample pairs are all of the same size. Apparently, size of the fish has little to do with the probability of variation in either oil or moisture content.

(2) Maturity.—Although no planned study was made on the influence of degree of maturity on proximate composition, several sample pairs that might indicate a trend, if any, can be found in Table 3. The sample of bumper obtained on October 19, 1959, is almost certainly juvenile, yet it does not differ significantly in composition from the adults caught on October 12, 1960. A similar instance is found in the samples of September croaker. On the other hand, the juvenile silver eels caught September 22, 1960, differ significantly in moisture content from the adults caught on September 24, 1958, although not in oil content. It thus is unlikely that degree of maturity—at least between juveniles and adults—greatly influences composition.

(3) Sex.—Table 4 shows the physical measurements and average proximate composition of croaker and spot that were sorted according to sex. With the exception of the October sample of spot, there are no significant differences between the sexed samples in either physical measurements or proximate composition. The October spot sample shows a significant difference in the oil and moisture content of

Table 4.—Comparison of weight, length, and proximate composition of male and female croaker and spot

Species	Date of catch	Fish analyzed		Length		Weight		Protein content		Oil content		Ash content		Moisture content	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
		No.	*No.*	*Cm.*	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Croaker	3/29/62	8	8	17.2	16.8	50.5	47.3	16.7	16.8	2.4	2.9	5.17	3.85	75.6	76.5
	4/19/62	8	8	18.5	18.3	69.7	67.4	17.3	17.1	2.9	2.8	4.54	4.76	75.5	75.4
	5/8/62	12	4	17.2	17.0	58.6	52.0	16.8	16.8	5.6	5.3	5.00	6.24	72.3	71.3
	5/29/62	8	8	19.2	19.7	83.5	95.7	17.7	17.2	3.3	3.5	4.63	3.66	74.4	75.4
	7/9/62	8	8	17.9	18.3	63.7	68.2	16.8	17.2	5.9	5.6	4.41	4.75	73.3	72.4
	9/7/62	12	4	18.5	18.1	74.5	71.1	16.9	17.0	6.1	6.0	3.50	3.77	74.0	72.7
	10/1/62	4	12	15.0	16.2	38.1	49.0	17.0	17.1	5.4	4.5	3.13	3.81	74.8	75.0
Spot	3/29/62	8	4	16.9	17.9	67.0	76.0	16.5	15.8	2.3	2.7	3.42	2.46	77.7	79.0
	4/19/62	12	4	17.3	17.2	75.1	70.3	17.0	16.8	5.4	4.4	3.94	3.34	73.6	74.9
	5/8/62	12	4	18.3	18.4	94.8	95.9	16.7	16.4	8.4	7.7	3.19	3.12	71.8	72.9
	5/29/62	12	3	18.2	17.9	92.3	88.7	16.8	16.9	7.9	8.1	2.50	3.31	72.8	70.8
	6/18/62	3	12	16.8	18.4	84.6	116.3	16.8	16.6	11.4	12.7	2.67	2.12	69.1	68.4
	7/9/62	8	8	19.1	19.1	104.2	112.5	17.0	16.7	10.5	12.4	2.74	3.02	70.2	67.9
	9/7/62	8	8	16.8	16.8	82.3	86.9	16.7	16.5	9.0	10.1	2.86	2.72	71.6	71.2
	10/1/62	8	8	15.2	15.8	53.5	68.3	17.2	16.8	3.2	8.3	1.62	1.63	78.1	73.9

the male and female specimens, the males being significantly lower in oil content and higher in moisture content. The sampling period extends through the period of high and variable oil content for both species (Tables 5A and 14A, Figures 5A and 14A) and thus should show significant variations if such were present. Instead, there is only 1 significantly different pair—as might be expected if such variation in pairs were due to chance.

(4) Reproductive cycle.—The possibility arises that the observed variations in pairs might occur during a particular portion of the reproductive cycles of these species. Unfortunately, the periodicity of the reproductive cycles of the various industrial fish in the Gulf of Mexico has not been studied extensively. Since data are available for only 3 of the major species—croaker, spot, and white trout—this discussion is limited to these species. According to Roithmayr (1964), the period of spawning for croaker begins in September and continues through November. Roithmayr (1961) also states that the period of spawning of white trout begins in August and lasts through October. Spot start to spawn in December and continue through March (Pearson, 1928). Figures 5A, 14A, and 17A, together with the dated pairs, show that the paired oil and moisture values that are significantly different occur for the most part on the portion of the curve where the oil content is changing the most rapidly with time. Whether the difference is due to an actual difference in population during 1 year, or from year to year, or whether it is due to sampling difficulties within the total population is a difficult question to answer. As was previously pointed out, samples of male and female croaker and spot caught in the same trawl did not vary significantly in oil and moisture content even during the period of high oil content. This lack of correlation would seem to rule out sex differences in a single population. The absence of differences during other parts of the year tends to eliminate year-to-year variations per se as a cause of variations in oil and moisture content. Thus, year-to-year time-sequence variations come to the fore as an explanation of the observed variations. The portion of the curve most greatly affected by year-to-year time-sequence variation of environmental conditions and their influence upon compositional changes would be that portion of rapid change from low oil content (or high moisture content) to high oil content (or low moisture content). If the high oil content and low moisture content are connected with the reproductive cycle in some manner, then there should be some variability from year to year even within a small time lapse, since the inception of the reproductive cycle is in itself influenced by a variety of environmental conditions. The exact combination of conditions, such as food, temperature, hours of light, etc., could not always be expected to occur at a given point in calendar time. This in itself should be a chance situation, as the data indicate.

c. Variations in the season.—It is accepted in this area that the seasons may be classified as follows: the winter months are December, January, and February; spring—March, April, and May; summer—June, July, and August; and fall—September, October, and November. In the discussion that follows, this general division will be followed. Tables 2A-18A in the appendix list the date of catch, location of catch, number of fish analyzed, and the range and average values of the length, weight, protein, oil, ash, and moisture content of the various species analyzed.

(1) Relation of composition to season.—That there is a variation in the proximate composition of each species during the year is evident. The protein content of each species varies throughout the year, but in most cases remains within the species average ± 2.0 percent (Table 5). The exceptions to this are harvestfish, spot, star drum, and thread herring. In these species, the protein content varies as much within species as it does between species—the average variation being ± 3.4 percent. This change in protein content appears not to be connected with differences in the weight or length of the samples except as would be expected in connection with the general growth of the animal. It may or may not be related to the reproductive cycle; this relation will be discussed in a later section.

In general, the median protein content of the species falls into the high-protein classification of Stansby (1963) throughout most of the year. The exception to this rule is the bottom-trawl-caught menhaden, for which the protein content varies from an average of 13.6 percent in April to 16.4 percent in November, with a median value of 14.7 percent. Thus, the protein content of these species can be expected to range between 15 and 20 percent throughout the year. Further, regardless of the species composition of the catch, menhaden can be expected to be high in protein.

The ash content of these species varies throughout the year in the individual species, although not necessarily in direct relation to variation in weight and length. The ash content varies among the species, of course, in relation to the skeletal structure of the fish. Since the entire fish was ground, a species such as hardhead or croaker with a heavy frame would show a considerably higher ash content than would a fine-boned species such as the harvestfish or the butterfish. The heavy contribution of the frame to the total ash content makes comparisons of the variation in species extremely difficult.

Table 5.—Seasonal range and overall change in protein and oil content of industrial fish together with medium protein and oil values

Species	Oil content				Protein content			
	Low	High	Change	Median	Low	High	Change	Median
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Anchovy	1.2	4.7	3.5	2.3	16.1	19.3	3.2	17.4
Bumper	1.3	13.2	11.9	4.1	16.1	19.5	3.4	18.2
Butterfish	0.9	14.8	13.9	2.7	15.1	18.6	3.5	16.5
Croaker	1.0	10.0	9.0	2.9	14.1	17.8	3.7	16.6
Croaker, banded	1.5	9.4	8.9	3.7	16.5	18.7	2.2	17.7
Hardhead	2.5	10.7	8.2	5.8	14.2	17.6	3.4	16.3
Harvestfish	0.5	9.1	8.6	5.0	14.1	18.5	4.4	16.3
Menhaden	1.9	20.5	18.6	13.3	13.4	17.2	3.8	14.7
Pigfish	2.1	11.0	8.9	4.5	14.8	18.4	3.6	16.8
Porgy	1.3	4.9	3.0	2.3	15.8	18.9	3.1	17.6
Razorbelly	1.7	12.2	10.5	6.2	17.0	19.9	2.9	18.6
Silver eel	1.7	8.7	7.0	3.4	15.3	19.1	3.8	17.5
Silver perch	1.5	6.4	4.9	3.7	15.9	18.3	2.4	16.8
Spot	0.9	16.7	15.8	4.7	12.7	17.9	5.2	16.3
Star drum	1.5	5.0	3.5	3.8	13.9	18.2	4.3	15.8
Threadfin	1.2	11.4	10.2	4.1	16.9	19.2	2.3	18.1
Thread herring	2.6	21.0	18.4	5.1	14.1	20.8	6.7	18.5
White trout	1.6	7.8	6.2	4.7	15.4	18.7	3.3	17.1

The oil and moisture content of these species exhibits the greatest variation throughout the year. As is often the case, the contents of oil and moisture bear an inverse relation to each other. Figures 2A-17A show the change in oil and moisture content throughout the year for the species studied. In general, the species show an extremely high oil content during 1 period of the year, with 1 or more secondary highs. The change in oil content of some of the species is quite remarkable. Within a few weeks, the oil content may increase 10 percent or more; for example, the oil content of the thread herring *(Opisthonema oglinum)* rose from an average of 4.3 percent on September 22, 1959, to 15.6 percent on October 19, 1959. In other species, the change is not nearly so great nor does it occur in such a short time. As indicated in Table 5, all species reach a yearly low in oil content of 2.6 percent or less. This apparently represents a spent state indicative of poor condition, since an examination of Tables 2A-18A indicates that the low level of oil is not necessarily connected with the size or maturity of the fish or with any of the other probable factors. The possibility arises that low oil content might be connected with scarcity of food or with poorness in oil content of the food itself. If such is the case, then members of the same family with similar eating habits and mode of life should exhibit low oil content at similar times. This is far from the case, however, as members of the family *Sciaenidae*—a family that includes the most abundant species—do not exhibit seasonal similarities in either low or high oil content. Periods of low oil content of these species are as follows: croaker, January 14; spot, January 21; white trout, May 14; silver perch, June 20; star drum, August 16; and banded croaker, November 22. Periods of high oil content of these species are as follows: star drum, March 18; banded croaker, April 12; spot, May 30; croaker, June 9; silver perch, October 13; and white trout, December 9. This seems to leave little doubt that variations in oil content can be attributed more directly to the physiological changes in the fish themselves than to availability or type of food or to both availability and type.

If it is assumed that a low content of oil represents the basic nature of the species and that any increase in oil content is a function best ascribed to physiological necessity, then it appears that the species can be assigned to 2 distinct groups—those with a yearly variation in oil content of less than 10 percent and those with a yearly variation of greater than 10 percent. In the former group, those with a variation of less than 10 percent are anchovy, croaker, banded croaker, hardhead, harvestfish, pigfish, porgy, silver eel, silver perch, star drum, and white trout. In the latter group, those with a variation of greater than 10 percent are bumper, butterfish, menhaden, razorbelly, spot, threadfin, and thread herring. It is interesting to note that in the group having greater than 10 percent variation, the only bottom species is spot. The remainder of the species in this group are pelagic and, as such, can be expected to be extremely active and perhaps to require greater reserves of oil.

A glance at the median oil contents shown in Table 5 indicates that by far the greater majority of the species fall in Stansby's (1963) Category A (oil content of less than 5 percent). 4 species—hardhead, menhaden, razorbelly, and thread herring—fall into Category B (oil content of 5 to 15 percent). The median value is used here for classification, since the individual species vary so greatly in oil content that it is possible for most of them to fall into any of the classifications at some time during the year. The median represents the category by which they may be classified most of the time.

There appears to be no particular time of the year during which most of the fish have a high oil content, nor does high oil content seem to be related to family groupings. In the winter, a high oil content is reached by anchovy, harvestfish, silver eel, and white trout; in the spring, by bumper, butterfish, banded croaker, porgy, razorbelly, spot, and star drum; in the summer, by croaker, menhaden, and porgy; and in the fall, by hardhead, silver perch, threadfin, and thread herring. If specific-catch fishing methods could be found, it would be possible to fish year-round for species of high oil content in the Gulf of Mexico, and the fish-oil industry would not need to be based upon menhaden alone.

The oil-moisture curves of the species are similar in that, although peaks are not found at the same time, only 1 high rise occurs in oil content, and it is of relatively short duration (4 to 8 weeks). Menhaden and thread herring, however, experience a rapid rise in oil content to a high level that lasts for 14 weeks in the case of thread herring and 30 weeks in the case of menhaden. 4 of the species studied—bumper, harvestfish, razorbelly, and silver eel—appear to have secondary periods of high oil content where the oil content rises to a height almost equal to that of the primary peak of high oil content. A discussion of the moisture curves of the various species may be avoided, since the oil-moisture relation of these species is highly correlated in a negative manner, and the same observations hold true except in reverse.

(2) Relation of composition to reproductive cycle.—Periods of high oil content may be related to the reproductive cycle of the species. The following discussion is based upon members of the family *Sciaenidae* (croaker, spot, and white trout), since estimates of periods of ripening and spawning are not available for the other species in the Northern Gulf of Mexico.

(a) Croaker.—Roithmayr (1964) states: "Previous studies of croaker east of the Delta since 1961 showed that quantities of ripe fish were present from 3 to 7 fathoms in the Gulf from September through November. Assuming this to be the principal spawning . . . ." Pearson (1928) studied fish along the Texas Coast and extended the spawning period through December. Figure 3 shows the proximate composition of the croaker throughout the year in relation to the spawning period. Also plotted are the average weights of the samples collected. All of the samples weighed over 15 grams—a division that Roithmayr makes between young virgin fish and those older and capable of reproduction. There appears to be no relation between weight and seasonal change in proximate composition, as there is a tendency for the average weights of the samples to scatter about a straight line at about the 60-gram level. A slight decrease in ash content occurs in the latter part of July and again in October. Whether this decrease can be related to the spawning condition is doubtful, since, as previously mentioned, the contribution of the frame to the ash content is so great that small deviations due to change in physiological function are likely to be obscured. The protein content of the croaker seems relatively unchanged throughout the year despite intense activity during spawning migration. This is contrary to findings (Stansby, 1962) elsewhere that protein content generally decreases during intensely active periods. The oil content of the croaker increases to a high (and consequently the moisture content decreases to a low) 3 months prior to the beginning of spawning. After this height is reached, the oil content gradually drops off until, at the beginning of the spawning period, it is at nearly the same level as it is after spawning ends. In this case, it would appear that oil reserves are built up during the gonad-ripening period. As shown in Table 4, no significant differences in oil content between male and female croakers occur; therefore, this rise in oil content can be considered as being common to this period in both sexes.

(b) Spot.—According to Pearson (1928), the spawning period of spot extends from December through March. The variation in proximate composition and weight of samples obtained throughout the year of the spot are shown in Figure 4. Once again, the samples appear to be those of adult second-year fish, the scatter of weights forming around the 70-gram level. Relatively little, if any, change occurs in ash content throughout the year. The protein content varies to a greater extent than does that of the croaker; however, it does not tend to decrease markedly, if at all, during the spawning period. The period of high oil content (and low moisture content) occurs in June and July—a full 5 to 6 months prior to spawning. It is unlikely that this represents the gonad-development time of this species. As with the croaker, there is no significant difference in composition between male and female spot during this period. The explanation for the extremely high oil content during the period thus remains in doubt.

(c) White trout.—Roithmayr (1961) reported that the spawning period of white trout is August, September, and October. Although the weights of the individual samples of white trout indicate that these fish were all adults, the larger white trout appear to be more abundant in the catch from May through October (Figure 5). The ash content appears to increase from February through May. This increase, however, is most likely due to smaller fish being in the samples obtained during this period and the consequent greater contribution of the frame to the whole of the sample. Again, there appears to be no great difference in protein content throughout the year. The oil content begins to rise in June and continues to rise during the spawning months, reaching a high in December—2 months after the end of the recognized spawning period. The peak in oil content is reached as the average sample weight decreases. As with spot, it is not possible to relate the high oil content with the gonad-development time. At the same time, however, it is also not possible to relate a decrease in oil content to periods of high activity in the white trout, since a general increase occurs during the spawning season.

In summation, in the 3 species for which accurate spawning seasons are known, high oil content appears to be related (1) to the gonad-development period (croaker), (2) to no particular reproductive period (spot), and (3) to the spawning season (white trout). Obviously, it is impossible to make a generalized statement regarding the relation of period of high oil content to the reproductive cycle of these fish. Indeed, it is quite probable that there is no general relation, or at least no direct one.

B. PREDICTABILITY

In this second subsection, the predictability of compositional factors is discussed, and a method for the prediction of the oil content of a mixed lot is presented.

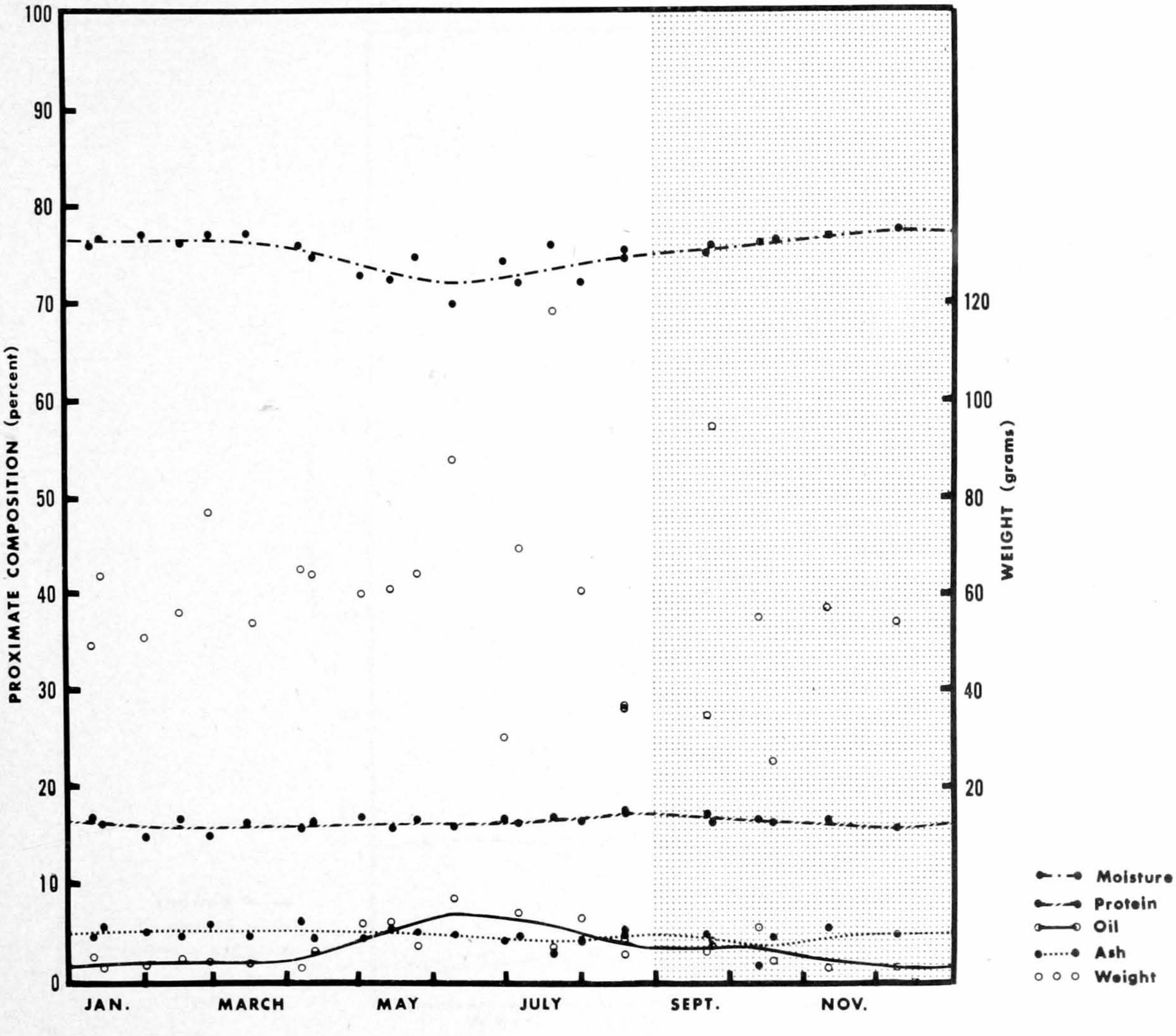

Figure 3.—Variation in weight and proximate composition in relation to the reproductive cycle of the croaker.

1. Intercorrelation of Variables

The possibility of relations among the various constituents of these species and with their physical measurements prompted a study of the intercorrelation of the 6 factors—protein, oil, ash, moisture, weight, and length—of each of the species. The values for the standard error of the estimating equation (S_{YX}), the correlation coefficient (r), and the probability level (P) using the Student t as a measure of correlation are to be found in Tables 19A, 20A, and 21A in the appendix. The probability level is included only if the correlation is statistically significant at the 95-percent level or higher. A summary of these statistically significant correlations is shown in Table 6. The minus sign is used if the correlation is negative—that is, if 1 constituent increases as the other decreases. The plus sign is used to indicate a correlation that is positive—that is, both constituents increase or decrease in a like manner.

A study of Table 6 reveals several interesting facts. There is a high degree of negative correlation between the oil and moisture content of all the species studied. A similar pattern of negative correlation exists between the ash and oil content; however, it is not as closely related linearly as is the moisture content, since S_{YX} is much higher in most cases. Thus, as the content of oil increases, oil apparently displaces water as a fluid constituent. Further, presumably because mineral constituents are not soluble in oil to any great degree, it also causes an apparent

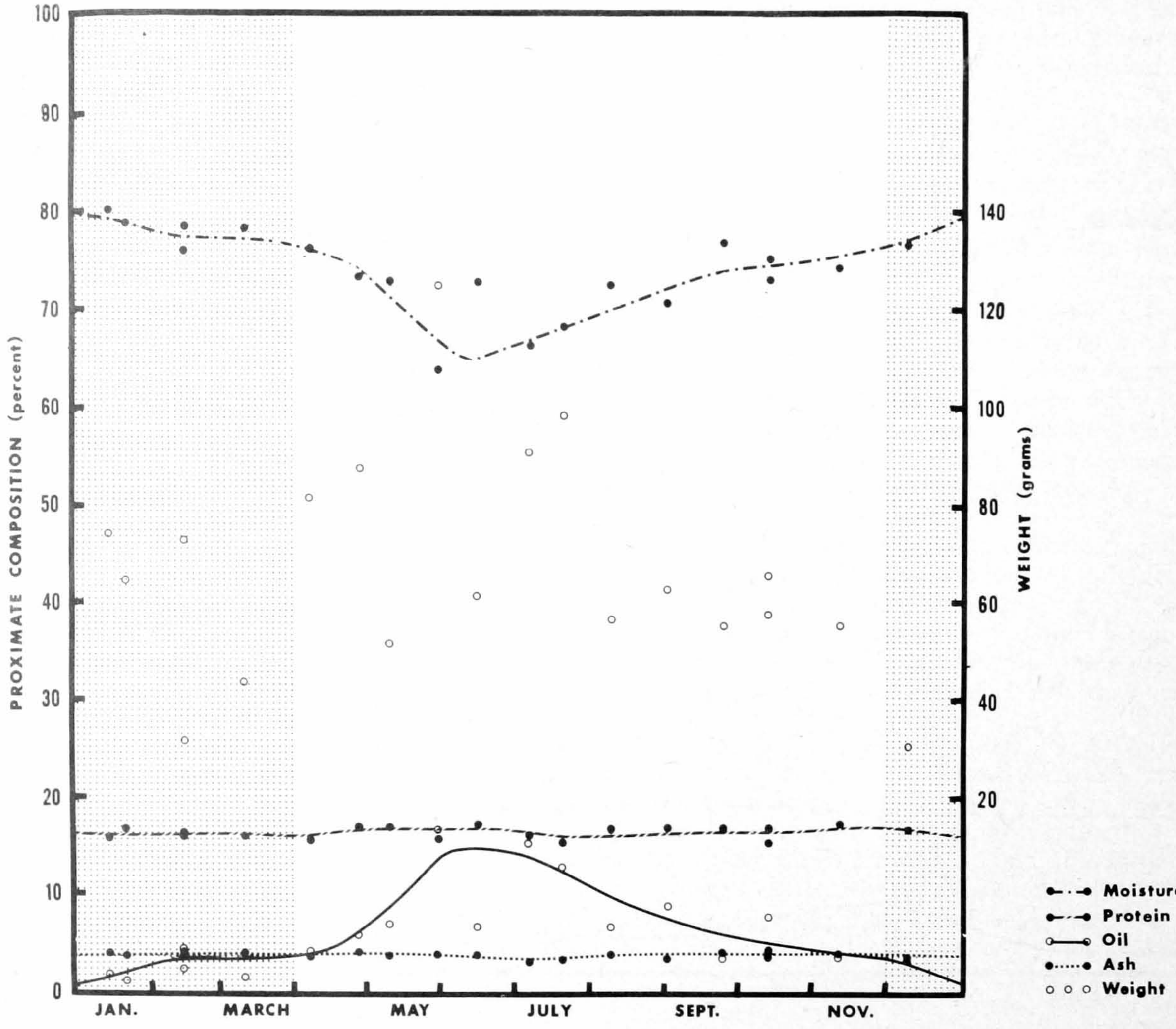

Figure 4.—Variation in weight and proximate composition in relation to the reproductive cycle of the spot.

decrease in ash content. With the exception of those fish of Group 1, moisture is negatively correlated with protein—indicating that, with increasing protein content, the tissues become less fluid. Also showing is the obvious positive correlation between length and weight.

The species studied have been divided into 3 general groups according to the pattern of correlation among the proximate composition factors. It proved impossible to group the species if length and weight were included. Group 1 includes menhaden, razorbelly, and thread herring. These species are the species with the consistently highest oil content of those studied. This group is characterized as follows: as the oil content increases, the moisture content decreases, the protein content decreases, and the ash content decreases. Group 2 contains anchovy, butterfish, harvestfish, silver eel, and silver perch and is characterized as follows: as the oil content increases, the moisture content decreases, the protein content increases, and the ash content decreases. Group 3 contains bumper, croaker, banded croaker, hardhead, pigfish, porgy, spot, star drum, threadfin, and white trout and is characterized as follows: as the oil content increases, the moisture content decreases, and the protein and ash contents vary, depending upon the variable with which they are associated.

The pelagic fish, with the exception of bumper, fall into either Group 1 or Group 2. The benthic

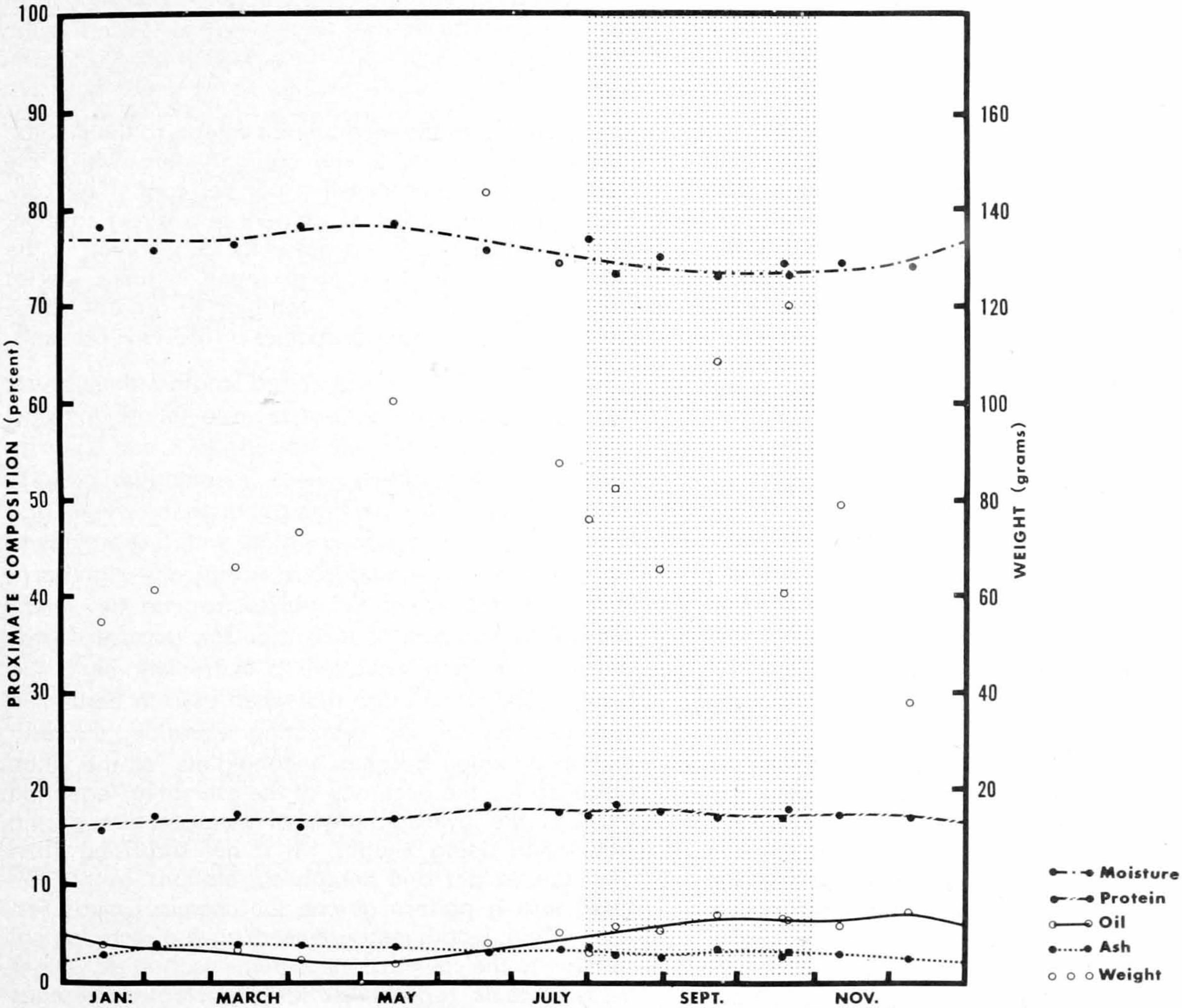

Figure 5.—Variation in weight and proximate composition in relation to the reproductive cycle of the white trout.

Table 6.—Intercorrelations (95-percent level or above) for the characteristics of industrial fish, together with possible group classifications

Groups	M O	M P	M A	P O	P A	A O	M W	M L	P W	P L	A W	A L	O W	O L	W L	Habit	Activity	Median content of: Oil	Median content of: Protein	Category
																		Percent	*Percent*	
Group 1																				
Menhaden	−	+		−			−	−		+	−	−	+	+	+	Pelagic	***	13.3	14.7	B
Razorbelly	−						−						+	+	+	Pelagic	***	6.2	18.6	B
Thread herring	−	+		−	+	−	+	+	+	+	+	+	−	−	+	Pelagic	****	5.1	18.5	B
Group 2																				
Anchovy	−	−	+	+	−	−	−				−		+		+	Pelagic	**	2.3	17.4	A
Butterfish	−	−	+			−	−		+	+	−				+	Pelagic	****	2.7	16.5	A
Harvestfish	−	−	+	+		−					−				+	Pelagic	***	5.0	16.3	A
Silver eel	−	−		+			+		+					−		Benthic	**	3.4	16.8	A
Silver perch	−	−		+			+	+	−	−		+	−	−	+	Benthic	**	3.7	17.5	A
Group 3																				
Bumper	−	−			+	−	−	−	+	+			+	+	+	Pelagic	****	4.1	18.2	A
Croaker	−	−				−			−							Benthic	**	2.9	16.6	A
Croaker, banded	−					−									+	Benthic	**	3.7	17.7	A
Hardhead	−	−	−	−	+	−	−	−	+	+			+			Benthic	**	5.8	16.3	B
Pigfish	−	−			+				−	+	−	−		+	+	Benthic	**	4.5	16.8	A
Porgy	−	−	−				−	−		−	+	+	+		+	Benthic	***	2.3	17.6	A
Spot	−					−	−	−	−	−			+	+	+	Benthic	**	4.7	16.3	A
Star drum	−	−												−	+	Benthic	**	3.8	15.8	A
Threadfin	−						−	−				+	+	+	+	Benthic	*	4.1	18.1	A
White trout	−	−				−			+					−	+	Benthic	***	4.7	17.1	A

Key: M — moisture
O — oil
P — protein
A — ash
W — weight
L — length

\+ — positive correlation
− — negative correlation
* — activity (* = inactive to **** = very active)

species fall into Group 2 or Group 3. The species are classified according to Stansby's classification into Category A, high protein (15 to 20 percent), low oil (less than 5 percent); Category B, high protein (15 to 20 percent), medium oil content (5 to 15 percent); and Category C, low protein (less than 15 percent), high oil content (over 15 percent). The median values are used because of the seasonal variation and its ability to influence an average. With the exception of hardhead, all Category B fish fall in Group 1; and Category A fish in Group 2 and Group 3. Several generalizations might be made as follows: a species of general low oil content that is pelagic might best be placed in Group 2, where oil and protein increase proportionately in the same direction; a species with a low oil content that is benthic might best be placed in Group 3, where protein and oil are inversely proportional and not related to moisture and ash in a consistent fashion; and if a species has a medium or high oil content and is pelagic, it will likely fall in Group 1, where oil and protein are inversely proportional and are related to moisture and ash in a consistent fashion.

The activity[2] of a species, indicated by a graduation of * as inactive to **** as being the most active, is apparently not directly related either to the group classification, to the median oil content, to the median protein content, or to the category into which the species fall. Thus activity, per se, cannot be connected with a species' oil content in a direct fashion. In all probability, this is not a factor involved in the great increase in oil content found in some species nor is it involved in an explanation of the difference in levels of oil content of species of like environments.

The correlations of weight and length with moisture, oil, protein, and ash do not seem to follow any particular pattern within the groups, nor can they be arranged into another more meaningful pattern. Tables 19A to 21A show that, although the weight and length measurements do correlate with the proximate composition components at a statistically significant level, the scatter of the values around the linear estimating equation is such that the standard error of the estimating equation is extremely high. In general, S_{YX} is so large that when used to determine the accuracy of the estimating equation, the estimating equation becomes meaningless, as the value obtained for the accuracy of the estimating equation exceeds the average physical measurement of the population being sought. It is not surprising then that the weight and length correlations cannot be fitted into a pattern as can the chemical measures. As a whole, length measurements have a more logical relation to the chemical measurements than do weight measurements, suggesting that physiological changes may be more closely related to overall age rather than to the physical condition revealed by weight.

[2] Activity denotes known behavior of the species primarily diagnosed through depth recordings and trawl-behavior studies by members of the Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base at Pascagoula, Mississippi.

2. Estimating Equation

As previously mentioned, the oil and moisture contents of these species are negatively correlated to an extremely high degree. The probability of the correlation's being significant is 0.001 in all cases. The S_{YX} of the moisture and oil correlation equations in each case shows that it is possible to predict the oil content, when the moisture content is known, with considerable accuracy.

The value obtained when S_{YX} is doubled indicates the degree of deviation from the mean that can be expected of 95 percent of the predicted values. In the 18 species studied, the accuracy of prediction ranges from an average of $\pm$ 0.5 percent for anchovy to an average of $\pm$ 3.9 percent for thread herring.

The estimating equation for each of the species reveals a remarkable similarity among them. Thus, the possibility of developing a single estimating equation for determining the oil content of mixed lots was good. To this end, the oil and moisture values for 16 of the species studied were correlated without regard to species. (The data for silver perch and star drum were not used in this correlation, as these 2 species failed to appear a significant number of times in the catch.) The estimating equation of the entire lot was found to be $Y = 65.3 - 0.8X$, where Y equals the unknown oil content and X equals the known moisture content. The standard error of this estimating equation, developed without regard to species, is $\pm$ 0.3 percent. Thus, with known moisture content, it should be possible to predict the oil content 95 percent of the time within $\pm$ 0.6 percent. An equation such as this could be very valuable in estimating the oil content of various catches of undetermined species composition.

Toward this end, a number of samples that had been mixed and ground and that were of unknown species composition were obtained from a local pet-food concern over a period of 4 years. The oil and moisture analysis of these samples is shown in Table 7, together with the oil content as predicted through the use of the estimating equation. The deviations of the predicted value from the analyzed value are also shown. The predicted oil content is close to the analyzed oil content throughout the period that samples were collected. The S_{YX} of the estimating equation indicates that the deviation of the predicted values from the observed values should not exceed 1.2 percent ($\pm$ 0.6 percent from the average of the 2) more than 5 percent of the time. A slightly larger percentage of error is found —in the neighborhood of 15 percent of the values exceeding the expected 1.2 percent deviation. This larger incidence of error may be due to particular catches being heavily loaded in favor of 1 of the species for which the estimating equation does not closely resemble the aggregate estimating equation. Nevertheless, the equation can predict oil values accurately enough to be of great use to industrial concerns lacking laboratory facilities at the site of operation. The largest deviation from the known oil content is a negative deviation of 3.0 percent. The average deviation is -0.1 percent, the median deviation being 0.0 percent.

SUMMARY

17 species of industrial fish common to the inshore waters of the Gulf of Mexico were measured, and their proximate composition was analyzed on a monthly basis over several years. A number of other species present in the area were analyzed on a less frequent basis. The fishery is well defined, having an eastern boundary near Cape St. George, Florida, and a western boundary at Vermillion Bay, Louisiana, and never extending beyond the 30-fathom curve. The temperature of the water does not vary appreciably in pattern or actual warmth from east to west or from inshore to the 30-fathom curve. Bottom conditions—that is, substrate composition and available food—do not vary appreciably.

The data gathered over a 3-year period were statistically analyzed, with the following results:

1. No significant differences were found in protein and ash content for individual species samples either (1) from 1 end of the geographical area to the other or (2) from year to year.

2. No greater probability exists that the oil and moisture content of individual species samples will vary than that the content will not vary when considered on the basis of (1) geographical variation or (2) yearly variation. Thus, another factor or factors are probably the cause of the variations that do exist.

3. The environmental variations of water temperature and available food were considered as possible influences on sample variation and were ruled out because of their singular lack of variation in the area.

4. Variations in the fish, such as (1) size, (2) maturity, (3) sex, and (4) reproductive cycle of individual species, were considered as possible influences on compositional variation of samples. Once again, the data eliminated any definite

Table 7.—Known oil and moisture contents of mixed-species samples, together with oil content predicted from the estimating equation $Y = 65.3 - 0.8X$

Sample	Date	Moisture content	Experimental oil content	Calculated oil content	Error in estimation
Number		*Percent*	*Percent*	*Percent*	*Percent*
1	4/24/58	78.2	4.8	2.7	−2.1
2	4/24/58	77.7	4.5	3.1	−1.4
3	4/25/58	75.1	5.2	5.2	0.0
4	4/28/58	67.7	14.1	11.1	−3.0
5	5/6/58	75.9	4.6	4.6	0.0
6	5/18/58	79.1	3.4	2.0	−1.4
7	5/27/58	73.4	6.5	6.6	+0.1
8	6/17/58	78.5	3.7	2.5	−1.2
9	7/7/58	75.7	5.2	4.7	−0.5
10	7/15/58	78.2	2.2	2.7	+0.5
11	7/23/58	75.8	4.4	4.7	+0.3
12	7/31/58	75.9	4.4	4.6	+0.2
13	7/31/58	78.3	4.2	2.7	−1.5
14	8/14/58	75.7	4.0	4.7	+0.7
15	8/20/58	72.8	8.5	7.1	−1.4
16	9/3/58	78.1	3.5	2.8	−0.7
17	9/10/58	79.3	2.6	1.9	−0.7
18	9/22/58	77.9	3.5	3.0	−0.5
19	10/6/58	77.2	3.5	3.5	0.0
20	10/14/58	76.7	4.3	3.9	−0.4
21	10/22/58	76.5	2.4	4.1	+1.7
22	10/29/58	77.7	3.5	3.1	−0.4
23	11/3/58	78.2	2.4	2.7	+0.3
24	11/18/58	78.0	2.3	2.9	+0.6
25	11/22/58	78.9	2.3	2.2	−0.1
26	12/1/59	73.5	7.0	6.5	−0.5
27	12/21/59	77.1	2.8	3.6	+0.8
28	1/15/60	75.4	2.8	5.0	+2.2
29	1/22/60	79.4	2.0	1.8	−0.2
30	2/29/60	76.5	3.0	4.1	+1.1
31	3/7/60	77.3	1.9	3.5	+1.6
32	3/28/60	77.1	2.9	3.6	+0.7

Sample	Date	Moisture content	Experimental oil content	Calculated oil content	Error in estimation
Number		*Percent*	*Percent*	*Percent*	*Percent*
33	4/6/60	78.0	3.1	2.9	−0.2
34	4/8/60	76.9	4.4	3.8	−0.6
35	4/18/60	77.0	4.0	3.7	−0.3
36	4/22/60	70.9	8.1	8.6	+0.5
37	4/29/60	74.1	4.6	6.0	+1.4
38	5/6/60	77.3	4.0	3.5	−0.5
39	5/13/60	78.1	3.7	2.8	−0.9
40	6/3/60	74.6	5.6	5.6	0.0
41	6/17/60	76.9	4.5	3.8	−0.7
42	6/27/60	77.2	3.0	3.5	+0.5
43	7/1/60	80.0	1.9	1.3	−0.6
44	7/15/60	77.8	3.6	3.1	−0.5
45	7/22/60	76.9	3.4	3.8	+0.4
46	8/1/60	77.4	4.4	3.4	−1.0
47	9/30/60	77.1	3.2	3.6	+0.4
48	10/14/60	77.5	4.1	3.3	−0.8
49	11/11/60	78.5	3.1	2.5	−0.6
50	11/18/60	77.0	3.6	3.7	+0.1
51	11/25/60	78.9	2.0	2.2	+0.2
52	12/2/60	78.5	2.3	2.5	+0.2
53	12/9/60	78.2	1.9	2.7	+0.8
54	12/9/60	78.2	2.3	2.7	+0.4
55	12/16/60	79.0	1.6	2.1	+0.5
56	12/23/60	77.4	3.0	3.4	+0.4
57	12/30/60	78.8	1.6	2.3	+0.7
58	1/6/61	78.7	2.2	2.3	+0.1
59	1/13/61	76.7	2.9	3.9	+1.0
60	1/20/61	79.2	1.0	1.9	+0.9
61	1/27/61	79.1	2.4	2.0	−0.4
62	2/3/61	79.1	2.8	2.0	−0.8
63	2/10/61	79.3	2.3	1.9	−0.4
64	2/17/61	79.8	2.6	1.5	−1.1

relation of sample variation to any of these factors.

5. Time-sequence variations in an exact combination of factors, such as food, temperature, hours of light, and other factors of a chance nature, were indicated as causing variations in samples of individual species.

6. The variations of individual species composition throughout a year's period were examined. For the most part, protein and ash did not vary significantly during the year. The oil and moisture contents displayed a strong inverse relation to each other.

7. Family relationships, similar eating habits, and a similar mode of life apparently did not influence the seasonal pattern of the oil and moisture contents. However, most of the benthic species studied had a yearly variation in oil content of less than 10 percent. The pelagic species, for the most part, had a yearly variation in oil content of greater than 10 percent.

8. The possible relation of seasonal variations to the influence of the reproductive cycle for 3 members of family *Sciaenidae*—croaker, spot, and white trout—was examined. Explanation of seasonal variation by this means is apparently not satisfactory.

9. The species studied may be divided into 3 groups on the basis of correlation among the various composition factors. Group 1 contains species that may be characterized as follows: as the oil content increases, the moisture decreases, the protein decreases, and the ash decreases; Group 2, as follows: as the oil content increases, the moisture decreases, the protein increases, and the ash decreases; and Group 3, as follows: as the oil content increases, the moisture decreases, and the protein and ash are variable. The groups are discussed in terms of type of environment, the category of Stansby's in which the species belong, and the activity of the species.

10. An equation for the estimation of the oil content of a sample of fish of unknown species composition from a measured moisture content was evaluated. The equation, $Y = 65.3 - 0.8X$, could be used to predict oil content with an accuracy of $\pm$ 0.6 percent.

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APPENDIX

Table 1A.—Code number and area from which samples were taken

Code	Description
1	Bayou LaFourche
2	Belle Pass
3	Breton Island
4	Cape St. George
5	Cat Island
6	Chandeleur Island
7	Dauphin Island
8	East Gulf
9	Grand Isle
10	Horn Island
11	North Pass
12	Pascagoula River
13	Sand Island
14	Sanibel Island
15	Ship Island
16	Ship Shoal
17	South Pass
18	Southeast Gulf
19	Southwest Gulf
20	Timbolier Island

Table 2A.—Length, weight, and proximate composition—anchovy *(Anchoa hepsetus)*

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/15/59	11	56	8.9-12.6	11.0	7.8-16.2	11.9	16.4-16.8	16.7	1.2-1.7	1.6	3.80-4.41	4.06	77.7-78.2	78.0
2/15/59	18	40	10.4-12.6	11.1	8.6-13.6	11.5	18.7-19.3	18.9	3.6-4.0	3.8	3.00-3.49	3.27	74.0-74.3	74.2
2/15/60	9	32	10.4-12.6	11.9	10.2-22.0	16.9	18.5-18.8	18.7	4.4-4.8	4.6	2.46-3.15	2.61	73.3-74.8	74.3
2/28/58	10	49	10.9-12.9	11.7	13.3-25.1	19.0	16.3-17.9	17.3	2.5-2.8	2.6	3.44-3.76	3.53	75.3-76.3	75.7
3/17/59	10	80	9.3-11.2	10.1	8.2-14.5	10.8	16.1-16.6	16.4	2.3-2.6	2.4	3.22-3.66	3.44	77.3-77.9	77.7
4/6/59	12	64	10.5-12.2	11.3	10.9-17.7	13.7	16.6-17.1	16.9	1.7-1.9	1.8	3.24-3.74	3.58	77.3-77.6	77.4
5/14/59	13	60	9.1-12.5	10.7	6.8-16.6	10.6	17.2-17.5	17.4	1.5-1.7	1.6	3.26-3.42	3.36	77.5-77.8	77.7
6/9/58	3	60	10.1-11.8	10.8	8.4-19.4	12.3	17.1-17.3	17.2	2.2-3.3	2.6	3.20-3.44	3.29	76.9-77.6	77.3
6/10/60	2	40	10.1-17.8	13.0	11.5-20.3	15.0	17.6-17.8	17.7	2.1-2.3	2.2	2.63-3.23	2.97	77.1-77.7	77.3
7/6/59	8	48	10.4-11.9	11.0	11.6-15.5	14.4	17.4-17.9	17.6	4.1-4.7	4.4	2.98-3.30	3.13	74.6-75.0	74.8
7/20/60	9	40	7.2-12.6	10.1	4.5-17.6	12.1	18.2-18.5	18.4	3.6-3.9	3.7	2.61-3.17	2.93	74.8-75.5	75.1
8/9/59	8	40	10.1-12.9	11.3	11.5-19.0	15.2	17.1-17.8	17.5	3.5-4.5	3.9	3.03-3.39	3.29	75.9-77.0	76.4
8/30/59	10	40	8.3-11.9	10.8	7.5-20.5	15.1	17.3-17.6	17.5	2.2-3.5	2.7	2.74-3.32	3.11	76.3-77.1	76.7
9/22/59	6	40	8.4-12.1	10.4	5.8-16.8	12.0	16.9-17.0	16.9	1.9-2.0	2.0	2.81-3.41	3.14	77.4-77.8	77.7
10/21/58	10	40	10.4-12.7	11.5	10.6-20.4	13.7	16.1-16.4	16.2	2.7-3.8	3.1	3.53-3.91	3.69	76.6-78.2	77.2
11/11/59	8	60	8.7-10.8	9.9	6.0-14.9	10.6	17.6-17.8	17.7	1.9-2.2	2.1	3.30-3.50	3.40	76.5-77.1	76.7
12/11/59	6	60	9.3-11.4	10.3	8.7-15.9	11.7	17.3-18.3	17.9	1.9-2.2	2.1	2.87-3.62	3.23	76.5-77.1	76.8

[1] Forktail measurement.

Table 3A.—Length, weight, and proximate composition—bumper *(Chloroscombrus chrysurus)*

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/15/59	11	67	8.0- 9.9	9.0	5.3- 12.6	8.7	17.1-17.9	17.5	1.8- 2.2	2.0	4.48-5.33	4.90	75.8-77.4	76.8
2/28/60	2	20	11.6-15.6	13.9	21.1- 49.9	31.8	18.2-19.6	19.0	6.1- 7.7	6.9	2.65-4.59	3.78	69.6-72.3	71.1
5/12/60	15	16	12.0-14.6	13.2	48.2- 69.4	64.3	16.1-16.8	16.4	10.7-13.2	12.3	1.78-2.20	1.94	68.7-70.6	69.4
5/21/59	3	16	10.5-23.6	15.3	44.3-141.3	54.9	18.1-18.9	18.5	2.9- 3.7	13.2	4.22-5.23	4.86	71.6-74.5	73.3
6/15/59	13	16	15.7-20.5	16.9	51.8-100.2	64.2	19.0-19.5	19.3	2.4- 4.5	3.7	3.88-4.78	4.48	72.8-75.8	74.0
7/11/60	9	16	11.5-15.3	12.9	22.0- 51.6	31.6	18.3-19.3	18.8	4.4- 4.8	4.6	2.20-3.52	2.96	72.6-74.6	73.5
7/20/58	5	8	15.4-17.2	16.5	50.7- 71.1	61.0	18.6-18.9	18.7	4.8- 6.9	6.0	3.42-5.15	4.22	70.3-73.0	71.3
8/1/60	19	16	14.3-20.8	16.6	49.0-118.2	70.3	17.9-19.0	18.3	5.5- 8.9	7.1	4.04-5.03	4.34	70.1-73.2	72.3
8/9/59	8	16	15.4-19.1	16.6	51.2- 79.8	63.0	18.8-19.6	19.1	2.6- 4.2	3.2	4.17-5.58	4.70	73.2-75.5	74.1
8/30/60	10	16	9.7-12.3	10.9	21.3- 51.2	32.6	16.9-17.0	17.0	1.5- 4.2	2.7	1.27-3.43	2.37	77.4-80.4	78.8
9/22/60	7	16	13.0-19.3	15.8	33.5-100.8	58.8	16.5-17.5	17.1	4.2- 4.9	4.5	3.56-4.79	4.34	72.8-75.2	74.0
9/24/58	7	8	16.6-29.9	19.2	65.6- 97.2	80.3	18.1-19.2	18.6	4.7- 5.4	5.1	3.11-5.13	3.91	70.2-73.4	72.2
10/12/60	10	20	9.3-14.0	12.0	12.4- 36.5	23.4	17.3-18.5	17.7	2.5- 3.8	3.3	3.63-4.83	4.19	72.9-76.1	74.8
10/19/59	7	100	5.8- 8.6	7.1	2.6- 10.2	5.4	17.5-18.0	17.8	3.0- 5.2	3.7	3.40-4.97	4.31	74.9-75.5	75.3
11/18/59	7	160	5.5- 8.6	6.8	2.6- 6.6	4.0	18.3-18.4	18.4	1.3- 1.4	1.3	4.60-5.38	5.03	75.8-77.0	76.3

[1] Forktail measurement.

Table 4A.—Length, weight, and proximate composition—butterfish *(Poronotus triacanthus)*

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/15/59	4	24	9.7-13.1	12.0	15.6- 39.0	29.1	16.4-16.8	16.5	1.1- 1.7	1.3	3.20-3.49	3.37	79.5-80.7	80.1
2/28/58	10	12	12.5-16.8	14.7	53.5-100.0	75.4	14.6-16.2	15.1	1.6- 3.4	2.2	2.56-3.01	2.82	77.1-80.3	79.3
3/17/59	10	24	11.3-13.1	12.3	32.8- 51.4	40.5	16.1-16.6	16.4	3.1- 4.0	3.4	3.49-3.56	3.53	76.9-77.8	77.4
4/6/59	12	20	10.6-13.4	12.4	24.4- 47.8	39.3	15.8-16.3	16.1	4.1- 4.6	4.2	2.76-3.14	3.02	75.5-77.6	76.6
4/27/60	16	16	8.4-14.2	12.6	16.2- 82.2	60.4	15.8-16.7	16.3	12.2-14.8	13.8	1.75-1.98	1.91	67.2-70.2	68.2
6/9/58	9	13	9.7-15.0	11.6	19.0- 90.9	42.2	15.0-15.9	15.6	4.9- 7.4	6.2	1.49-3.12	2.36	74.2-78.5	76.0
6/20/60	9	16	10.8-14.0	12.3	36.9- 69.0	48.5	15.9-17.6	16.9	4.1- 6.6	5.7	1.63-2.73	2.34	73.5-78.1	75.1
7/6/59	8	20	9.4-12.2	11.0	19.3- 44.4	31.8	17.4-17.8	17.6	1.8- 3.5	2.7	2.47-3.55	2.93	75.9-78.1	76.7
8/9/59	8	16	10.9-13.5	12.2	35.9- 62.1	46.7	17.1-17.5	17.4	1.8- 3.0	2.5	1.91-3.07	2.57	77.4-79.4	78.0
9/23/59	15	16	10.4-12.5	11.7	29.0- 50.5	39.4	15.9-16.7	16.5	1.4- 1.6	1.5	2.85-3.54	3.18	78.1-78.9	78.6
10/12/60	10	16	12.2-14.2	12.9	43.0- 65.1	51.4	16.9-17.4	17.2	0.9- 1.5	1.3	2.31-3.29	2.96	77.2-79.0	78.1
10/13/59	7	16	12.3-13.9	13.1	48.4- 69.2	59.9	16.9-17.6	17.2	4.3- 5.2	4.7	2.43-2.68	2.55	74.9-76.5	75.7
11/11/59	8	16	13.0-15.5	13.9	48.2- 92.1	65.8	16.5-18.2	17.4	2.1- 4.5	3.3	2.01-3.72	2.93	74.3-78.5	76.2
11/12/58	7	8	8.1-16.0	13.0	16.8-135.6	76.4	16.1-16.9	16.6	1.5- 3.1	2.6	1.92-2.85	2.37	76.9-80.6	78.5
12/17/59	3	16	13.8-16.7	14.9	59.9-100.4	74.1	17.3-18.6	18.0	1.0- 1.5	1.3	2.26-3.29	2.89	76.7-79.4	77.8

[1] Forktail measurement.

Table 5A.—Length, weight, and proximate composition—croaker *(Micropogon undulatus)*

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/10/58	20	16	16.0-18.3	17.1	39.5- 60.1	49.8	16.7-17.2	17.0	1.8- 3.0	2.6	4.15-4.83	4.53	75.4-76.6	76.0
1/14/59	6	16	16.6-19.2	19.1	37.7- 88.1	65.2	15.9-16.8	16.4	1.0- 1.7	1.4	4.94-6.68	5.74	75.6-78.7	76.9
2/6/59	10	16	16.2-20.1	17.8	36.1- 67.4	51.4	14.1-15.8	15.0	1.5- 1.9	1.7	4.90-5.41	5.21	76.3-78.1	77.2
2/16/60	9	16	17.0-19.9	18.1	46.0- 70.0	56.6	15.1-17.7	16.8	1.9- 2.5	2.2	2.97-6.06	4.77	73.6-79.8	76.3
2/28/58	10	12	18.6-21.6	19.8	61.0-116.0	77.4	14.5-15.8	15.2	1.6- 2.8	2.2	4.59-6.42	5.98	75.9-78.5	77.2
3/15/60	10	16	16.6-18.7	17.5	42.2- 69.2	54.4	15.8-16.9	16.4	1.8- 2.0	1.9	4.25-5.40	4.66	76.5-78.3	77.2
4/7/59	7	16	17.5-20.8	18.9	50.8- 87.6	65.6	15.1-16.7	15.9	1.4- 1.8	1.6	5.58-7.60	6.41	75.5-76.8	76.3
4/12/60	9	16	16.7-22.4	18.1	51.5-122.7	64.4	14.8-16.8	16.4	2.8- 3.7	3.2	5.10-6.02	5.42	74.6-75.2	74.9
5/2/60	2	16	15.6-19.5	17.9	42.5-101.7	60.6	16.4-17.2	16.7	5.2- 7.2	6.1	3.73-4.83	4.25	72.0-74.1	73.0
5/14/59	9	16	15.6-20.8	17.8	40.5- 97.9	61.6	15.7-15.9	15.8	5.9- 6.6	6.2	4.93-6.11	5.46	72.1-72.9	72.5
5/25/60	10	16	15.5-18.8	18.2	35.6- 93.4	64.3	16.4-17.3	16.8	2.9- 4.6	3.7	4.71-5.78	5.08	73.9-75.6	74.8
6/9/58	9	8	17.9-21.0	19.4	65.6-111.3	88.1	15.6-16.3	15.9	6.3-10.0	8.6	4.29-5.60	4.85	67.1-73.0	69.9
6/30/60	10	20	12.0-16.8	13.9	18.5- 50.8	30.5	16.1-17.3	16.7	4.0- 6.0	4.6	3.93-4.60	4.29	73.5-75.0	74.4
7/6/60	9	16	16.8-20.0	17.9	53.3- 92.3	69.8	15.3-16.8	16.3	7.0- 7.9	7.4	4.39-4.96	4.73	71.1-73.8	72.1
7/20/58	5	8	20.2-26.0	22.2	81.4-181.7	118.5	16.4-16.9	16.7	2.8- 4.5	3.6	2.37-3.43	3.05	75.0-77.8	76.0
8/1/60	19	16	16.6-18.9	18.0	45.9- 75.9	60.8	16.4-16.6	16.5	6.2- 6.9	6.6	4.02-4.97	4.54	71.9-72.5	72.2
8/19/59	7	16	13.3-16.7	15.2	22.1- 49.4	36.5	17.4-17.6	17.5	3.8- 4.9	4.3	4.20-5.23	4.58	73.7-75.5	74.5
8/19/59	6	16	13.8-17.4	15.3	27.0- 57.4	36.9	17.2-17.6	17.4	1.6- 3.5	2.6	4.88-5.83	5.18	74.7-76.8	75.4
9/22/59	6	16	14.4-15.9	15.3	28.4- 42.9	36.1	16.7-17.8	17.2	2.4- 3.8	3.0	4.02-5.50	4.80	72.9-76.9	75.0
9/24/58	7	8	19.3-21.4	20.7	73.6-110.2	94.7	16.0-17.1	16.5	2.9- 4.2	3.6	2.73-5.29	3.96	74.3-76.9	76.0
10/13/61	10	16	15.0-18.8	17.0	28.3- 72.1	55.5	16.4-17.1	16.7	4.0- 7.3	5.7	1.27-1.84	1.45	74.6-78.3	76.1
10/19/59	6	20	12.6-15.4	13.6	19.0- 34.6	25.9	15.9-16.5	16.3	1.8- 2.2	2.1	4.08-5.03	4.83	75.7-77.3	76.5
11/11/59	8	16	15.8-20.0	18.0	34.1- 88.4	57.1	16.0-17.1	16.7	1.0- 2.5	1.5	4.58-6.20	5.55	74.6-78.3	76.8
12/9/59	6	16	16.7-20.1	17.9	42.4- 77.6	54.6	14.3-16.6	15.8	1.3- 1.8	1.5	3.95-5.74	4.74	76.2-78.9	77.7

[1] Overall measurement.

Table 6A.—Length, weight, and proximate composition—croaker, banded *(Larimus fasciatus)*

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/14/59	5	16	14.3-18.5	16.5	38.0- 98.7	63.7	16.8-17.6	17.2	2.9-3.8	3.5	3.55-4.80	4.50	73.8-75.3	74.5
2/6/59	10	16	14.5-18.5	15.9	37.4- 77.4	50.6	17.1-17.8	17.5	3.3-4.2	3.7	3.78-5.72	5.03	72.7-75.4	74.0
3/31/60	9	16	16.0-19.7	18.2	63.2-127.8	98.6	17.6-18.2	17.9	7.9-8.9	8.4	3.62-5.04	4.35	68.3-70.7	69.2
4/12/60	15	16	14.0-16.5	15.3	36.8- 67.4	52.5	17.1-18.1	17.8	8.0-9.4	8.6	2.20-2.84	2.58	70.7-72.9	71.4
5/12/60	9	16	14.3-16.4	15.6	42.5- 63.8	54.4	17.8-17.9	17.8	5.3-7.5	6.3	1.84-3.78	2.59	72.6-74.4	73.6
6/20/60	9	16	13.5-16.6	15.6	34.9- 73.0	59.6	17.4-18.5	17.9	4.4-5.6	5.0	3.13-3.64	3.37	74.1-74.7	74.3
7/8/59	8	16	13.5-18.6	16.2	31.5- 99.2	61.6	17.7-18.7	18.2	3.3-5.7	4.6	3.79-5.58	4.65	70.7-74.3	72.8
7/18/60	7	16	12.8-16.4	14.5	34.9- 75.9	54.2	16.9-18.3	17.8	3.0-4.5	3.8	2.57-4.43	3.41	74.2-76.9	75.2
8/9/59	7	16	14.7-19.4	17.1	45.8-125.6	77.9	17.4-18.5	17.9	3.0-4.2	3.5	2.93-4.06	3.55	73.4-76.5	75.4
9/21/59	9	16	12.3-17.3	14.7	29.5- 92.2	49.0	16.5-17.1	16.8	2.0-4.5	3.2	4.33-5.74	4.91	73.2-75.9	74.4
10/13/59	7	16	11.5-14.3	12.9	21.6- 50.6	30.6	16.7-17.1	16.9	2.9-3.1	3.0	3.69-3.94	3.86	75.7-76.4	76.1
11/22/58	8	8	18.6-20.5	19.5	83.9-124.5	103.1	17.5-18.1	17.8	1.5-2.8	2.3	3.08-4.54	4.03	74.2-76.9	75.6
11/30/60	9	16	16.3-19.1	17.7	68.8-112.3	88.0	16.5-17.5	17.1	2.7-4.9	3.3	2.36-3.79	3.12	74.3-77.7	76.2
12/11/59	10	16	16.3-20.0	18.4	64.1-113.3	87.7	17.8-18.5	18.0	1.9-3.1	2.5	5.18-5.85	5.44	73.6-75.2	74.2

[1] Overall measurement.

Table 7A.—Length, weight, and proximate composition—hardhead *(Galeichthys felis)*

Date sample obtained	Location	Total Number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/14/59	5	16	13.1-22.9	19.4	25.0-131.1	76.3	15.9-16.9	16.5	4.1- 6.4	5.5	5.85-7.88	7.00	70.2-72.0	70.9
2/6/59	10	16	16.5-22.6	19.6	43.5-113.4	75.7	16.1-16.8	16.6	4.1- 6.5	5.5	5.82-6.95	6.37	68.9-71.0	70.1
3/15/60	10	16	20.4-26.8	22.7	91.6-257.7	138.3	16.3-17.8	17.1	5.1- 6.1	5.7	5.32-7.43	6.44	69.9-71.1	70.8
4/20/59	11	16	16.1-20.8	18.4	44.9-116.6	71.7	15.1-15.9	15.5	2.9- 5.1	4.3	5.75-6.20	5.95	72.0-74.6	73.3
5/3/60	9	20	11.3-13.3	12.2	19.6- 30.6	23.6	15.4-15.8	15.7	4.8- 5.4	5.2	4.79-5.96	5.19	72.5-74.6	73.8
5/14/59	13	16	15.6-21.6	18.2	36.5-131.2	69.5	16.3-16.7	16.5	2.7- 7.7	5.4	6.33-7.69	7.00	69.7-73.7	71.6
6/9/58	9	4	22.1-24.2	23.3	149.8-204.2	182.6	16.6-17.5	17.0	6.1- 7.2	6.7	2.70-5.06	4.14	70.5-72.1	71.0
6/10/60	2	20	11.1-19.0	13.0	18.3- 80.7	30.1	16.6-17.4	17.0	4.7- 5.6	5.1	4.81-6.04	5.60	71.5-73.0	72.3
7/6/59	8	16	14.2-23.5	19.2	35.2-140.4	86.2	16.3-16.8	16.6	2.5- 4.0	3.7	6.44-6.99	6.72	73.6-75.4	74.4
8/12/59	8	16	14.3-16.9	15.4	31.5- 63.9	43.3	16.6-17.6	17.3	3.9- 4.8	4.2	6.57-6.70	6.65	71.7-72.3	72.1
8/16/60	9	16	15.4-24.5	20.6	57.2-156.5	106.0	14.2-16.6	15.2	5.3-10.7	8.7	3.62-7.37	5.68	67.7-73.2	70.9
8/30/60	10	16	11.4-15.6	14.2	20.1- 48.0	37.2	15.0-16.2	15.6	6.3- 7.6	7.0	4.31-5.93	5.13	70.6-73.1	72.2
9/22/59	6	16	12.6-17.8	15.1	25.6- 68.7	44.9	16.3-16.5	16.4	6.3- 8.5	7.1	5.18-7.16	6.08	69.4-72.0	70.5
10/7/60	7	16	11.9-19.7	15.6	21.0-118.5	52.5	14.9-15.5	15.2	6.6- 8.7	7.5	4.00-6.10	5.26	69.3-74.5	72.0
10/13/59	15	16	11.3-14.8	12.9	21.2- 43.7	31.1	14.5-14.9	14.7	4.5- 5.4	5.0	3.81-4.25	4.05	74.8-76.8	75.9
11/12/58	8	11	14.3-21.8	17.4	40.2-146.7	69.4	15.4-16.0	15.7	7.9- 9.7	8.8	4.23-6.31	5.34	69.1-70.8	69.8
12/10/59	6	16	12.1-19.2	14.8	18.4- 86.9	41.9	16.6-16.9	16.7	5.6- 6.8	6.0	4.67-5.27	4.96	71.6-72.0	71.7

[1] Forktail measurement.

Table 8A.—Length, weight, and proximate composition—harvestfish *(Peprilus alepidotus)*

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/15/59	4	40	7.3-10.1	8.5	10.7- 33.1	17.8	14.4-14.9	14.7	1.2-1.5	1.4	2.55-3.14	2.86	80.5-81.5	81.1
2/15/60	9	16	8.7-18.4	10.8	22.3-107.3	46.6	15.0-16.3	15.6	8.4-9.1	8.8	1.60-2.37	2.11	72.8-74.8	73.9
3/23/60	10	17	7.8-13.7	10.4	16.3- 88.8	41.4	15.1-15.8	15.5	5.4-7.5	6.5	1.59-2.69	2.24	74.0-77.4	75.7
4/6/59	12	16	12.4-15.6	13.8	61.6- 97.9	80.0	15.5-16.1	15.9	2.3-2.9	2.6	2.54-2.93	2.68	78.8-80.0	79.2
5/21/59	3	16	12.4-16.6	14.7	70.9-168.9	115.2	15.6-16.9	16.5	5.2-7.6	6.2	2.49-3.13	2.75	73.4-75.5	74.5
6/15/59	13	16	13.8-17.4	15.6	92.2-180.5	131.9	17.3-18.3	17.9	4.2-7.4	5.3	2.49-2.76	2.57	71.8-76.7	74.8
7/20/58	5	7	13.0-16.2	14.8	83.9-129.9	111.2	16.1-16.8	16.4	4.8-9.0	7.5	2.08-2.69	2.31	70.4-76.9	73.0
7/20/60	9	16	12.3-17.4	14.1	90.3-209.4	142.2	16.8-17.6	17.2	7.1-7.7	7.5	2.01-2.65	2.30	72.8-74.4	73.5
8/12/59	8	16	13.9-16.5	14.9	97.3-158.0	120.7	17.2-18.0	17.6	5.3-8.2	6.4	2.32-2.72	2.52	73.0-74.9	74.2
9/24/58	7	7	14.2-16.7	15.3	57.7- 84.2	68.8	18.0-18.5	18.3	2.9-4.7	3.6	2.02-2.94	2.60	74.1-75.9	75.1
10/13/59	10	40	6.5- 8.0	7.2	9.2- 19.5	14.3	15.5-15.7	15.7	1.5-3.0	2.5	2.25-2.90	2.67	77.6-80.2	78.8
10/13/60	10	28	5.6- 9.4	7.3	10.2- 27.0	17.9	14.1-14.7	14.4	0.4-0.7	0.5	2.94-3.29	3.14	81.8-82.0	81.9
11/11/59	8	16	10.9-12.5	11.5	44.9- 68.8	54.9	16.6-17.2	16.9	4.6-5.4	5.0	1.80-2.52	2.26	75.7-76.7	76.2

[1] Forktail measurement.

Table 9A.—Length, weight, and proximate composition—menhaden (*Brevoortia patronus*)

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/14/59	6	24	12.3-15.5	13.4	25.9- 55.1	33.0	14.6-15.1	14.9	3.3- 4.4	3.7	4.06-4.81	4.52	76.7-78.2	77.4
2/16/60	7	32	10.1-11.7	10.9	15.2- 24.3	18.6	13.9-14.7	14.5	5.2- 5.9	5.5	2.91-4.25	3.35	75.4-77.9	76.8
3/15/60	10	12	16.2-19.8	18.1	88.0-162.4	124.3	15.1-15.3	15.3	12.6-14.2	13.2	2.24-3.14	2.64	68.1-70.4	69.2
4/20/59	11	20	11.4-16.1	13.1	26.1- 77.4	42.9	13.4-13.7	13.6	13.9-15.9	15.1	4.18-5.03	4.65	66.3-67.6	67.0
5/21/59	3	16	13.5-16.5	14.6	46.1- 75.6	59.4	14.0-14.6	14.4	14.7-17.3	15.8	3.91-6.46	4.84	64.2-66.0	65.1
6/20/61	9	16	12.3-16.8	14.6	36.3- 82.2	58.2	14.1-14.7	14.5	12.8-14.3	13.6	2.53-3.38	2.93	68.1-70.0	69.1
7/21/59	8	16	13.5-17.1	15.2	42.0- 90.5	69.5	14.9-15.4	15.2	11.5-14.5	13.2	3.50-3.99	3.83	67.3-70.3	68.6
8/22/58	6	7	15.9-19.5	17.4	82.2-161.4	110.3	14.1-16.1	14.9	13.1-20.5	17.8	3.30-4.08	3.66	60.5-66.8	63.3
9/22/60	7	16	14.3-18.2	16.2	55.3-107.3	84.9	13.8-14.4	14.1	14.2-18.1	16.5	2.47-2.76	2.63	65.5-69.6	67.3
10/20/58	12	8	13.0-18.0	16.3	42.4-122.6	94.8	14.7-14.9	14.8	15.1-16.8	16.0	2.79-3.90	3.38	63.9-66.7	65.4
11/11/59	8	16	15.1-17.4	16.2	63.6- 97.9	78.8	16.1-17.2	16.4	3.2- 4.8	4.1	3.20-3.91	3.52	74.5-76.6	75.5
12/9/59	6	16	10.3-19.1	15.1	16.7-139.8	56.3	14.7-15.9	15.5	1.9- 2.7	2.4	2.85-3.96	3.30	78.1-81.1	79.3

[1] Forktail measurement.

Table 10A.—Length, weight, and proximate composition—pigfish (*Orthopristis chrysopterus*)

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/15/59	4	24	10.1-14.3	12.6	14.3- 47.2	28.1	16.1-16.5	16.3	3.7- 5.5	4.7	3.65-4.81	4.26	74.3-75.0	74.7
2/24/60	10	16	15.2-19.9	17.3	59.2-156.4	88.5	15.6-16.5	16.1	2.9- 3.7	3.3	3.13-4.36	3.88	75.4-78.7	76.7
4/12/60	9	16	14.8-21.0	18.5	53.8-145.2	105.1	14.8-15.4	15.1	2.1- 2.4	2.2	2.80-3.91	3.27	77.7-79.5	78.8
6/14/59	13	16	13.4-17.1	15.3	37.5- 85.2	60.2	15.4-15.9	15.7	6.6- 7.6	7.1	4.09-6.44	4.97	71.8-72.8	72.2
8/8/59	8	16	16.0-20.1	17.7	64.8-132.6	87.5	16.2-17.1	16.8	8.0-11.0	10.0	2.97-3.92	3.28	68.9-71.7	70.0
8/12/59	8	20	11.7-16.4	13.1	25.7- 76.6	39.6	17.1-17.4	17.3	3.3- 5.4	4.1	3.97-4.41	4.16	74.0-75.7	75.0
9/22/59	6	16	12.3-15.4	13.9	28.8- 62.0	46.0	17.8-18.4	18.2	3.9- 5.6	4.6	4.12-4.74	4.37	71.7-74.0	73.1
10/13/59	7	16	11.3-16.5	13.8	25.0- 80.1	46.4	16.8-17.5	17.2	2.4- 4.6	3.7	4.03-5.16	4.49	73.3-75.8	74.7
11/11/59	8	20	10.9-16.9	13.0	19.9- 75.1	36.9	16.8-17.2	17.0	3.2- 4.6	3.9	3.95-5.12	4.38	74.7-75.8	75.1
12/11/59	6	16	13.0-18.2	14.6	34.8- 97.1	52.9	15.8-17.7	17.1	4.6- 9.8	7.1	2.32-4.95	3.99	69.1-76.8	72.5

[1] Forktail measurement.

Table 11A.—Length, weight, and proximate composition—porgy (*Stenotomus caprinus*)

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/10/60	20	24	9.4-10.3	9.8	19.8-30.6	24.3	16.3-17.6	17.2	1.3-1.8	1.7	5.89-7.24	6.63	73.5-76.5	74.6
1/21/60	9	23	8.7-11.4	10.2	19.4-38.7	27.8	15.8-17.0	16.4	1.8-3.2	2.4	3.75-7.81	6.46	72.8-77.3	74.3
2/10/60	9	24	9.2-11.3	9.9	15.8-32.0	23.4	18.1-18.2	18.1	1.8-2.4	2.2	6.02-7.79	6.91	71.9-73.6	73.0
3/11/59	10	40	8.5-10.2	9.5	14.8-25.3	19.2	17.1-17.4	17.2	2.3-2.7	2.5	5.18-6.32	5.84	74.1-74.9	74.5
4/7/59	7	16	11.8-16.4	13.7	31.5-96.0	58.1	17.0-17.9	17.4	2.4-3.6	3.0	8.21-8.77	8.49	70.3-71.6	71.1
4/12/60	17	16	9.6-13.4	11.6	26.7-59.6	41.2	16.7-17.2	17.0	3.1-3.6	3.5	5.47-5.85	5.67	73.3-74.1	73.6
5/25/60	10	16	11.2-13.2	12.1	37.5-65.1	49.3	16.6-18.1	17.6	3.8-4.9	4.4	4.80-7.49	6.55	70.0-73.7	71.4
6/14/59	13	20	9.0-11.0	9.8	15.0-28.3	21.9	16.1-18.1	17.1	1.9-2.8	2.4	4.80-6.29	5.79	73.8-76.5	74.9
7/6/59	8	28	9.4-11.9	10.6	22.6-43.3	28.4	18.0-18.7	18.3	3.4-4.6	3.8	5.21-6.67	5.98	70.4-72.3	71.4
8/9/59	8	64	6.1- 8.3	7.0	6.0-15.3	9.7	17.9-18.5	18.3	1.8-2.0	1.9	5.02-5.86	5.44	74.1-75.2	74.8
9/28/59	7	32	7.6- 9.5	8.4	12.6-24.6	17.5	16.9-17.5	17.3	1.7-2.1	2.0	6.02-7.00	6.49	73.3-74.3	73.7
10/13/60	10	28	7.9-10.2	8.8	14.5-27.1	19.6	17.8-18.0	17.9	1.7-2.2	2.0	6.17-6.80	6.59	73.1-74.2	73.7
10/13/60	10	16	7.3-14.3	9.7	15.4-78.3	33.3	16.3-18.0	17.0	2.2-4.8	3.3	5.52-6.63	6.13	72.6-73.9	73.5
11/11/59	8	40	8.1-10.5	9.3	14.7-37.6	21.4	18.6-18.9	18.7	2.2-2.4	2.3	5.82-6.49	6.21	72.1-72.8	72.5
12/10/59	6	32	8.4-10.4	9.3	14.2-26.3	20.3	18.1-18.6	18.4	1.8-2.7	2.2	5.98-7.30	6.73	71.5-73.5	72.6

[1] Forktail measurement.

Table 12A.—Length, weight, and proximate composition—razorbelly *(Harengula pensacolae)*

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/15/59	4	48	8.3-11.2	9.6	8.2-18.2	12.7	18.6-19.3	19.0	2.4- 2.8	2.6	5.38-6.63	6.14	71.5-74.2	72.4
2/28/58	10	36	14.4-15.0	14.8	32.3-37.4	35.4	18.2-19.7	18.9	6.5- 9.3	7.7	6.09-8.11	7.15	66.2-68.0	67.1
2/28/60	2	16	15.0-17.4	16.3	66.5-97.2	79.7	17.0-17.9	17.5	10.6-11.9	11.2	4.13-4.91	4.39	66.2-68.4	67.0
3/17/59	10	24	11.2-12.7	11.9	23.7-36.1	29.0	18.2-18.6	18.5	5.3- 6.5	6.0	3.79-5.46	4.74	70.5-73.6	71.4
4/6/59	12	20	10.7-13.5	12.5	21.9-44.0	34.1	18.4-18.8	18.5	6.9- 7.7	7.4	3.64-4.84	4.28	68.9-70.4	69.8
4/21/60	9	16	10.2-13.9	11.6	23.4-52.2	33.5	17.8-18.9	18.2	11.3-13.1	12.1	3.74-6.10	4.53	63.1-66.9	65.5
5/12/60	7	20	10.1-11.9	11.3	22.0-33.0	31.1	17.9-19.9	19.0	9.5-12.1	10.3	2.74-3.87	3.42	66.2-68.2	67.3
5/14/59	13	24	9.2-15.1	11.2	11.7-51.7	25.0	19.1-19.7	19.4	3.7- 5.3	4.7	3.34-5.02	4.31	71.4-73.9	72.7
6/9/58	3	16	11.0-15.0	12.9	22.8-60.1	37.5	17.1-18.9	18.4	4.4- 5.4	5.0	3.64-5.61	4.81	70.9-73.4	71.8
7/6/59	8	20	11.9-14.9	13.3	29.3-58.0	40.5	18.8-19.4	19.2	2.3- 3.2	2.8	3.37-5.63	4.60	72.4-76.3	74.0
8/9/59	8	16	12.4-15.5	13.7	33.3-71.3	46.9	18.5-19.9	19.0	1.7- 2.0	1.8	3.67-4.81	4.15	74.6-76.9	76.0
8/30/60	10	20	10.0-12.5	10.7	19.5-40.2	25.1	18.1-18.4	18.3	2.8- 3.7	3.4	2.96-4.01	3.39	74.7-75.8	75.2
9/24/58	7	20	11.8-14.4	13.0	27.8-51.0	38.6	18.1-18.8	18.5	6.2- 7.3	6.7	4.80-6.92	5.82	68.5-70.2	69.0
10/13/59	7	16	11.1-14.6	12.8	26.8-60.4	39.1	17.8-19.0	18.4	4.8- 7.1	6.3	3.75-6.28	5.02	68.4-72.0	70.3
11/11/59	8	16	12.0-15.4	13.6	32.9-64.9	47.4	18.3-19.0	18.6	6.4- 7.1	6.9	4.51-5.75	4.97	68.9-70.5	69.9
12/9/59	6	16	9.1-15.2	11.1	11.0-36.5	27.6	18.9-19.2	19.1	2.5- 4.6	3.8	4.15-5.99	5.08	71.2-73.3	72.0

[1] Forktail measurement.

Table 13A.—Length, weight, and proximate composition—silver eel *(Trichiurus lepturus)*

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/14/59	5	17	34.3-54.2	44.9	17.3- 68.9	38.8	17.1-17.3	17.2	2.6-3.7	3.2	2.47-3.01	2.77	76.5-77.9	77.0
1/21/60	9	16	41.3-49.1	45.7	30.8- 53.1	39.7	15.9-18.2	17.2	3.0-4.5	3.9	1.80-2.58	2.27	74.8-78.5	76.4
2/28/58	10	16	36.7-45.8	42.8	25.4- 48.6	37.6	17.9-18.2	18.1	4.1-4.4	4.3	2.63-2.97	2.96	75.0-75.8	75.4
3/17/59	10	20	35.1-48.1	41.3	17.2- 48.6	33.0	16.1-16.7	16.5	3.5-4.4	3.8	2.56-3.02	2.78	75.9-77.8	76.7
4/6/59	12	18	38.7-51.0	45.3	23.2- 64.8	43.4	16.8-17.1	17.0	2.6-3.6	3.1	2.44-2.99	2.62	76.7-77.6	77.2
4/12/60	9	16	37.8-50.5	43.5	33.0- 61.9	43.2	15.3-16.6	15.9	4.5-5.3	4.9	1.66-2.36	2.00	75.6-77.5	76.7
5/14/59	13	20	31.3-48.7	40.1	10.1- 66.4	34.3	16.9-17.4	17.2	3.3-3.9	3.6	2.18-2.67	2.41	75.9-77.4	76.8
6/9/58	9	12	38.3-54.7	48.5	26.4- 99.8	62.5	15.9-16.6	16.3	2.3-2.8	2.6	1.90-2.91	2.26	77.2-78.8	77.9
6/20/60	9	16	32.7-74.3	51.6	47.2- 89.5	62.1	16.7-17.8	17.3	2.3-3.4	2.9	1.51-1.81	1.66	77.9-78.6	78.3
7/8/59	8	16	46.2-54.4	50.5	58.8- 95.1	78.0	18.0-18.8	18.3	5.1-5.4	5.3	1.00-2.33	1.74	74.6-75.4	75.0
8/9/59	8	16	38.0-56.8	49.3	31.2-120.5	76.2	17.6-18.6	18.2	3.4-4.3	3.9	1.92-2.27	2.08	75.2-76.2	75.7
8/16/60	9	16	34.2-63.4	48.6	59.2-103.4	78.4	16.5-17.2	16.8	2.4-3.4	2.8	2.74-3.29	3.01	76.7-77.6	77.3
9/22/60	10	24	21.0-44.5	30.1	11.2- 27.0	15.1	17.5-17.7	17.6	2.0-2.4	2.2	2.04-2.44	2.30	78.2-78.9	78.6
9/24/58	7	4	65.0-72.1	67.4	147.1-211.5	179.5	17.5-18.0	17.8	1.9-3.3	2.7	3.09-4.04	3.51	75.5-77.8	76.4
10/13/59	7	16	50.6-60.8	56.1	79.7-145.9	104.1	17.7-18.1	17.9	1.7-2.2	1.9	2.46-2.80	2.62	77.6-78.5	78.1
10/13/60	10	16	32.0-62.7	46.3	41.0- 96.5	71.5	17.0-17.6	17.3	2.2-2.4	2.3	2.21-2.65	2.40	77.8-78.5	78.1
11/11/59	7	16	36.0-53.6	42.5	23.9- 82.8	43.8	18.3-19.1	18.7	5.0-5.9	5.4	2.27-2.47	2.37	73.5-73.8	73.6
12/9/59	6	21	28.9-43.4	35.9	12.8- 47.3	25.8	17.7-18.4	18.1	5.5-8.7	7.2	1.67-2.35	2.14	72.5-74.1	73.3

[1] Overall measurement.

Table 14A.—Length, weight, and proximate composition—spot *(Leiostomus xanthurus)*

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/14/59	6	16	17.4-20.6	18.8	54.3- 96.9	74.2	15.6-16.4	15.9	1.5- 2.1	1.8	2.87-5.04	3.71	77.8-81.2	80.1
1/21/60	9	16	14.3-18.8	16.8	41.3- 83.9	64.2	15.5-17.8	16.7	0.9- 1.5	1.2	2.93-4.13	3.70	77.2-80.1	78.8
2/16/60	7	19	12.3-15.8	13.3	26.1- 59.9	31.9	15.6-16.2	15.9	3.7- 4.8	4.3	3.06-3.98	3.55	74.9-77.2	76.0
2/16/60	9	16	15.6-19.8	17.7	51.7-100.9	72.8	16.0-16.3	16.2	1.7- 2.9	2.2	3.51-4.80	3.87	78.1-79.0	78.5
3/11/59	10	16	14.8-19.0	16.4[2]	32.5- 67.7	43.9	15.4-16.3	15.9	1.5- 1.7	1.5	3.79-4.15	3.97	77.8-79.2	78.4
4/7/59	7	16	18.0-20.5	19.5[2]	65.6- 93.5	81.5	15.2-15.8	15.5	3.6- 4.8	4.1	3.13-4.12	3.59	74.7-77.7	76.4
4/27/60	16	16	15.9-20.6	18.7	70.6-120.8	87.7	16.7-17.4	17.0	5.4- 6.9	5.8	3.80-4.20	4.02	72.2-73.9	73.2
5/10/60	8	16	12.5-15.6	14.7	31.4- 52.7	51.3	16.9-17.1	17.0	6.3- 7.2	6.9	2.70-3.92	3.52	72.1-73.8	72.8
5/30/58	1	8	19.0-21.0	20.0	109.8-143.5	125.0	15.5-16.2	15.8	16.0-16.8	16.5	3.27-4.17	3.74	63.3-64.4	63.9
6/15/59	13	16	13.0-19.6	15.8	30.3-124.0	61.1	16.8-17.3	17.2	5.4- 8.9	6.7	3.35-3.75	3.60	70.8-74.0	72.6
7/6/60	9	16	14.6-18.4	17.3	53.1-111.5	90.9	15.7-16.4	16.0	14.4-15.7	15.1	2.60-3.62	2.90	66.0-66.6	66.2
7/20/58	5	8	17.7-19.5	18.5	84.7-112.3	98.3	14.8-15.6	15.2	11.6-13.7	12.9	2.85-3.78	3.39	67.1-70.4	68.1
8/9/59	8	16	14.8-16.4	15.5	44.5- 69.6	56.6	16.4-17.3	16.8	5.3- 8.0	6.6	3.30-4.28	3.89	70.3-74.7	72.3
9/1/60	10	16	13.0-19.2	15.2[2]	39.1-123.9	62.5	16.3-17.8	16.9	8.4-10.8	8.9	3.14-3.94	3.54	68.8-73.0	70.6
9/24/58	7	12	14.6-16.2	15.4	44.6- 62.8	55.1	16.7-17.1	16.9	2.4- 4.1	3.5	3.34-4.31	4.00	75.7-77.3	76.7
10/13/59	7	16	14.1-16.5	15.3	41.5- 68.0	57.5	16.8-16.9	16.8	2.7- 4.6	3.8	4.04-4.29	4.17	73.7-76.2	75.0
10/13/60	10	16	14.9-17.1	15.8	42.3- 92.0	65.3	14.8-15.7	15.2	7.1- 8.2	7.9	3.03-4.01	3.59	71.8-73.5	72.9
11/11/59	8	16	13.7-17.1	15.7	37.6- 67.9	55.3	16.7-17.9	17.2	2.8- 4.4	3.6	3.38-4.54	3.89	71.9-76.0	74.3
12/9/59	6	20	12.0-15.3	13.4	23.2- 49.6	30.7	15.7-17.1	16.6	2.5- 4.6	3.4	2.65-4.07	3.49	74.0-78.9	76.4

[1] Forktail measurement.
[2] Overall measurement.

Table 15A.—Length, weight, and proximate composition—threadfin *(Polydactylus octonemus)*

Date sample obtained	Location	Total number analyzed	Length[1]		Weight		Protein		Oil		Ash		Moisture	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
4/21/60	17	160	6.4- 8.8	7.6	3.0- 9.8	4.6	17.9-18.3	18.1	4.5- 4.8	4.7	3.54-3.83	3.64	73.4-73.6	73.6
5/12/60	7	40	9.1- 9.9	9.5	9.1-12.5	11.0	16.9-18.0	17.7	2.7- 3.6	3.3	1.24-3.07	2.03	75.5-78.3	77.2
6/15/59	13	36	8.8-11.6	10.4	10.3-20.7	15.9	18.2-18.4	18.3	2.3- 2.6	2.5	3.22-3.63	3.40	75.9-77.0	76.3
7/20/58	5	32	10.4-12.2	11.3	15.9-27.9	20.7	16.9-17.6	17.3	1.6- 2.1	1.8	3.52-4.15	3.98	76.2-77.3	76.6
8/12/59	8	16	11.8-13.8	12.9	26.5-49.5	36.6	18.8-19.2	19.1	3.5- 4.2	3.9	3.58-4.28	3.89	73.0-74.5	73.9
8/30/60	10	20	10.0-12.5	11.1	17.6-27.8	21.8	17.8-18.6	18.1	1.2- 1.6	1.5	3.08-4.53	3.81	75.9-78.5	77.1
9/22/59	6	16	12.5-15.1	14.0	33.3-56.2	45.4	18.2-18.6	18.4	6.9- 7.7	7.5	2.63-3.69	3.36	70.6-71.5	71.1
10/13/59	7	16	13.3-16.4	14.5	38.2-95.8	58.0	17.8-18.4	18.1	10.0-11.4	10.9	2.83-4.06	3.52	66.8-69.5	67.9
11/3/58	13	16	12.9-16.5	14.6	29.7-73.1	47.7	17.3-18.3	17.8	5.1- 8.5	6.8	3.44-4.12	3.73	69.9-72.9	71.7

[1] Forktail measurement.

Table 16A.—Length, weight, and proximate composition—thread herring *(Opisthonema oglinum)*

Date sample obtained	Location	Total number analyzed	Length[1] Range	Length[1] Average	Weight Range	Weight Average	Protein Range	Protein Average	Oil Range	Oil Average	Ash Range	Ash Average	Moisture Range	Moisture Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
2/16/60	10	24	11.1-14.2	12.4	17.6- 44.9	27.9	14.6-14.8	14.7	17.8-19.7	18.6	2.46-3.18	2.84	62.9-64.8	63.9
2/28/58	10	16	13.4-15.4	14.3	36.8- 52.8	43.8	18.5-19.2	18.9	7.8- 8.3	8.1	2.57-3.66	3.24	68.4-70.1	69.3
3/30/58	10	8	17.0-19.6	18.3	77.2-115.5	95.6	19.4-19.4	19.4	4.8- 5.4	5.0	4.46-4.94	4.59	69.9-70.8	70.4
4/5/59	14	16	13.4-15.5	14.4	38.2- 58.8	47.6	17.4-18.3	17.9	3.7- 4.4	4.1	2.25-3.34	2.79	74.3-76.7	75.4
5/8/59	6	16	12.6-15.0	13.7	32.5- 51.0	40.9	18.9-19.4	19.2	3.8- 4.3	4.1	3.11-3.91	3.53	73.2-74.1	73.5
6/14/59	13	12	17.9-21.3	18.9	98.0-133.9	113.5	19.7-20.5	20.2	2.6- 3.7	3.0	3.74-5.16	4.53	72.9-74.6	73.5
7/6/59	8	16	14.8-19.6	17.5	62.3-129.6	94.3	20.1-20.8	20.4	4.7- 5.8	5.2	3.10-4.27	3.61	69.6-72.4	71.4
8/19/58	5	5	17.4-18.8	18.5	89.0-109.9	100.1	18.3-18.8	18.6	3.2- 3.9	3.5	2.76-4.19	3.27	73.4-75.2	74.4
9/22/59	6	16	13.4-18.0	15.4	43.0- 96.3	61.1	19.0-19.5	19.3	3.2- 5.6	4.3	3.68-4.64	4.12	71.3-72.5	72.0
10/3/60	8	12	10.4-20.3	15.6	26.4-134.8	68.1	17.1-18.5	17.7	6.4- 7.7	6.8	3.59-4.11	3.95	70.4-71.6	71.2
10/19/59	7	16	12.4-14.9	13.9	30.8- 54.6	43.3	15.1-15.6	15.3	14.4-17.5	15.6	3.27-4.35	3.71	64.3-66.0	65.3
11/18/59	7	16	11.8-14.5	13.3	26.5- 52.2	39.8	14.4-14.7	14.6	18.5-21.0	19.2	3.00-3.53	3.32	61.6-63.5	62.9
12/9/59	6	16	9.3-14.1	12.1	11.9- 47.2	29.0	14.1-14.9	14.7	13.3-19.5	16.1	2.48-3.20	2.94	63.7-68.6	66.5

[1] Forktail measurement.

Table 17A.—Length, weight, and proximate composition—white trout *(Cynoscion nothus)*

Date sample obained	Location	Total number analyzed	Length[1] Range	Length[1] Average	Weight Range	Weight Average	Protein Range	Protein Average	Oil Range	Oil Average	Ash Range	Ash Average	Moisture Range	Moisture Average
			Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1/15/59	4	16	16.4-21.5	18.8	36.0- 80.4	54.7	15.4-15.8	15.6	3.5-4.1	3.7	2.03-2.50	2.25	77.7-78.6	78.2
2/6/59	10	16	17.2-21.6	19.4	42.8- 83.0	61.4	16.9-17.3	17.1	3.0-4.2	3.6	3.18-4.01	3.61	74.0-76.8	75.6
3/11/59	10	16	17.7-23.8	19.8	49.5-114.4	66.0	17.1-17.8	17.4	2.4-3.9	3.3	3.05-4.35	3.75	74.3-77.6	76.3
4/6/59	12	16	19.2-23.9	21.1	51.1- 99.1	73.2	15.4-16.4	16.0	1.7-2.2	2.1	2.83-4.10	3.55	78.0-78.9	78.4
5/14/59	9	16	19.6-24.8	22.7	62.5-124.6	100.6	16.4-17.1	16.8	1.6-1.8	1.7	2.97-3.84	3.47	78.1-78.9	78.5
6/21/59	8	16	18.3-31.2	24.0	61.9-319.6	143.6	17.9-18.5	18.2	2.6-4.8	3.9	2.72-3.21	2.91	75.0-77.3	75.8
7/20/58	5	7	17.6-29.9	22.2	55.1-128.0	87.8	17.0-18.1	17.5	3.3-6.3	5.0	2.56-3.76	3.09	73.1-76.5	74.3
8/1/60	19	16	16.7-23.8	20.1	45.7-107.3	75.9	16.1-17.7	17.0	2.5-3.5	3.0	2.28-4.30	3.27	75.1-78.7	76.8
8/12/59	8	16	16.4-22.6	20.2	36.9-111.5	82.3	18.1-18.7	18.4	5.4-6.2	5.7	2.39-3.08	2.70	73.3-73.6	73.4
8/30/60	10	16	15.4-21.0	18.5	45.1- 88.9	65.8	17.4-17.7	17.6	4.7-5.4	5.2	2.05-2.89	2.45	74.2-75.9	75.0
9/22/59	6	16	17.6-27.5	22.3	45.2-187.3	108.4	16.5-16.9	16.7	5.6-7.8	6.8	2.72-3.50	3.23	72.2-74.4	73.1
10/19/59	7	16	16.0-20.3	18.6	40.0- 77.4	60.5	16.3-17.1	16.7	5.8-7.3	6.5	1.34-2.82	2.25	73.4-76.4	74.4
10/21/58	10	8	19.9-24.2	22.4	90.6-141.1	120.0	17.4-18.2	17.7	4.6-7.4	6.2	2.41-3.89	2.93	72.2-74.9	73.1
11/11/59	8	16	19.1-21.5	20.3	58.6- 92.6	79.0	16.5-17.6	17.1	4.8-7.0	5.7	2.39-2.99	2.68	73.7-75.4	74.4
12/9/59	6	18	14.8-19.8	16.3	25.0- 74.2	37.5	16.7-17.3	17.0	5.4-8.6	7.3	1.40-3.00	2.42	71.5-77.5	73.9

[1] Overall measurement.

Table 18A.—Length, weight, and proximate composition—miscellaneous species

Common name	Scientific name	Date of sample	Location	Total number analyzed	Length		Weight		Protein	
					Range	Average	Range	Average	Range	Average
					Cm.	*Cm.*	*Grams*	*Grams*	*Percent*	*Percent*
Grunt	*Haemulon* sp.	9/24/58	7	8	13.0-19.0[1]	16.0	31.3-121.7	67.1	16.0-17.1	16.6
Scad	*Trachurus lathami*	10/21/58	10	32	10.9-14.4[1]	11.8	15.1-30.0	19.6	16.9-17.5	17.3
Silver perch	*Bairdella chrysura*	1/15/59	11	28	9.6-18.4[2]	12.7	7.7-72.7	24.8	16.8-16.9	16.8
		2/7/59	2	20	12.2-16.4[2]	14.6	14.9-46.3	30.8	17.4-17.8	17.6
		4/20/59	11	16	12.3-16.4[2]	14.4	18.9-48.6	32.0	16.3-17.2	16.8
		6/20/59	9	16	12.2-16.6[2]	14.9	19.6-55.9	38.4	15.9-16.8	16.6
		10/13/59	10	32	8.9-10.4[2]	9.7	15.2-29.8	22.5	18.2-18.4	18.3
		10/21/59	10	16	14.8-18.4[1]	16.9	32.3-62.6	51.9	15.9-16.9	16.4
		12/9/59	6	18	11.9-15.9[1]	13.3	17.3-44.9	24.8	17.3-18.1	17.8
Silversides	*Menidia* sp.	2/28/58	10	109	7.5-9.8[1]	8.7	4.4-9.2	6.3	17.2-17.6	17.4
Star drum	*Stellifer lanceolatus*	1/6/59	5	25	10.0-14.7[2]	12.5	10.5-45.4	25.7	13.9-15.2	14.2
		2/15/60	9	32	9.7-11.3[2]	10.6	9.8-20.4	13.3	16.4-18.2	17.4
		3/18/60	9	24	9.7-13.3[2]	11.7	16.6-36.1	24.1	14.3-15.5	15.1
		5/14/59	9	20	12.4-14.8[2]	13.8	23.3-38.5	32.2	15.8-16.5	16.3
		6/19/58	10	38	10.9-13.9[2]	12.5	10.8-29.4	20.2	14.4-15.2	15.0
		8/16/60	9	16	12.3-14.5[2]	13.3	22.5-34.5	28.1	15.8-17.2	16.5
		12/2/59	9	24	10.3-14.6[2]	13.1	12.1-38.6	25.6	17.1-17.9	17.7

Common name	Scientific name	Date of sample	Location	Total number analyzed	Oil		Ash		Moisture	
					Range	Average	Range	Average	Range	Average
					Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Grunt	*Haemulon* sp.	9/24/58	7	8	7.1-11.8	9.9	2.99-4.48	3.71	68.1-72.5	70.2
Scad	*Trachurus lathami*	10/21/58	10	32	2.0-2.5	2.2	3.03-4.28	3.55	76.5-77.6	76.9
Silver perch	*Bairdella chrysura*	1/15/59	11	28	3.2-4.8	4.0	2.79-4.94	3.80	73.2-76.5	74.9
		2/7/59	2	20	3.7-4.3	4.1	4.55-5.33	4.86	72.2-74.0	73.2
		4/20/59	11	16	2.3-3.0	2.7	3.51-4.76	4.11	75.0-77.0	76.5
		6/20/59	9	16	1.5-2.7	2.2	2.53-3.61	3.20	77.0-78.8	77.6
		10/13/59	10	32	5.6-7.0	6.1	3.05-3.67	3.36	72.0-72.5	72.2
		10/21/59	10	16	1.5-2.5	2.2	3.15-5.07	4.48	75.6-79.1	76.9
		12/9/59	6	18	4.8-6.4	5.7	3.92-4.88	4.35	71.9-72.9	72.3
Silversides	*Menidia* sp.	2/28/58	10	109	5.6-6.1	5.9	7.74-8.44	8.23	66.8-68.1	67.5
Star drum	*Stellifer lanceolatus*	1/6/59	5	25	3.2-4.2	3.8	3.87-5.13	4.67	74.8-77.5	76.3
		2/15/60	9	32	3.8-4.2	4.1	3.58-4.05	3.78	73.8-75.0	74.6
		3/18/60	9	24	4.5-5.0	4.7	3.67-5.58	4.51	73.9-77.4	75.6
		5/14/59	9	20	3.7-4.2	4.0	3.77-4.84	4.25	73.9-75.6	74.7
		6/19/58	10	38	3.4-4.0	3.8	3.89-4.28	4.11	75.1-76.9	76.3
		8/16/60	9	16	1.5-1.7	1.6	3.89-5.55	4.50	77.3-78.9	78.3
		12/2/59	9	24	3.0-3.9	3.4	3.54-5.32	4.53	73.6-75.9	74.3

[1] Forktail measurement.
[2] Overall measurement.

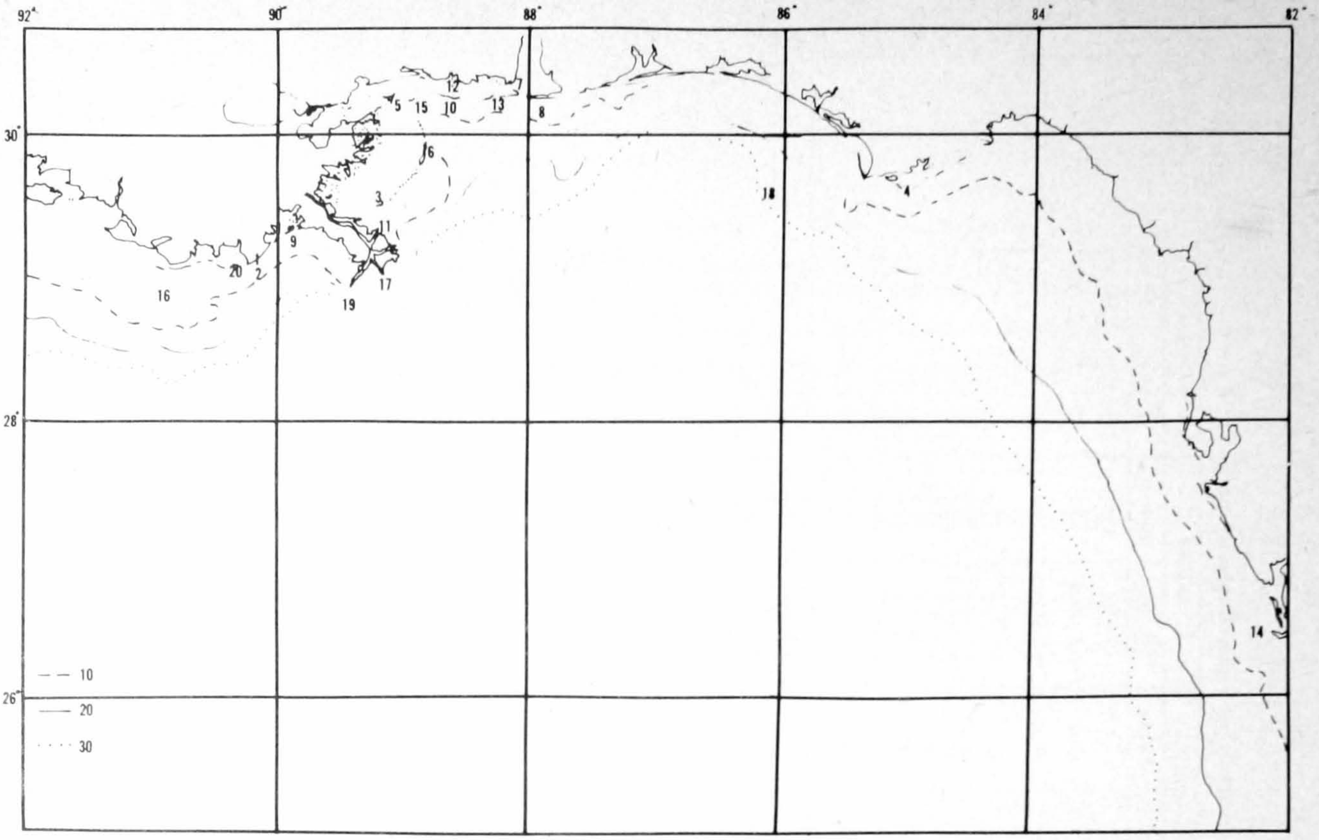

Figure 1A.—Map of fishing grounds indicating locations where samples were obtained. See Table 1A for meaning of code numbers.

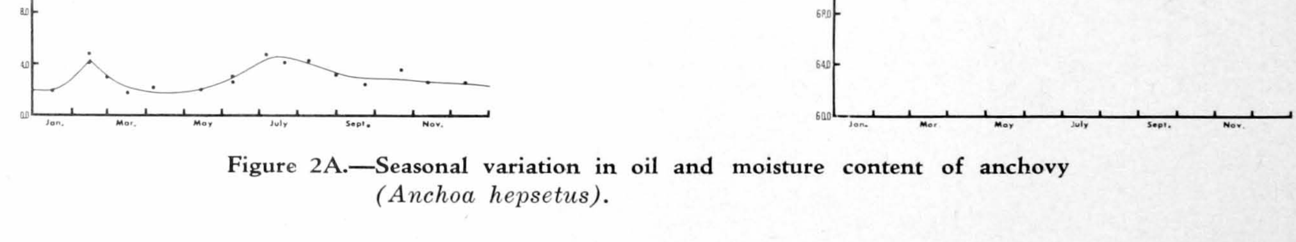

Figure 2A.—Seasonal variation in oil and moisture content of anchovy *(Anchoa hepsetus)*.

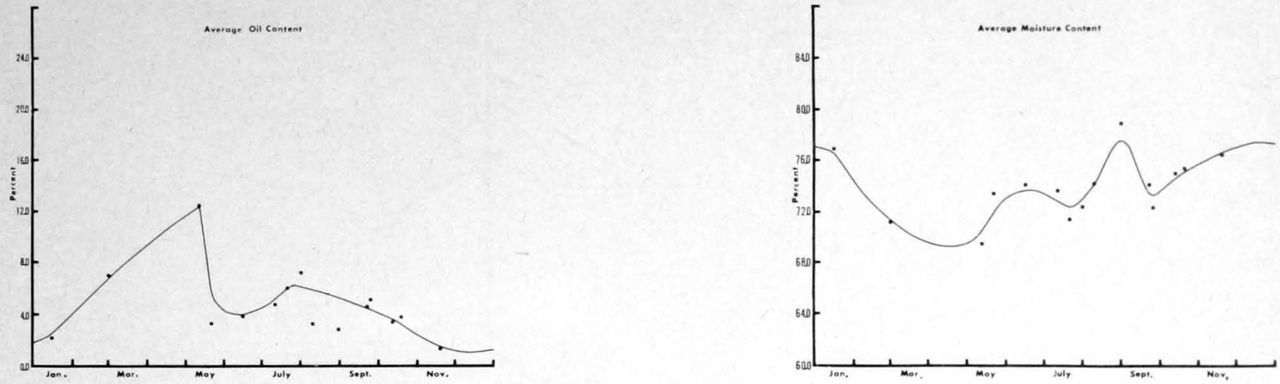

Figure 3A.—Seasonal variation in oil and moisture content of bumper *(Chloroscombrus chrysurus).*

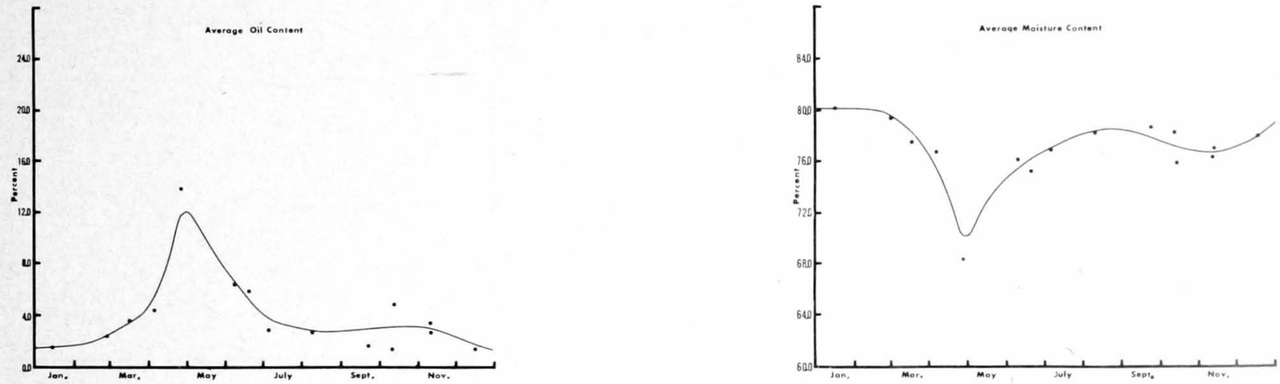

Figure 4A.—Seasonal variation in oil and moisture content of butterfish *(Poronotus triacanthus).*

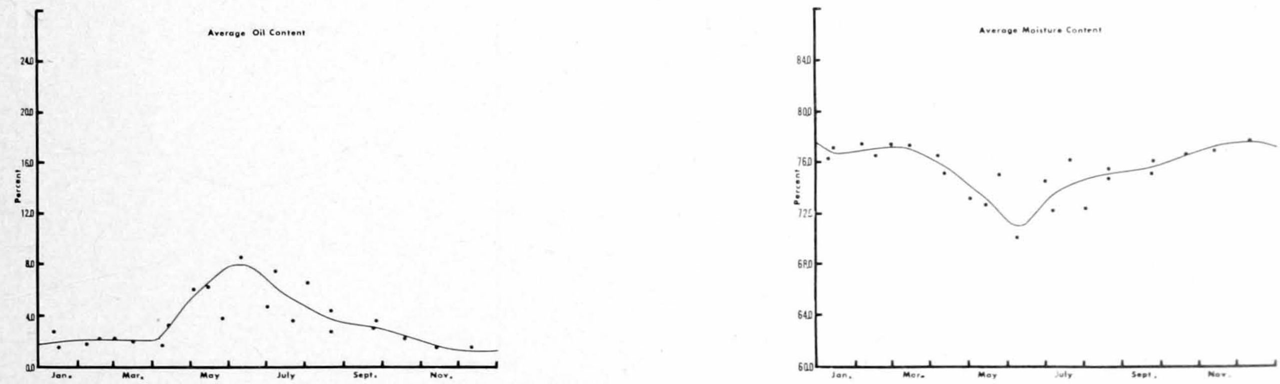

Figure 5A.—Seasonal variation in oil and moisture content of croaker *(Micropogon undulatus).*

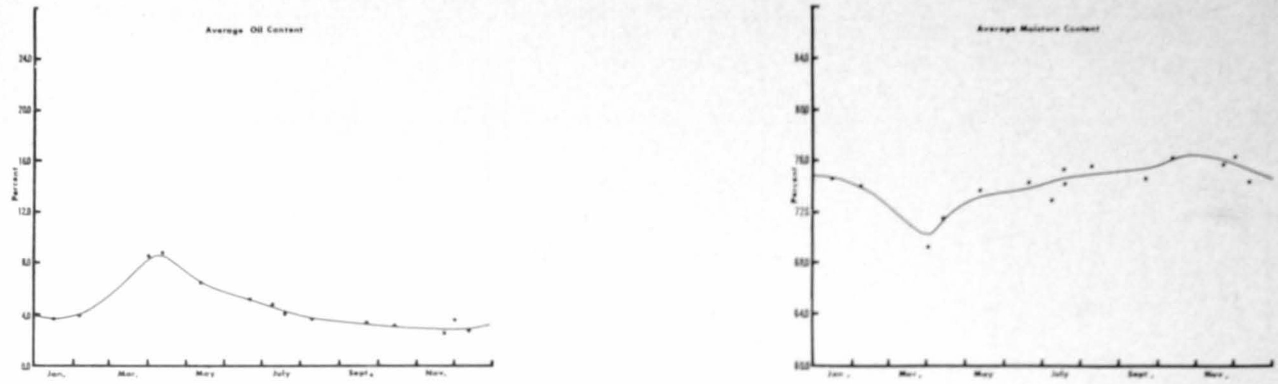

Figure 6A.—Seasonal variation in oil and moisture content of banded croaker *(Larimus fasciatus)*.

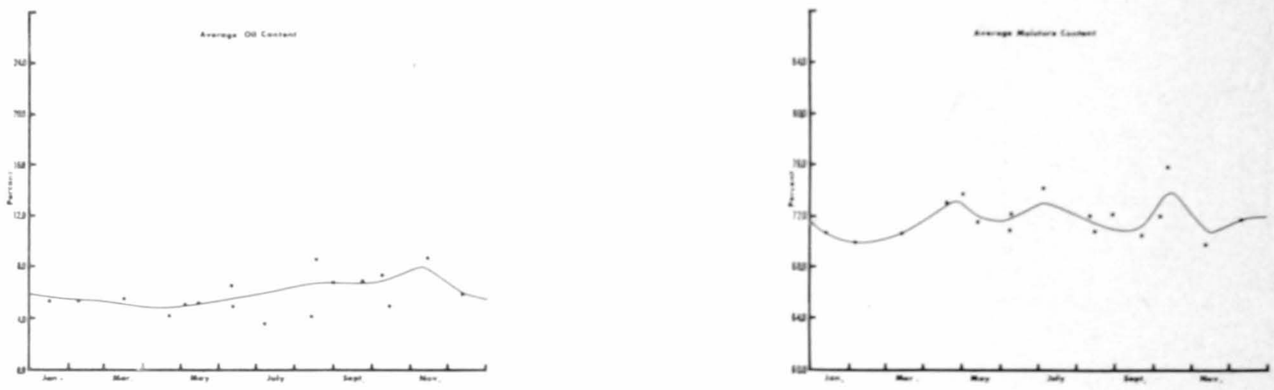

Figure 7A.—Seasonal variation in oil and moisture content of hardhead *(Galeichthys felis)*.

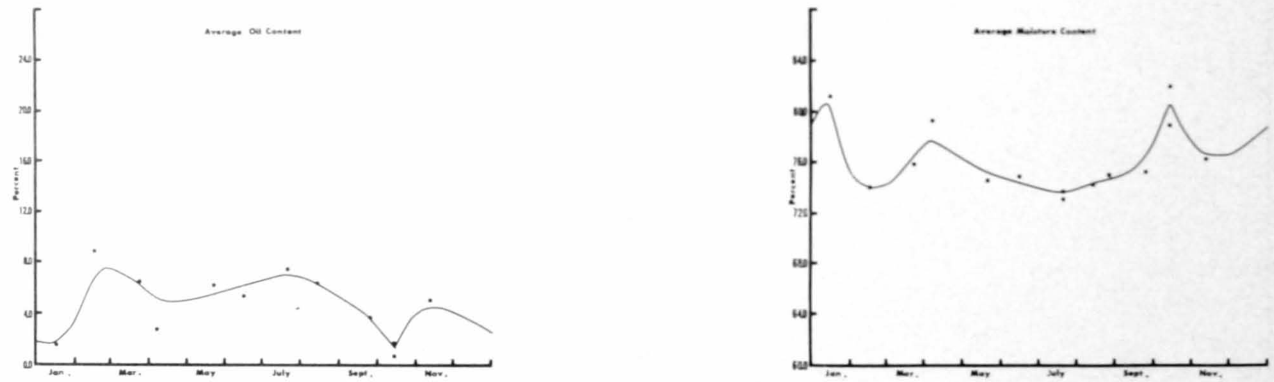

Figure 8A.—Seasonal variation in oil and moisture content of harvestfish *(Peprilus alepidotus)*.

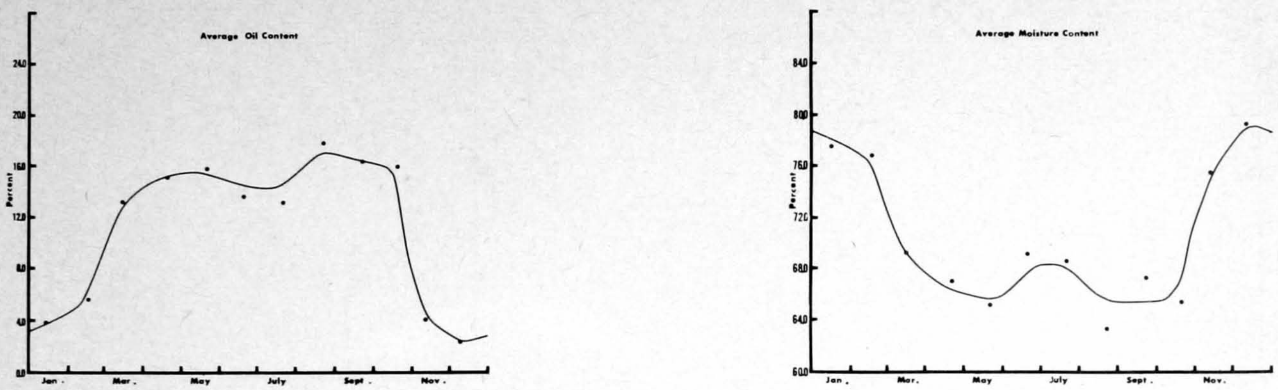

Figure 9A.—Seasonal variation in oil and moisture content of trawl-caught menhaden *(Brevoortia patronus)*.

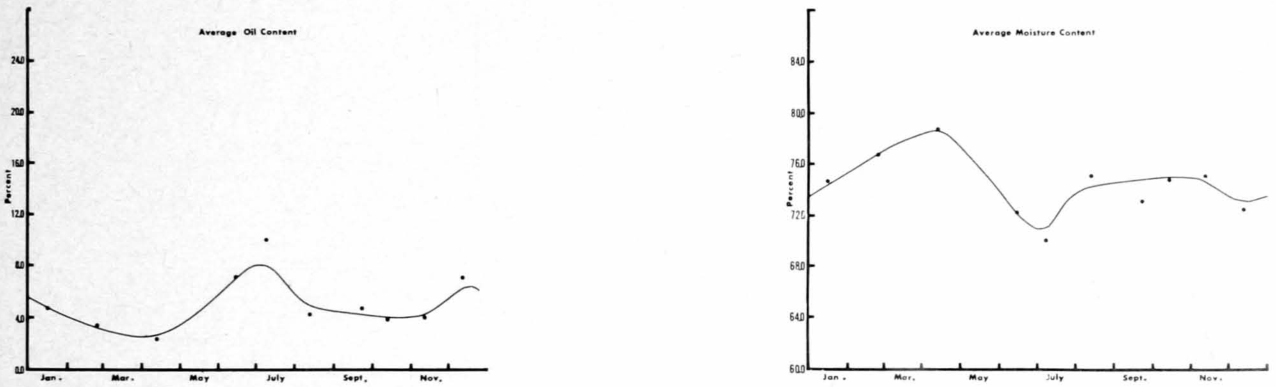

Figure 10A.—Seasonal variation in oil and moisture content of pigfish *(Orthopristis chrysopterus)*.

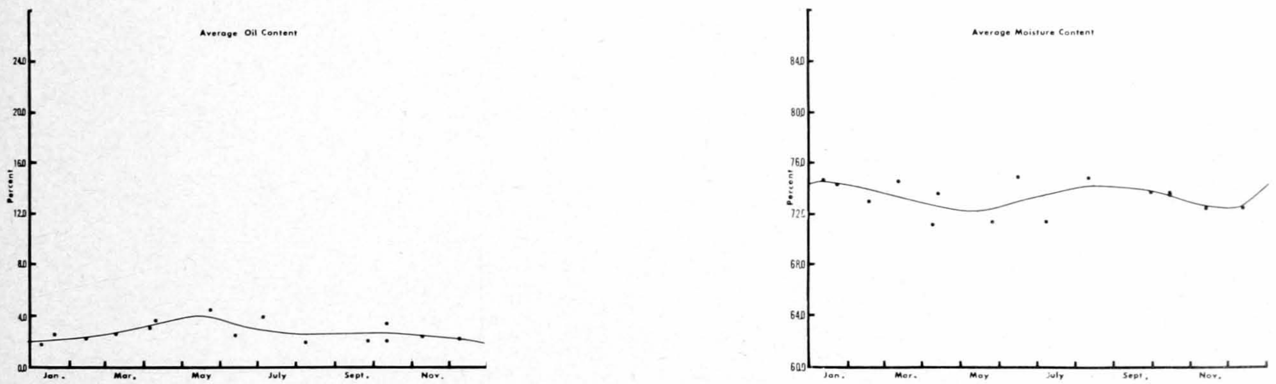

Figure 11A.—Seasonal variation in oil and moisture content of porgy *(Stenotomus caprinus)*.

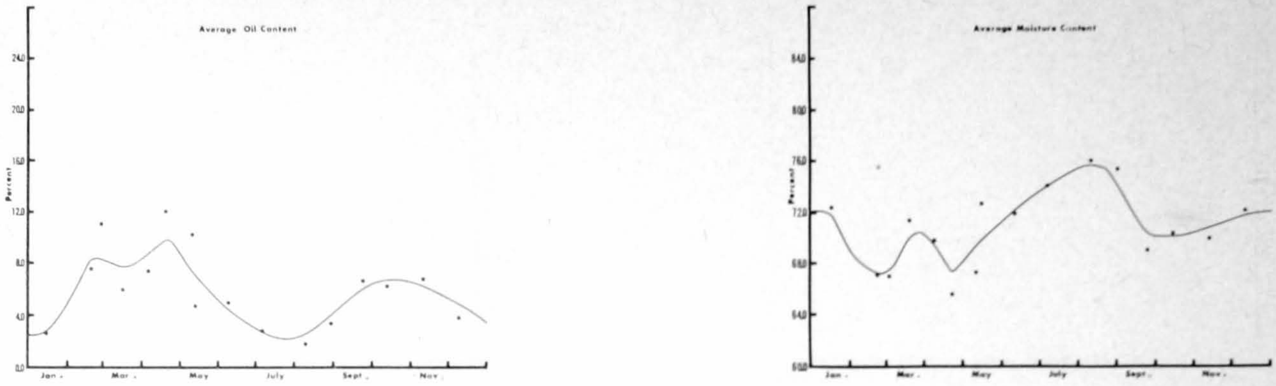

Figure 12A.—Seasonal variation in oil and moisture content of razor-belly *(Harengula pensacolae)*.

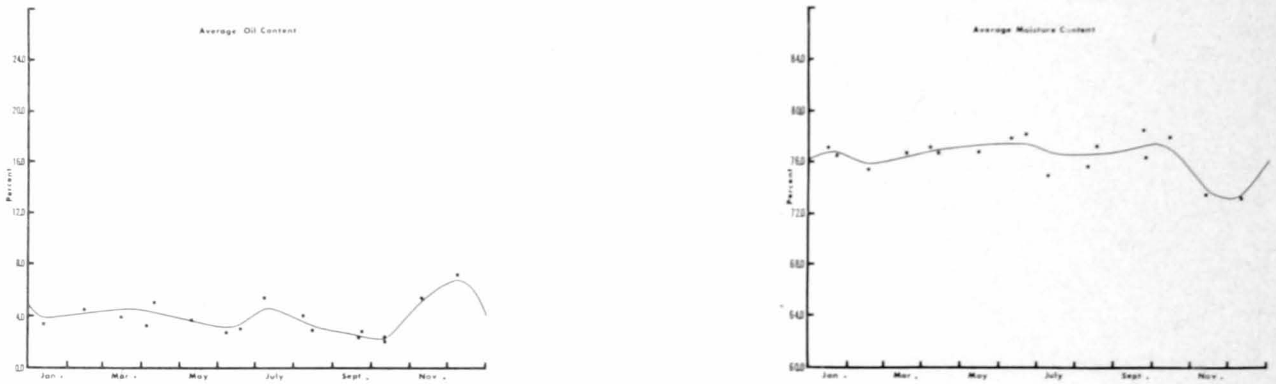

Figure 13A.—Seasonal variation in oil and moisture content of silver eel *(Trichiurus lepturus)*.

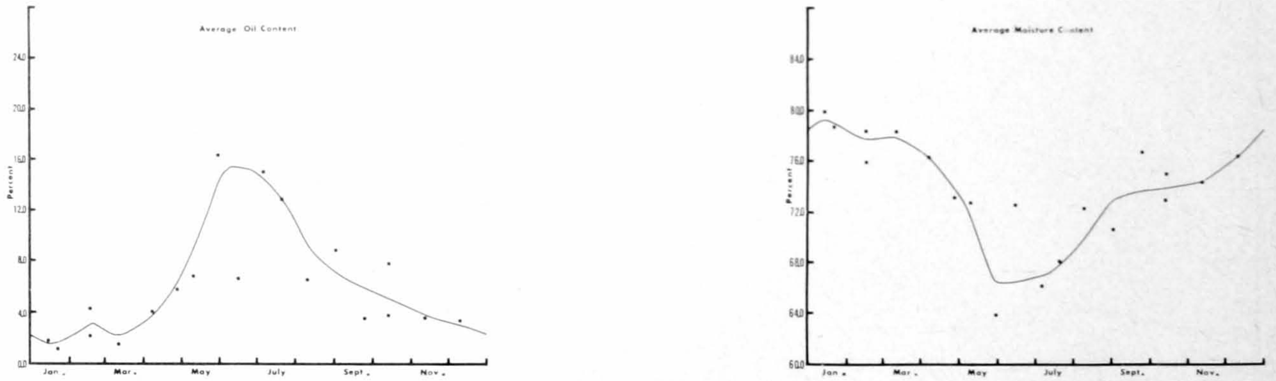

Figure 14A.—Seasonal variation n the oil and moisture content of spot *(Leiostomus xanthurus)*.

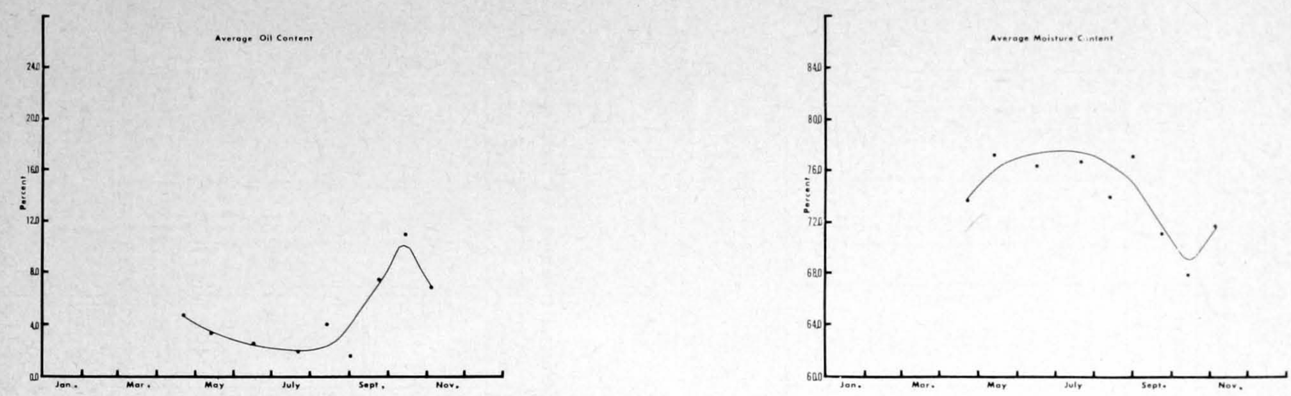

Figure 15A.—Seasonal variation in the oil and moisture content of thread-fin *(Polydactylus octonemus).*

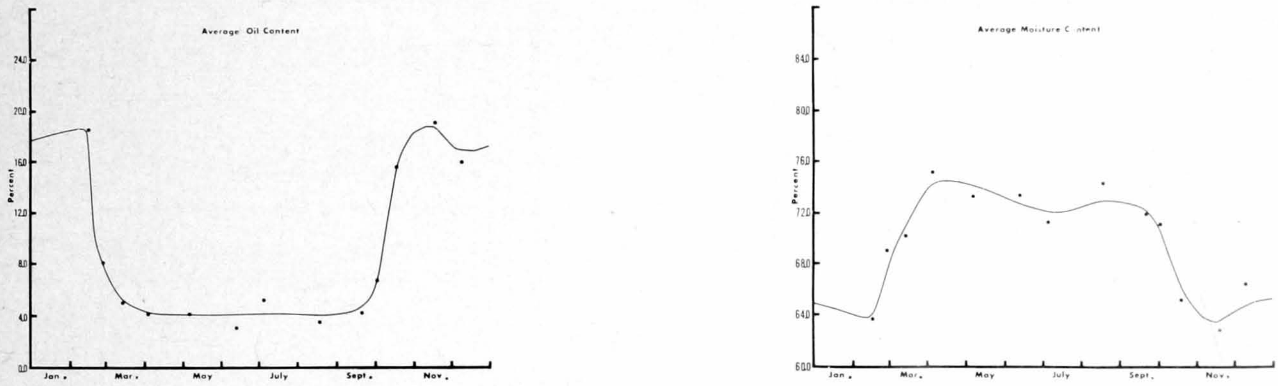

Figure 16A.—Seasonal variation in the oil and moisture content of thread herring *(Opisthonema oglinum).*

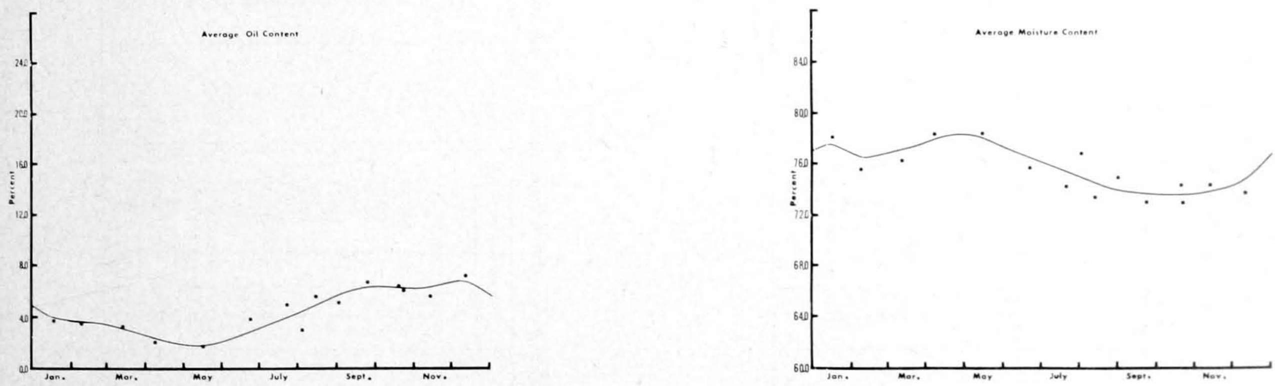

Figure 17A.—Seasonal variation in the oil and moisture content of white trout *(Cynoscion nothus).*

Table 19A.—Standard error of estimate (S_{YX}), correlation coefficient (r), and probability (P) based on Student t values) of data pairs

Species	Moisture and oil content			Moisture and protein content			Moisture and ash content			Moisture content and weight			Moisture content and length		
	S_{YX}	r	P	S_{YX}	r	P	S_{YX}	r	P	S_{YX}	r	P	S_{YX}	r	P
Anchovy	0.27	.9613	.001	0.29	.9189	.001	0.35	.4397	.001	1.70	.4009	.005	0.74	.1161	--
Bumper	1.66	.7710	.001	0.87	.2905	.025	1.07	.0741	--	20.95	.6004	.001	3.11	.5693	.001
Butterfish	1.75	.8160	.001	0.97	.2547	.050	0.50	.3218	.010	19.09	.2503	.050	2.02	.1442	--
Croaker	1.17	.8312	.001	0.74	.2177	.050	1.12	.0435	--	20.93	.0842	--	15.00	.0173	--
Croaker, banded ..	1.25	.7853	.001	1.40	.0721	--	1.00	.1378	--	21.10	.1424	--	1.72	.1228	--
Hardhead	1.33	.6311	.001	0.76	.4210	.001	1.04	.3078	.025	39.59	.8370	.001	3.02	.4363	.001
Harvestfish	1.11	.8950	.001	0.93	.6496	.001	0.34	.3983	.005	--	--	--	9.77	.0685	--
Menhaden	1.30	.9725	.001	0.69	.4120	.005	0.83	.0974	--	27.50	.5150	.001	1.88	.4023	.005
Porgy	0.72	.5265	.001	0.65	.4703	.001	0.65	.7231	.001	8.65	.7196	.005	1.29	.5794	.001
Pigfish	1.06	.8956	.001	0.67	.5182	.001	0.71	.2765	--	25.16	.1743	--	2.09	.1063	--
Razorbelly	1.39	.8925	.001	2.20	.1466	--	0.95	.2102	--	14.07	.2924	.025	1.55	.2027	--
Silver eel	0.76	.8338	.001	0.67	.5182	.001	--	--	--	38.00	.3947	.001	8.12	.1019	--
Silver perch	0.71	.8857	.001	0.36	.8536	.001	0.74	.2531	--	7.76	.6178	.001	1.65	.6267	.001
Spot	1.75	.9131	.001	0.88	.0400	--	0.51	.1606	--	17.91	.5941	.001	1.83	.2609	.025
Star drum	0.74	.5915	.001	1.17	.4316	.025	0.58	.2349	--	5.74	.2853	--	1.01	.2630	--
Threadfin	0.94	.9473	.001	0.52	.1862	--	0.65	.2416	--	10.82	.7896	.001	2.44	.6476	.001
Thread herring ...	1.94	.9465	.001	1.29	.7879	.001	0.66	.1819	--	24.00	.5483	.001	1.86	.5785	.001
White trout	0.86	.8794	.001	0.66	.5183	.001	--	--	--	29.78	.0761	--	2.44	.1345	--

Table 20A.—Standard error of estimate (S_{YX}), correlation coefficient (r), and probability (P) (based on Student t values) of data pairs

Species	Protein and oil content			Protein and ash content			Protein content and weight			Protein content and length			Ash and oil content		
	S_{YX}	r	P	S_{YX}	r	P	S_{YX}	r	P	S_{YX}	r	P	S_{YX}	r	P
Anchovy	0.85	.5232	.001	0.30	.6259	.001	1.82	.1805	--	0.75	.0640	--	0.92	.3807	.005
Bumper	2.55	.2154	.001	0.90	.5503	.001	25.13	.2817	.025	3.42	.4293	.001	2.35	.4371	.001
Butterfish	3.01	.0793	--	0.53	.1043	--	19.01	.2657	.050	1.87	.4053	.001	2.63	.4902	.001
Croaker	2.11	.0583	--	1.11	.1652	--	20.30	.2559	.025	15.00	.0360	--	2.02	.3056	.005
Croaker, banded ..	1.98	.1905	--	1.00	.1697	--	21.07	.1532	--	1.72	.1452	--	1.86	.3897	.005
Hardhead	1.65	.2711	.050	0.97	.4488	.001	41.11	.5686	.001	3.24	.2598	.050	1.65	.2584	.050
Harvestfish	2.32	.3672	.010	0.36	.2343	--	--	--	--	9.80	.0141	--	2.18	.4840	.001
Menhaden	4.72	.5343	.001	0.83	.1330	--	31.37	.2102	--	1.96	.2942	.050	5.59	.0264	--
Pigfish	2.36	.1734	--	0.69	.3360	.050	21.17	.5600	.001	1.74	.5608	.001	2.39	.0282	--
Porgy	0.85	.0905	--	0.94	.0768	--	11.95	.2820	--	1.52	.2891	.025	0.85	.0223	--
Razorbelly	3.10	.0223	--	0.94	.2465	--	14.60	.1252	--	1.57	.1459	--	3.05	.1711	--
Silver eel	1.33	.2681	.025	--	--	--	37.58	.9512	.001	8.13	.0948	--	1.35	.2142	--
Silver perch	0.73	.8766	.001	0.76	.1220	--	7.71	.6241	.001	1.53	.6918	.001	1.53	.0300	--
Spot	4.21	.2002	--	0.51	.1649	--	21.45	.2685	.025	1.78	.3497	.005	4.09	.3074	.005
Star drum	0.89	.2319	--	0.60	.0316	--	5.90	.1676	--	--	--	--	0.91	.1421	--
Threadfin	2.92	.1063	--	0.65	.1992	--	17.39	.1691	--	3.12	.2258	--	2.94	--	--
Thread herring ...	2.24	.9283	.001	0.59	.4985	.001	19.79	.7243	.001	1.52	.7451	.001	5.53	.3982	.001
White trout	1.79	.1714	--	0.64	.1489	--	27.90	.3569	.010	2.42	.1902	--	1.67	.4019	.001

Table 21A.—Standard error of estimate (S_{YX}), correlation coefficient (r), and probability (P) (based on Student t values) of data pairs

Species	Ash content and weight			Ash content and length			Oil content and weight			Oil content and length			Weight and length		
	S_{YX}	r	P	S_{YX}	r	P	S_{YX}	r	P	S_{YX}	r	P	S_{YX}	r	P
Anchovy	1.75	.3272	.010	0.74	.1063	--	1.56	.5392	.001	0.73	.1979	--	0.52	.7103	.001
Bumper	26.19	.0244	--	3.76	.1131	--	23.06	.4743	.001	3.56	.3417	.010	1.38	.9309	.001
Butterfish	18.89	.2872	.025	2.03	.0989	--	19.59	.1166	--	2.04	.0141	--	0.99	.8734	.001
Croaker	20.89	.1024	--	14.99	.0500	--	20.58	.1987	--	15.00	.0282	--	14.96	.0812	--
Croaker, banded	21.18	.1153	--	1.70	.1984	--	21.32	.0141	--	1.73	.0500	--	0.52	.9527	.001
Hardhead	42.34	.0866	--	3.29	.1984	--	41.79	.3862	.005	3.34	.1161	--	--	--	--
Harvestfish	41.58	.8895	.001	9.77	.0768	--	--	--	--	9.79	.0469	--	9.39	.2856	.050
Menhaden	29.49	.3939	.010	1.91	.3708	.010	27.78	.5003	.001	1.89	.3865	.010	0.74	.9315	.001
Pigfish	22.83	.4489	.005	1.86	.4643	.005	25.48	.0721	--	2.08	.1536	--	0.28	.9910	.001
Porgy	10.32	.5601	.050	1.42	.4471	.001	8.55	.7272	.005	1.26	.6035	.001	0.46	.9551	.001
Razorbelly	14.67	.0768	--	--	--	--	13.50	.3979	.005	1.52	.2891	.025	0.42	.9644	.001
Silver eel	--	--	--	7.99	.2012	--	--	--	--	7.79	.2991	.025	--	--	--
Silver perch	9.59	.2332	--	1.94	.4065	.050	6.59	.7462	.001	1.24	.8103	.001	1.09	.8574	.001
Spot	22.15	.1009	--	1.90	.0141	--	16.83	.6545	.001	1.81	.2893	.010	0.90	.8787	.001
Star drum	5.88	.1886	--	5.88	.1886	--	5.76	.2698	--	0.96	.3962	.050	0.46	.8968	.001
Threadfin	17.20	.2229	--	2.72	.5312	.001	11.00	.7819	.001	2.68	.5491	.001	1.55	.8756	.001
Thread herring	23.69	.5642	.001	1.89	.5606	.001	21.30	.6702	.001	1.63	.7000	.001	0.40	.9845	.001
White trout	29.73	.0964	--	2.42	.1822	--	29.83	.0458	--	2.37	.2670	.050	1.08	.8973	.001

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