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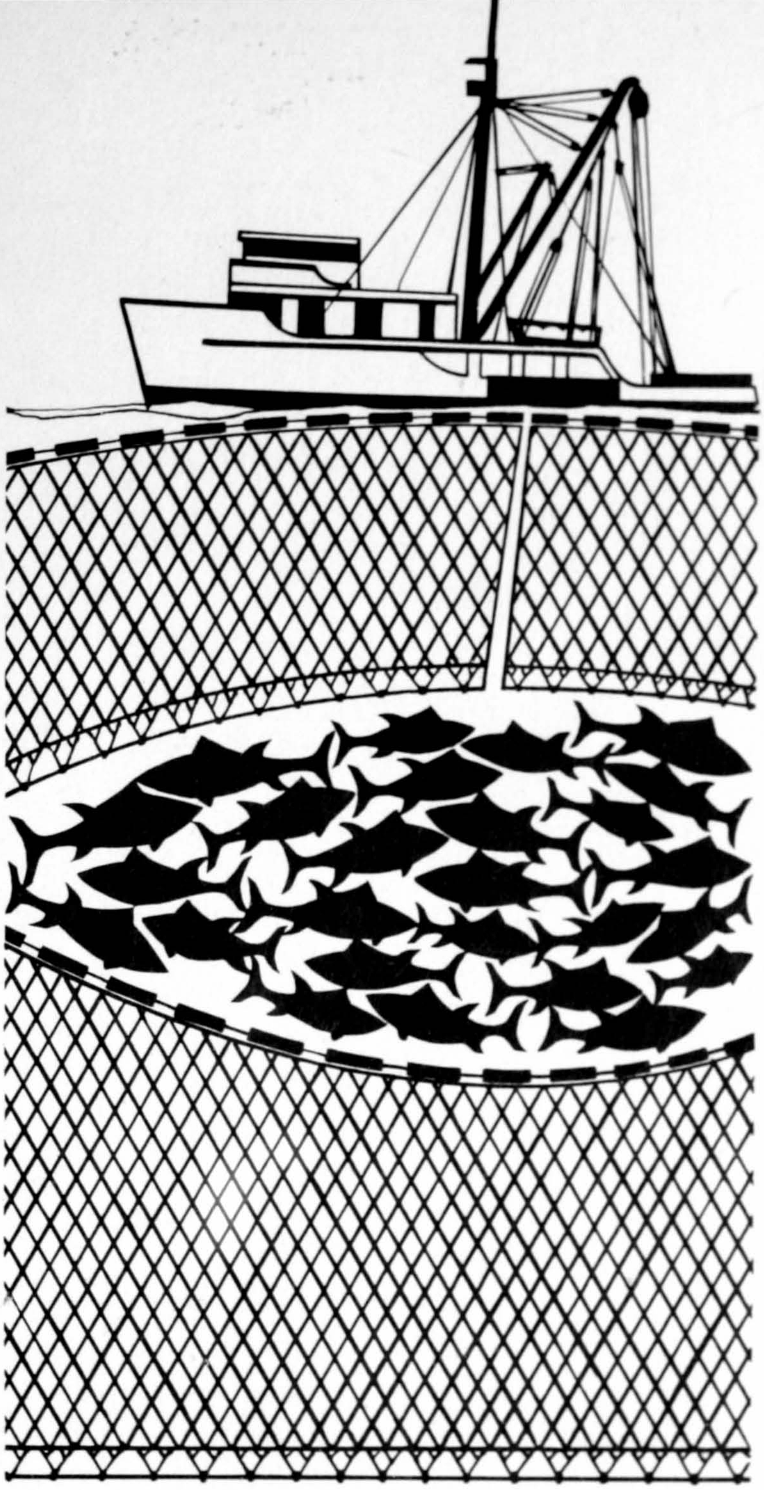

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OPENING OYSTERS AND OTHER BIVALVES USING MICROWAVE ENERGY

by

Joseph M. Mendelsohn, Louis J. Ronsivalli, Frederick J. King,
Joseph H. Carver, Robert J. Learson,
Barry W. Spracklin, and Ernest M. Kenyon

ABSTRACT

A commercial process using microwave energy can save 33 percent over hand-shucking costs and has several other advantages as well.

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INTRODUCTION

Opening the shell of oysters and of other bivalves is difficult, time-consuming, and potentially dangerous. The rate of shucking depends mainly on the capability of the shucker to insert a knife between the halves of the shell. Some shuckers find it easier to crack the shell with a hammer to provide a site for inserting the knife (Markos, 1968, personal communication).[1] These hand operations may be dangerous because the shucker's hand may be cut even though he wears a cotton glove or a rubber guard for protection. If the shell is broken, time may be lost in removing small pieces of broken shell imbedded in the meat.

Shuckers are usually paid according to the number of gallons of meats they produce. With large oysters, an exceptionally good shucker can produce up to 20 gallons of meats per 8-hour day (McGinnes, 1968, personal communica-

[1] Peter J. Markos, P. J. Markos Co., 8½ Topsfield Road, Ipswich, Massachusetts.

Authors: Joseph M. Mendelsohn, Frederick J. King, Joseph H. Carver, and Robert J. Learson, *Research Chemists*, Louis J. Ronsivalli, *Supervisory Research Food Technologist*, Barry W. Spracklin, *Physical Science Aid*, Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Massachusetts 01930; and Ernest M. Kenyon, *Supervisory Food Technologist*, Process and Development Division, Food Laboratories, U. S. Army Natick Laboratories, Natick, Massachusetts 01760.

Preprint No. 70, issued February 1969.

tion).[2] Under similar conditions, the average shucker can produce from 12 to 15 gallons per day (Seiling, 1968, personal communication).[3] With small oysters, the rate of production is lower — for example, an average shucker can produce from 10 to 12 gallons of meats per day.

The rate of production of an inexperienced shucker is so low that he cannot earn the wages he must receive under minimum wage laws. Shuckers get from $1.40 to $2.25 per gallon of meats, depending on the supply and demand for labor and raw material and on workmanship. A shucker's output is influenced by: (1) the area from which the oysters are harvested (cold-water oysters yield more meats than do warm-water oysters), (2) the season, and (3) the thickness of the shell (thick shells are more difficult to open).

About 1 percent of the oysters landed in 1965 were heat-treated to open their shells slightly (gape) and, in some instances, to loosen the meats from the shells (Lyles, 1967). Steaming conditions vary widely (Jarvis, 1943), but all of them involve cooking the meats. After the heated oysters have opened slightly, they either are cooled and the meats are removed by hand, or the hot oysters are mechanically shaken to separate the meats from the shells.

In comparison with hand-shucking, steaming offers advantages of easier removal of meats, fewer accidents, and lower labor costs even though the steaming equipment represents an added capital investment. More people, however, buy raw oysters than buy cooked oysters. The steaming process also has other disadvantages, as follows: (1) the meats are cooked and thus are not salable as raw oysters on the half-shell, (2) during cooking, juices are exuded from the meats and, because the cooked meats cannot retain these juices, weight and nutrients are lost, and (3) a significant period of time may be required to heat and then cool a batch of oysters in comparison with the time required to shuck them by hand.

Because the steaming method is not used as extensively as is hand shucking, it was not considered in the cost analyses described later in this paper.

Owing to the disadvantages of hand-shucking the oysters or of steaming them, several attempts have been made by members of the oyster industry and by private researchers and by university researchers to automate shucking by use of mechanical devices (Anonymous, 1967) such as machines (1) that crush or break oyster shells, (2) that gape the shells by mechanically shocking the oysters, and (3) that are reported to use other methods, such as enzymes or freezing. Apparently, however, most of these devices are still in an experimental stage or are not completely satisfactory. We therefore investigated a number of other methods, such as using vacuum, concentrated heat, electric shock, ultrasonic vibrations, asphyxiation, or chemical alteration of muscular tonus. In preliminary experiments, we found that the use of microwave energy was the most promising.

Accordingly, the purpose of this paper is to report on a microwave method of opening bivalves. The paper is divided into two main parts. The first deals with oysters; the second, with other bivalves.

I. OYSTERS

This part of the paper (A) discusses the microwave process and (B) compares the cost of hand-shucking with that of continuous processing.

A. MICROWAVE PROCESS

The microwave process can be adapted to either batch processing or continuous processing.

1. Batch Processing

A Raytheon Mark V (2,450 megahertz) "Radarange"[4] (Figure 1) having a power out-

[2] Frank McGinnes, Virginia Seafoods, Inc., Irvington, Virginia.

[3] Fred W. Seiling, Department of Chesapeake Bay Affairs, State of Maryland, Annapolis, Maryland.

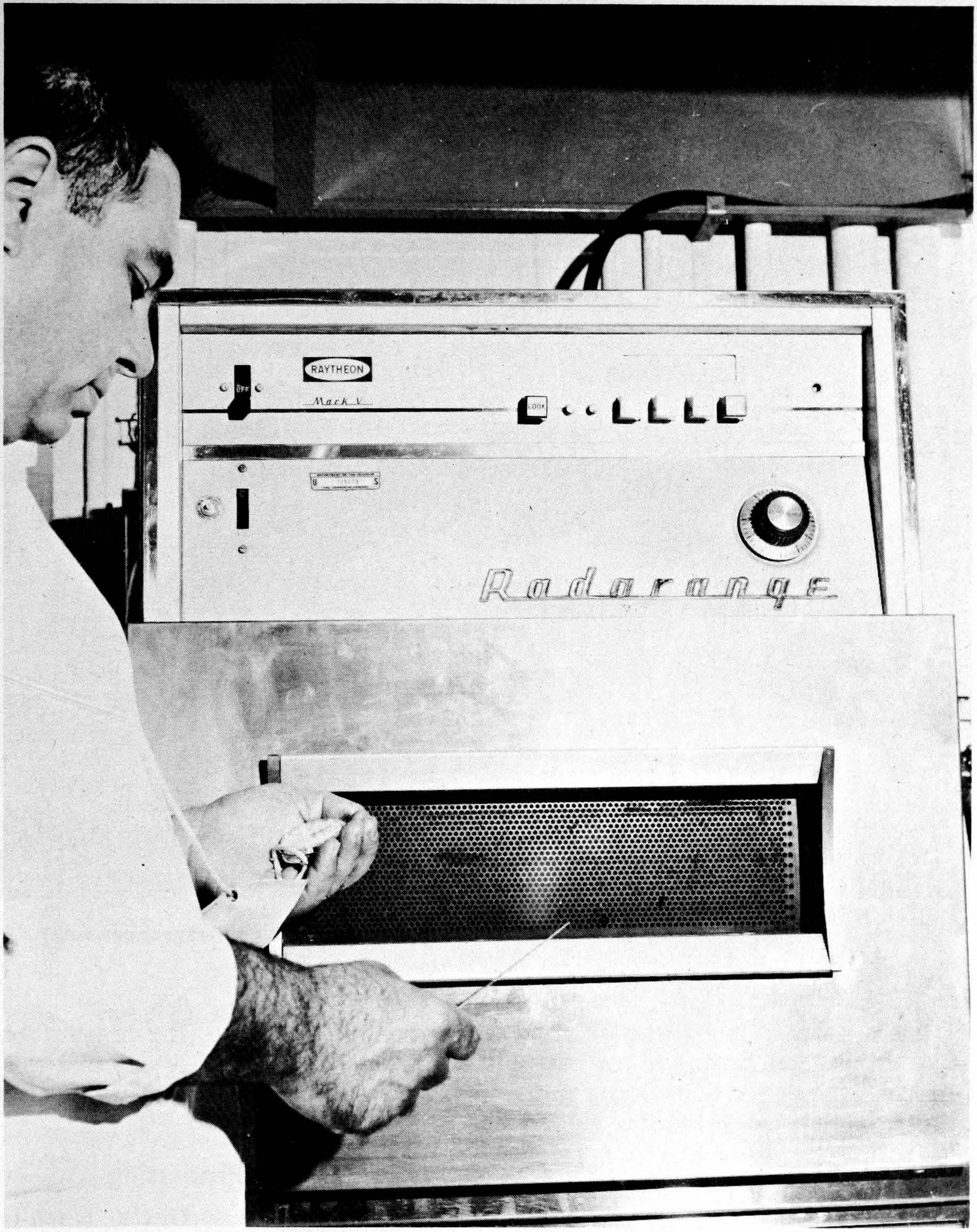

Figure 1.—A microwave-energy range used in the batch process to open bivalves.

put of 1.5 kilowatts was used initially to open oysters wide enough to permit a knife to be inserted. To overcome the problem of non-uniform heating, or hot spots, we placed a metal-free, remote-controlled turntable in the oven (Figure 2). In this batch-type process, 6 to 10 oysters (*Crassostrea virginica*) were placed on the turntable, and the turntable was rotated slowly during the exposure of the oysters to the microwaves. Exposure times were accurately controlled with the aid of a stopwatch.

[4] Use of trade names is to facilitate descriptions; no endorsement is implied.

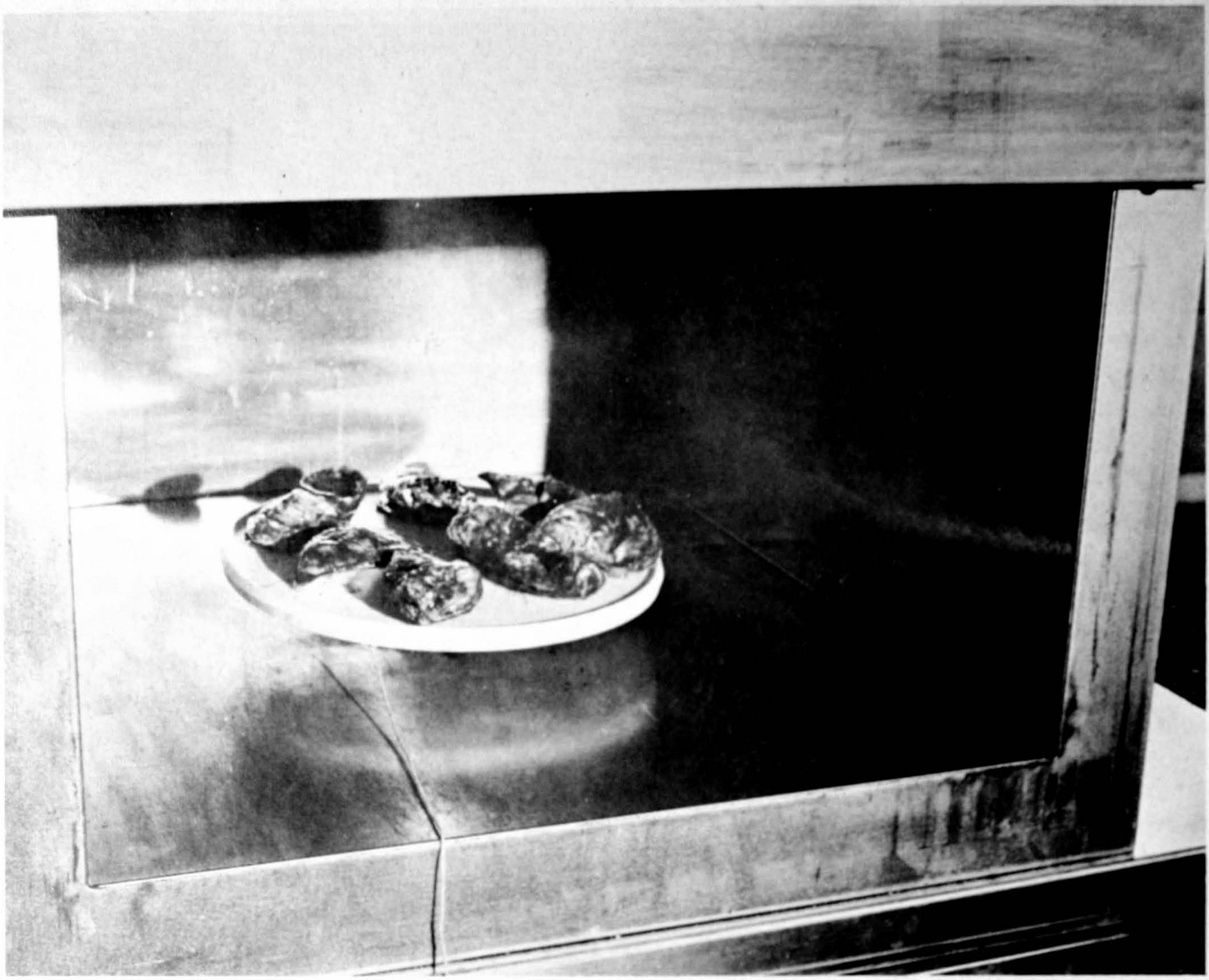

Figure 2.—Oysters on a metal-free turntable inside the oven of the microwave-energy range.

Several batches of oysters gaped after either a two-step or a one-step exposure to the microwaves. In the two-step treatment, six large oysters were exposed for 20 seconds and for 15 seconds with a 2-minute waiting period between exposures. In the one-step process, the time of exposure was somewhat less than that in the two-step process — six large oysters were opened in one 30-second treatment.

Batch-type microwave processing ovens are coming into more use in restaurants and institutions (Decareau, 1968, personal communication).[5] Our findings indicate that this equipment facilitates the preparation of raw oysters on the half-shell and that this delicacy should, therefore, find a place in more menus.

2. Continuous Processing

Following the successful batch-type tests described in the immediately preceding Section 1, we scaled up the experiments to learn about the commercial feasibility of continuous microwave shucking. A 10-kilowatt Litton (2,450 megahertz) Microwave Conveyor Oven (located at the U. S. Army Natick Laboratories, Natick, Massachusetts), shown in Figure 3, was used. It has four independently controlled modules, and each module has an output of either 1.25 or 2.50 kilowatts. It also has a

[5] Robert V. Decareau, Ph.D., Publisher and Editor of Microwave Energy Applications Newsletter, Box 241, Amherst, New Hampshire.

12-inch-wide conveyor belt, the speed of which can be controlled.

For these tests, the oysters were sorted roughly into two commercially recognized

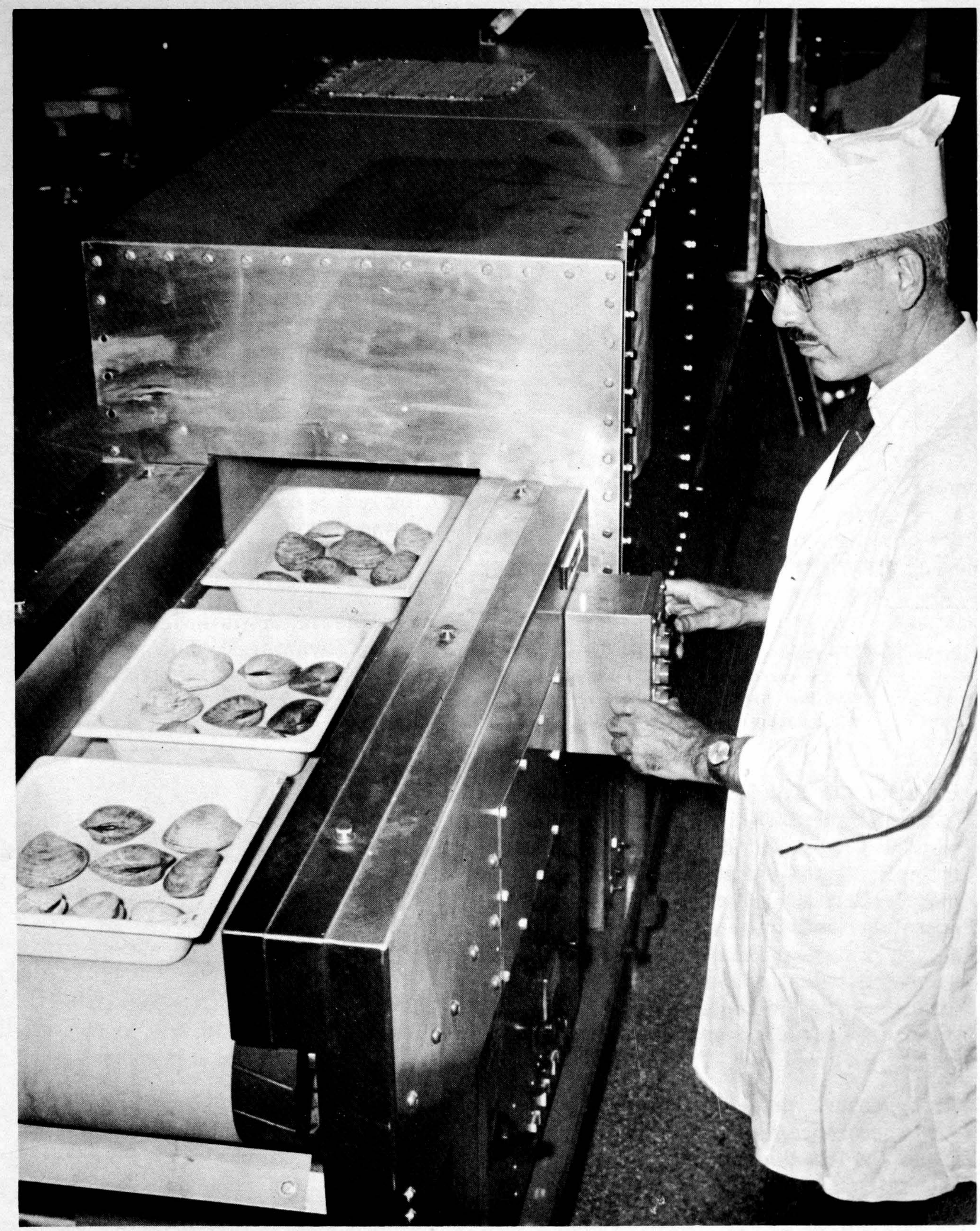

Figure 3.—A microwave conveyor oven for opening shellfish.

sizes — namely, large and small. Each lot was placed on a fiberglass tray (about 3 pounds per tray), and each tray was placed on the conveyor belt and exposed in a single pass. Figure 4 shows that 66 percent of the large oysters in a sample lot gaped after exposure

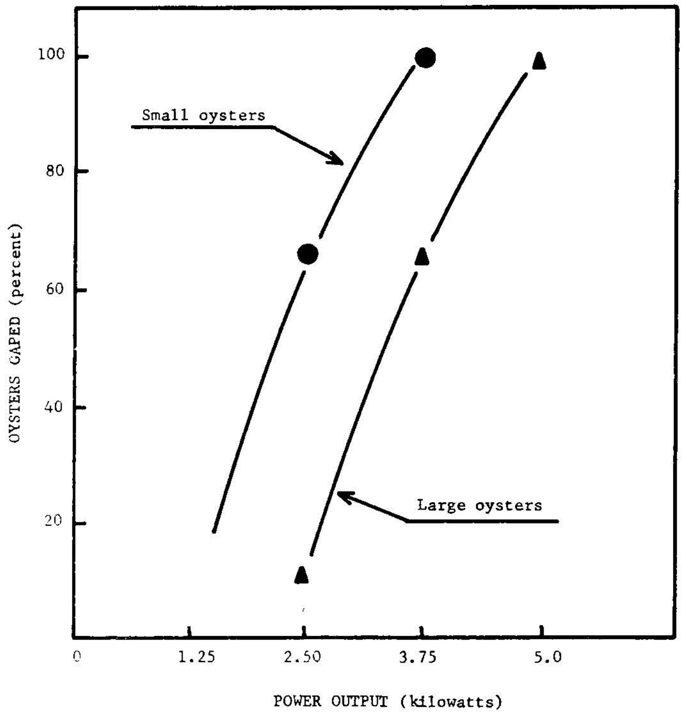

Figure 4.—The effect of varying microwave power output on the percentage of large and small oysters (200 and 300 per bushel, respectively) gaped at a constant exposure of 1 minute.

for 1 minute at a power output of 3.75 kilowatts (three 1.25-kilowatt units operating), whereas 100 percent of the small oysters gaped under the same conditions. A power output of 5.0 kilowatts (all four 1.25-kilowatt units operating) is required to obtain 100-percent gaping of large oysters in the same time. Figure 5 shows that a 50-percent increase in the exposure time is required to raise the percentage of gaped oysters from 71 to 100 percent.

To ensure that oysters do not lose their raw appearance, the operator must settle for somewhat less than 100-percent gaping of the shells. Our results show that between 90 and 95 percent of the oysters gaped after they received the minimum exposure necessary to open their shells and still retain their raw appearance. However, the ungaped oysters were relatively easy to shuck by hand, because opening them required no special skill. Oyster meats obtained by the microwave process described above were organoleptically indistinguishable from those obtained from the hand-shucked controls.

B. ANALYSES OF OPERATING COSTS

Comparative annual costs of hand-shucking and of continuous microwave processing of oysters were calculated (Tables 1 and 2). The values used in this comparison were obtained from the literature and from people associated with the oyster industry. The calculations included only the direct labor costs. A processor can add his own estimate of other costs, such as those for insurance, time lost due to accidents, and training new people.

The results of this comparison indicate that a continuous microwave process for shucking oysters is economically feasible. The cost analyses suggest that by the use of microwave energy, a savings of 33 percent in shucking costs is possible.

The microwave-energy method also has other advantages. The rate of production of

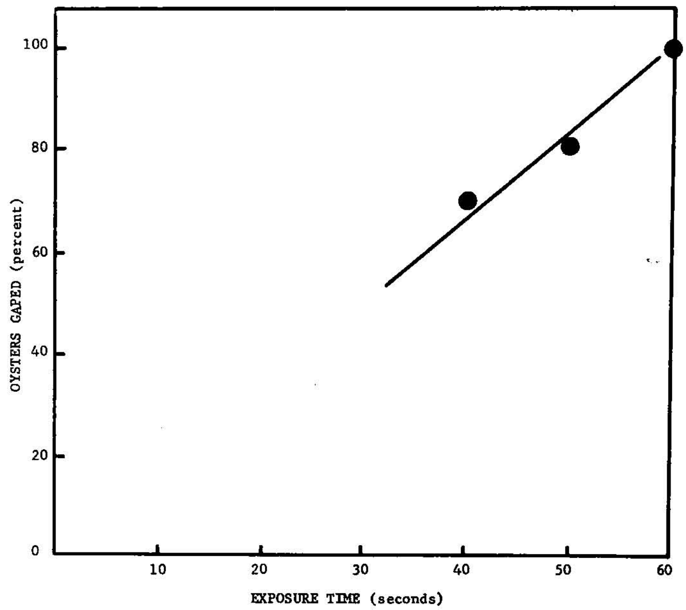

Figure 5.—The effect of varying the time of exposure of large oysters to microwave energy at a constant output of 5.0 kilowatts.

Table 1.—Annual cost of hand-shucking oysters for a processing plant designed to handle 50,000 pounds of oysters daily

Calculation formula	Results of calculation
Meat produced: $\frac{(50{,}000 \text{ lbs. oysters})}{(1 \text{ day})} \frac{(5.6 \text{ lbs. meats per bu.})}{(70 \text{ lbs. oysters per bu.})}$	= 4,000 lbs. meats per day
$\frac{(4{,}000 \text{ lbs. meats per day})}{(8.25 \text{ lbs. meats per gal.})}$	= 485 gals. meats per day
Wages to 44 shuckers: (485 gals. meats per day) ($1.60 per gal.)	= $776 per day
($776 per day) (176 working days per year)	= $136,300 per year

Note 1: The values used in these calculations are based on the following information:

1 bushel of oysters = 70 pounds and contains 200 to 300 oysters. This is an average value, since the weight of a bushel varies from one locality to another. A 70-pound bushel yields about 5.6 pounds of meats. This also is an average value: any given bushel may yield from 2.9 to 8.0 pounds of meats.

1 gallon of hand-shucked meats = 8.25 pounds, and it takes $\frac{(8.25 \text{ lbs. per gal.})}{(5.6 \text{ lbs. per bu.})}$ or 1.5 bushels of oysters to fill a 1-gallon can of meats.

Note 2: Because of seasonal limits, the number of days during which oyster meats are produced is about 176 (September to April) per year.

Table 2.—Annual cost for shucking oysters using a continuous microwave process in a plant designed to handle 50,000 pounds of oysters daily

Item	Annual cost
	Dollars
1. A microwave oven of 100-kilowatt output is adequate and costs about $150,000. Amortized over 10 years, the annual cost	= 15,000
2. Cost of interest charges on money borrowed to pay for oven, assuming 6.0 percent interest and no down payment	= 4,950
3. Cost of power to operate oven, assuming that the oven is only 50 percent efficient and that electricity costs $0.015 per kilowatt hour ($0.015 per K.W.H.) $\frac{(100 \text{ kw.})}{(50\%)} \frac{(7 \text{ hours})}{(1 \text{ day})} \frac{(176 \text{ days})}{(1 \text{ year})}$	= 3,700
4. Wages of 22 men to operate oven and remove meats from the gaped oysters[1] ($2.20 per man per hour (22 men)) $\frac{(8 \text{ hours})}{(1 \text{ day})} \frac{(176 \text{ days})}{(1 \text{ year})}$	= 68,150
Total annual costs (sum of Items 1, 2, 3, and 4)	= 91,800

[1] Cracking the shell, inserting a knife, and removing shell chips from the meats account for about 50 percent of the hand-shucking time (personal communication, Mrs. David H. Wallace, Director, Oyster Institute of North America, 22 Main Street, Sayville, Long Island, New York). Thus only half the manpower is needed.

a plant is no longer dependent on the productivity of the hand-shuckers. In fact, a plant could possibly double its rate by operating the oven in two shifts, using temporary inexperienced workers for the hand operations. High rates of production should also mean higher wages; and recruiting meat removers, instead of shuckers, should attract more people to work in an oyster plant. Microwave opening also eliminates the slow, potentially dangerous shell-stabbing or cracking operation and obviates the problem of having to remove shell fragments from the meats.

II. OTHER BIVALVES

Preliminary results suggest that the microwave process is applicable for gaping other species of bivalves such as ocean quahogs (*Arctica islandica*), hard clams (*Mercenaria mercenaria*), sea mussels (*Mytilus edulis*), surf clams (*Spisula solidissima*), and bay scallops (*Pecten species*). Because the meats from these species are often sold or handled cooked instead of raw, a slight overexposure to microwave energy is permissible to ensure 100-percent gaping of the shells. Severe overexposure should be avoided, however, because cooking is associated with appreciable losses in weight and, in some instances, with deleterious changes in the quality of the shucked meats. Further work is planned to evaluate the commercial usefulness and economy of the continuous microwave process for these and other bivalves.

SUMMARY

Oysters and other bivalves that are hard to open have been successfully opened with microwave energy. The method can be adapted both to a batch-type and to a continuous-type commercial process without noticeably changing the organoleptic quality of the shellfish. Hence, after being processed by this method, oysters, for example, can still be sold raw on

the half-shell. A comparison of costs with the hand-shucking method shows that a 33-percent saving can be realized using microwave energy. The method also has other advantages, such as increasing the productivity of a plant, enabling labor to be recruited more easily, lowering accident rates, and resulting in a product free from shell fragments.

ACKNOWLEDGMENT

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A NEW APPROACH FOR EVALUATING THE QUALITY OF FISHERY PRODUCTS

by

Robert J. Learson and Louis J. Ronsivalli

ABSTRACT

Although organoleptic panels lack precision, they are the only instrument that, at present, can integrate all the factors that affect quality. Described here is a new approach to improving panel precision. Using the approach, a panel expresses quality in terms of the estimated storage time of the sample rather than in such ambiguous terms as "excellent," "very good," and "borderline." The approach obviates the need for arbitrary terms to describe quality and assists the panelist in making his evaluations objectively. Statistical analysis of the results obtained when a panel used the method on samples of fresh cod fillets indicates that the storage age of such samples can be estimated to within ±2.2 days with a reliability of 95 percent.

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Authors: Robert J. Learson, *Research Chemist*, and Louis J. Ronsivalli, *Supervisory Research Food Technologist*, Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Massachusetts 01930

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INTRODUCTION

Statistical evaluations of the data obtained by organoleptic panels during sensory testing of foods have shown that panels are not always reliable as analytical tools. The need for accurate, more objective tests to measure the quality of foods has therefore spurred investigators to seek physical or chemical indices of quality. In this connection, fishery products have received much attention (Gould, 1965), and recent findings indicate that headway is being made (Spinelli, Eklund, and Miyauchi, 1964; Frasier, Pitts, and Dyer, 1968). Nevertheless, no practical, universal method is yet available for reliably measuring the overall quality of fish. The organoleptic panel, despite its lack of precision, is the only available instrument that can weigh all factors affecting quality and translate them into one overall assessment.

Because the organoleptic panel is indispensable at present, our problem was to make it a better instrument of analysis. Recognizing the inadequacy of the terminology used to express quality and the inherent subjectivity of panels, we attempted to devise a system that would minimize these difficulties and thereby decrease the variability in panel results — a system in which the method of evaluation and the quality scale would be developed to fit the ability of the panel.

In our study of this problem, we found that quality can be expressed more precisely in terms of the estimated number of days that the fish has been stored than in terms of such expressions as "excellent," "very good," and "borderline." This particular approach toward improving the precision of organoleptic testing is relatively untried. The purpose of this paper therefore is to report our attempts to improve the organoleptic evaluation of fishery products by showing how quality can be expressed reliably and consistently as a function of storage time.

The report is divided into two main parts. The first part discusses the variability involved in organoleptic evaluations of fishery products and indicates how the problem can be solved by expressing quality as a function of storage time. The second part reports on the degree of consistency obtained in data produced by panelists when they expressed the quality of a sample in terms of the estimated number of days that the sample had been stored under standardized conditions.

I. CAUSES OF, AND REDUCTION OF, VARIABILITY IN ORGANOLEPTIC DATA

The primary criterion of a panel's usefulness to the investigator is the amount of agreement among its members. Whether the panelists number 2 or 20, if they can consistently agree on the quality of a food product, they can be considered reliable within the framework of their own particular testing procedure. In our experience, two individuals consistently agreeing on whether or not samples are "good" or "bad" (a 2-point scale) are more valuable to a researcher than are 20 panelists scoring samples on a 20-point scale with little agreement. If a panel can agree within statistical limits of some measure of quality, regardless of how that measure is derived, that panel can be a valuable analytical tool for organoleptic testing.

In this part of the report, we shall look into the causes of the variability in panel data and consider how to reduce it. This variability can be traced to three principal sources — namely, (A) psychologically unsound or ambiguous descriptive terms used on the scoresheet, (B) unsuitable control samples, and (C) lack of sensory acuity in some members of the taste panel.

A. PROBLEM OF UNSUITABLE DESCRIPTIVE TERMS USED IN SCORESHEET

Discussed in this section are (1) how the use of unsuitable descriptive terms causes variability in panel data and (2) how the variability that is due to this cause can be reduced.

1. How the Use of Unsuitable Scoresheet Terminology Causes Variability

Variations in the assessment of quality can often be traced to the use of psychologically unsound or ambiguous terms on the scoresheet. For example, we have found that a relatively less desirable species, such as ocean perch or pollock, will be rated substantially lower than will a more desirable species, such as cod or haddock, even though the samples are all of the same storage age. Understandably, a panelist experiences difficulty in scoring "excellent" a sample of a fish that he dislikes, even if it is strictly fresh. Although he has been instructed to be objective, bias due to his individual preference makes itself evident in panel data gathered over a number of experiments.

Thus, the use psychologically unsound terms that conflict with the panelist's own evaluation of the sample's intrinsic quality, regardless of its freshness, or the use of such arbitrary terms as "excellent," "very good," "borderline," "very poor," "inedible," and "unmarketable," which have different meanings to different people, can lead to varying judgments of quality (Ehrenberg and Shewan, 1953).

2. How the Variability Due to Unsuitable Scoresheet Terminology Can be Reduced

We have found that the problem of terminology can largely be solved by expressing quality as a function of time.

In this section, we shall explain the reasoning behind our choice of this scoring method and then show how we incorporated it into our quality-evaluation scoresheets.

a. Rationale of the method.—The primary basis of the approach suggested here — expressing quality in terms of estimated storage time — is that the quality of fish fillets, though initially high, will decrease as the time of storage increases. Although the quality of the raw material may vary somewhat over a number of tests, an average spoilage rate can be determined, and the overall quality of the samples can be expressed as a function of the length of time that the sample has been stored under standard conditions.

Thus, after observing the spoilage pattern of a particular species a number of times, a panelist can learn to express the quality of samples of this species in terms of his estimate of the length of time that the samples had been stored under the standard conditions. It follows then that a capable panel, trained to express the quality of a species of fish in terms of a standard time scale, can estimate the quality of any sample of that species as a point on the scale, even though the conditions under which the test sample was stored were not standard. For example, a panelist may judge that a sample of fresh cod fillets stored at 4.5° C. for 7 days is equivalent in quality to cod fillets stored at 0.6° C. for 10 days. Thus, the test sample, regardless of the processing and storage conditions, can be evaluated as equivalent in overall quality to a fresh sample stored under the standardized conditions for a particular period of time.

Accordingly, in the use of the technique reported here, the panelist assumes that the test sample is a fresh fillet that has been stored at the temperature of melting ice up to the time of being served, regardless of how it actually was stored. Because the quality of the test sample must be compared with that of the fresh product, the panelist can compare the sample's quality not only with that of the very best fillets, but also with that of fillets over the entire quality spectrum. Figure 1 illustrates the type of quality curves that can be expected when this system of evaluation is used to express the quality of samples in terms of the standard scale.

b. Development of the scoresheet.—A problem in evolving the system of organoleptic testing described here was to devise a scoresheet for the species under consideration. During this process, a number of discussions with the panel was necessary so that descriptive terms that were agreeable to all of the

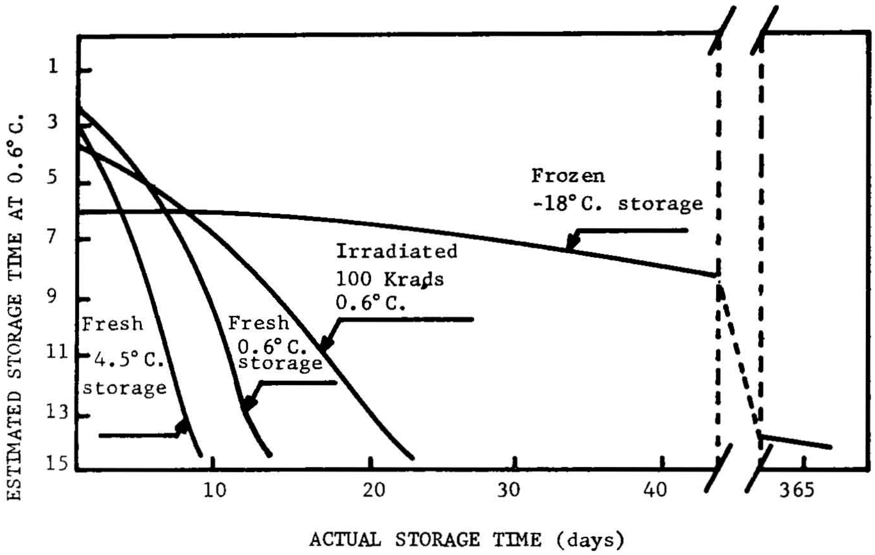

Figure 1.—Theoretical quality curves based on estimated storage time system.

panelists would be used as descriptors of quality on the scoresheet. For example, if one panelist decided that fillets had a "musty" odor at a particular time during spoilage, the term "musty" appeared in the column describing fillets of that particular age. By using all of the panelists' nomenclature in fitting our descriptors to the spoilage patterns that the panelists had discerned, we were able to develop a scoresheet showing the changes in quality as they appeared to our particular panelists.

Figure 2 shows the scoresheet that evolved from these discussions. The panel unanimously agreed to these descriptors, using the odor of the product as the primary indicator of quality and the appearance of the product as a secondary indicator only. The acceptance question ("Would you cook and eat this fish?") was added solely as an indication of the panelists' subjective level of acceptance or rejection. Preliminary results obtained from comparing panel averages with the number of acceptances or rejections indicate that, although the acceptance threshold of the individual panelists differed, the acceptance or rejection of the panel as a unit varied little.

B. PROBLEM OF UNSUITABLE CONTROL SAMPLES

Following the pattern used in Section A, we describe in this section how the use of unsuitable control samples causes variability and then how this variability can be reduced.

1. How the Use of Unsuitable Control Samples Cause Variability

An experimenter, to ensure that the quality of the reference controls used by him remains high over a period of time, sometimes uses frozen samples. Unfortunately, the use of frozen control samples as references tends to complicate the panelist's job, especially when the samples he is evaluating are fresh and unfrozen, because it forces him to make a two-step evaluation. The first is a comparison of the sample being judged with some remembered fresh sample of absolutely best quality. The second is a comparison of the sample being judged with the known control in the test.

On the other hand, the use of only fresh unfrozen controls can cause difficulty, too. If the quality of the controls is low, the panelist tends to score the test sample higher than he would if fresh controls of better quality were used. Thus, at two different times, he may give one sample two different scores, their value depending on the quality of the control being used at the moment.

2. How the Variability Due to Unsuitable Control Samples Can Be Reduced

We counteracted the variability due to the controls by developing a set of standard conditions under which the reference sample was stored. We could have established these con-

RAW EVALUATION - COD

USE ODOR AS THE PRIMARY BASIS OF JUDGMENT. Use appearance as a deciding factor in borderline cases only.

1. In Column A, write the number of each sample on the line opposite the number of days you estimate the sample has been stored.
2. In Column B, check the appropriate box for each sample.

Quality descriptors	Your estimate of time sampled was stored at 0.6° C.	Column A: Sample number	Column B: Acceptance — would you cook and eat this fish?					
			Sample number	Yes	No	Sample number	Yes	No
	Days							
Sea-fresh, seaweedy, briny, tangy, neutral, or little odor. Glossy or translucent appearance that decreases with age.	1							
	2							
	3		1			13		
	4							
Little odor or very slightly fishy, stale, salt cod, or musty odors. Little or no glossiness.	5		2			14		
	6		3			15		
Slightly fishy, rancid, sour, acidic, salt cod, slight but not persistent ammoniacal odors. Somewhat dull waxy or opaque. Some discoloration.	7		4			16		
	8		5			17		
Definitely fishy, rancid, sour, acidic, slight persistent ammoniacal odors. Slight yeasty, barnyard, fruity, or sweet odors. Opaque with moderate discoloration.			6			18		
	9		7			19		
	10		8			20		
Strong fishy, rancid, acidic, sour, or persistent ammoniacal odors. Definite yeasty, barnyard, fruity, or sweet odors. Opaque with moderate discoloration.	11		9			21		
	12		10			22		
	13		11			23		
Very strong fishy, yeasty, fruity, sour, sweet, or putrid odors. Obvious discoloration.	14							
	15							
	16		12			24		
	17							

Figure 2.—Panel scoresheet (quality equaled with estimated time).

ditions arbitrarily; however, to ensure greater interest on the part of the panelists, we used conditions reasonably close to those used commercially.

In preliminary work, we found that cod fillets obtained within 24 hours after the cod had been captured, packaged in flexible pouches, and stored at 0.6° C. had a shelf life that was fairly easy for the panel to break into increments. The shelf life was long enough to result in distinct stages of spoilage, yet short enough to produce a rememberable number of spoilage increments. We also found that a series of simultaneous storage tests gave the most satisfactory test samples. By adding fresh samples every 2 or 3 days and by retiring the spoiled ones, we had a continuously available supply of samples that not only were of known storage age but that reflected the entire quality spectrum of the fillets.

Throughout the tests, we procured the fish, stored the fillets, and presented the samples to the panelists in exactly the same manner, carefully eliminating nonstandard or unusual samples and strictly controlling the size and temperature of the samples. For raw evaluations, we presented the samples to the panelists in covered 1-liter beakers that were not more than three-fourths full. We then allowed the samples to warm up to about 7° C. Each panelist evaluated the quality of the sample by lifting the cover of the beaker and sniffing the odor.

C. PROBLEM OF LACK OF SENSORY ACUITY IN SOME PANEL MEMBERS

1. How the Lack of Acuity Causes Variability

A lack of sensory acuity in only a few members of a panel can cause their judgment to differ markedly and erratically from that of the other members. The result is that the average judgment of the panel varies more than it otherwise would if these members had not been present.

2. How the Variability Due to a Lack of Sensory Acuity Can be Reduced

Because the entire staff of our laboratory presented themselves as potential panel members, we were faced with the problem of a possible lack of sensory acuity in some panelists. To ensure that the members we selected would have adequate sensory acuity, we used a two-step screening process to eliminate any candidates who were unable to detect differences in odors of samples that did actually differ markedly in quality.

a. Preliminary screening of panel candidates.—During the preliminary screening, we asked each prospective panelist to smell raw samples having storage ages known to him so that he could become familiar with the spoilage characteristics of the species stored at near the temperature of melting ice (about 0.6° C.). To help ensure his later successful judging, we asked him to observe the entire spoilage pattern a number of times. On these occasions, we instructed him to describe the odors that he observed in the known samples. This exercise helped him to remember the spoilage characteristics of the samples and helped us when we were using his comments in developing our scoresheet.

After the candidates for the panel had learned the spoilage pattern of the species, we tested the candidates further by asking them to estimate the storage age of samples taken from lots of fillets having storage ages known to us but not to them. We began the testing slowly, presenting only one or two unknown samples along with a series of known ones that the candidates could use for comparison. As the testing proceeded, we steadily increased the number of unknowns. To maintain the candidates' interest, we informed them of their progress and allowed them to discuss what they had smelled and how they had arrived at the correct or incorrect answers. We selected the more capable candidates on the basis of their accuracy in estimating the age of the unknown samples. As a result of this preliminary screening, we were able to eliminate quickly all but 10 of the original candidates.

b. Final selection of panel candidates.—The testing and training of the remaining candidates were continued so that quality guidelines could be developed and the reliability of the candidates could be improved.

After testing the finalists continuously with unknown samples, we were able to determine the reliability of the 10-member panel by plotting the averages of the candidates' estimate of the storage age of the samples against the actual storage age. This plot showed us where to expect the greatest deviations and allowed us to set allowable limits on the deviations of the panel and on the performance of the individual panelist. From it, we were able to choose seven candidates who would work together best in giving us consistent data.

II. CONSISTENCY OF ORGANOLEPTIC DATA DERIVED BY THE NEW METHOD

In Part I, during our discussion of the need for counteracting the causes of variability in panel-derived data, we pointed out that the usefulness of an organoleptic panel can be measured by the amount of agreement among the panelists. In the present Part II, we shall show how well the carefully chosen panelists at our laboratory agreed among themselves when they worked with standardized controls and used a time-oriented scoresheet. Also, we shall discuss some of the elements that require continuing attention if consistency is to be maintained over an extended period.

A. TESTING FOR CONSISTENCY

Table 1 shows the estimates of storage age that the 10 most capable panel candidates made in evaluating the quality of skinless cod fillets. From these data, we selected the final 7 panelists — those who could indicate the storage age of cod fillets within ±2 days with better than 70-percent reliability. These 7 averaged 80.4-percent reliability within ±2 days; as individuals, their accuracy ranged from 71 to 88 percent.

Table 2 compares the average ages estimated by the panel with the known storage ages of the fillets. Out of 52 samples representing the entire quality range of fillets, the panel never deviated more than 3 days from the true storage age of the samples. It estimated the age of 56 percent of the samples within ±1 day and that of 90 percent of the samples within ±2 days. Statistical analysis of these data shows that the estimates were accurate within ±2.2 days with 95-percent reliability.

Figure 3 shows the curve, as plotted from the panel averages, of the rate of spoilage of cod fillets scored under the standard conditions. The curve falls very close to the ideal line for the 4-to-12-day storage time. The larger deviations that occurred in the first 4 days and in the last 5 days of storage suggest that the daily changes in quality during these periods were too slight to be detected reliably. Table 3, which shows the average deviations and standard deviations calculated for various sectors of the curve, adds support to this conclusion. For all samples studied, both the average deviations and the standard deviations were much smaller during the first 10 days of storage than during the last 7 days of storage. The panelists judged that most of the samples were spoiled after 10 to 12 days' storage. Apparently, once the samples became spoiled, the panel could not reliably detect further day-to-day losses in quality. Standard deviations for samples stored for from 1 to 10 days indicate that the panel could correctly estimate the true age of these samples within ±2.2 days with a reliability of 95 percent.

Table 1.—Reliability of final candidates in judging the true age of cod fillets stored at 0.6° C.

Panelists	Total samples judged	Samples judged as to storage age:							
		Without deviation from correct age		Within ±1 day's deviation from correct age		Within ±2 days' deviation from correct age		With more than ±2 days' deviation from correct age	
Retained	*No.*	*No.*	*% of total*	*No.*	*% of total*	*No.*	*% of total*	*No.*	*% of total*
A	48	16	33.3	30	62.5	39	81.3	9	18.7
B	41	24	58.5	29	70.7	36	87.8	5	12.2
C	51	19	37.3	30	58.9	40	78.5	11	21.5
D	46	18	39.1	31	67.4	40	87.0	6	13.0
E	48	5	10.4	19	39.6	34	70.9	14	29.1
F	41	7	17.1	27	65.9	34	83.0	7	17.0
G	51	17	33.3	26	50.9	38	74.4	13	25.6
Average	46	15	32.7	27	59.4	37	80.4	9	19.6
Not retained									
H	16	2	12.5	4	25.0	8	50.0	8	50.0
I	42	6	14.3	16	38.1	23	54.8	19	45.2
J	25	11	23.9	21	45.6	4	54.3	21	45.6

Table 2.—Performance of trained panel — comparison of known storage ages of samples with the panel's average estimates of the storage ages

True storage age	Panel's average estimate of age	Deviation	True storage age	Panel's average estimate of age	Deviation	True storage age	Panel's average estimate of age	Deviation
Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
1	2.3	+1.3	7	6.6	−0.4	12	11.9	−0.1
1	1.6	+0.6	7	7.1	+0.1	12	12.4	+0.4
1	2.1	+1.1	7	9.0	+2.0	12	11.8	−0.2
1	2.6	+1.6	7	5.6	−1.4	12	9.8	−2.2
2	2.3	+0.3	8	7.7	−0.3	13	11.0	−2.0
2	3.4	+1.4	8	7.0	−1.0	13	11.7	−1.3
2	2.0	0.0	8	7.6	−0.4	14	13.4	−0.6
3	4.4	+1.4	8	7.1	−0.9	14	13.0	−1.0
3	3.6	+0.6	8	10.7	+2.7	15	14.0	−1.0
3	2.3	−0.7	9	9.3	+0.3	15	12.1	−2.9
4	2.3	−1.7	9	8.5	−0.5	15	14.1	−0.9
4	3.1	−0.9	9	10.0	+1.0	15	13.8	−1.2
4	2.9	−1.1	9	9.8	+0.8	16	13.4	−2.6
5	6.0	+1.0	10	10.2	+0.2	17	15.4	−1.6
5	4.7	−0.3	10	10.4	+0.4	Sum of deviations 54.7		
5	6.4	+1.4	10	8.7	−1.3	Average deviation ±1.05		
6	5.3	−0.7	11	9.6	−1.4			
6	4.7	−1.3	11	8.8	−2.2			
6	6.0	0.0	11	13.0	+2.0			

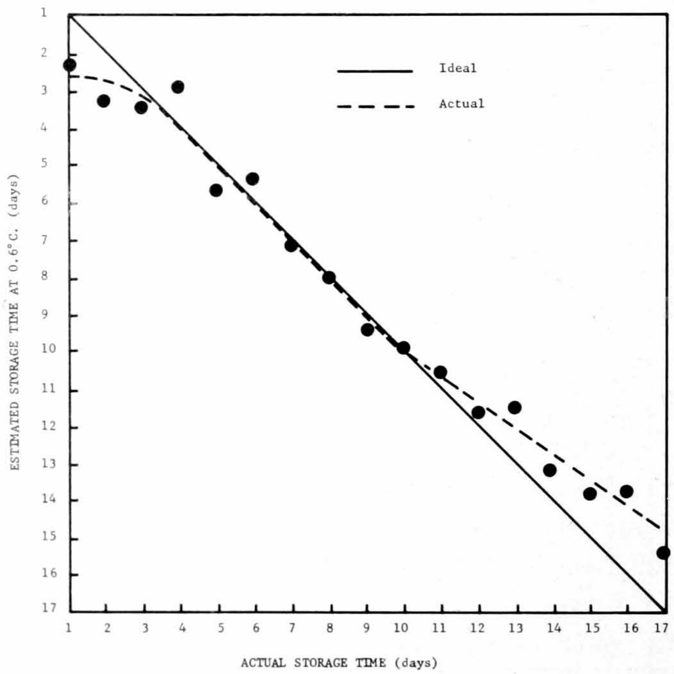

Figure 3.—Estimated storage age versus actual storage of raw skinless cod fillets at 0.6° C.

Table 3.—Deviation of panel's average estimate of storage age from true storage age of cod fillets

Storage time	Sum of deviations	Samples examined	Average deviation	Variance (σ^2)	Standard deviation (σ)
Days	*Days*	*No.*	*Days*		
1 - 4	12.7	13	±1.0	1.3	±1.1
5 - 10	18.4	22	±0.8	1.2	±1.1
11 - 13	11.8	9	±1.3	2.7	±1.6
14 - 17	11.8	8	±1.5	3.2	±1.8
1 - 10	31.1	35	±0.9	1.2	±1.1
11 - 17	23.6	17	±1.4	2.7	±1.7
1 - 17	54.7	52	±1.1	1.7	±1.3

The panel accepted almost every sample unanimously when it judged, on the average, that the sample had been in storage less than 7 days; it rejected the sample unanimously when it judged, on the average, that the sample had been in storage for from 10 to 12 days.

B. MAINTAINING CONSISTENCY

Maintaining a high degree of consistency requires unrelenting attention to details. The method of presenting the sample to the panelist, the upkeep of the panel's skill and interest, and the avoidance of nonstandard spoilage odors in the reference samples are the three most important. In the following discussion of these three requirements in the maintenance of consistency, we touch on some of the problems that may arise and some of the solutions that may be effective.

1. Standardizing the Method of Sample Presentation

The conditions under which the samples are presented to the panel must be standardized, so that variables affecting the reliability of the panel's judgment can be eliminated. For example, the temperature and size of the sample and the type and size of the container in which the sample is presented affect the intensity of odor from the samples.

The length of time that the odor is allowed to build up in the sample container also is a variable. In our evaluation of raw fillets, we used a covered 1-liter beaker as the sample container and presented each panelist with the same sample. The beaker appears to hold the odors better than a plate or pan does, and the odors appear to be more concentrated. But if one panelist sniffs the odor from a beaker immediately after another panelist has sniffed it, the second panelist does not get the same intensity of odor. Apparently, an interval of time must elapse between the samplings to allow the volatile substances producing the odor to buildup in the beaker. The use of different samples for each of the panelists would eliminate the dilution effect, but it would introduce a new variable, owing to differences among the samples.

2. Keeping Up the Panel's Skill and Interest

Although the initial training procedures are simple, we found that the panelists had to be retrained and retested continuously to keep their accuracy high.

The interest of the individual panelists must be maintained to ensure a high level of performance. We found that the performance of individual panelists tends to fall off with time and that panelists lose interest if their regular work is continuously interrupted for testing sessions. Apparently, some system of incentives would be worthwhile.

3. Eliminating Nonstandard Reference Odors

We originally theorized that odors not standard to the particular species, such as irradiation odors, would be a major problem in the use of this evaluation system. We found, however, that the panel was more confused by variability in reference samples than by odors different from those developed during normal spoilage. Accordingly, we took great care to eliminate nonstandard reference samples before the tests began. Despite these precautions, panelists stated that they preferred to rely on their training rather than on some of the reference samples that we gave them during the tests. Yet, known standard samples in different stages of spoilage seemed to aid the panelists in making judgments. Possibly, samples of artificial odor corresponding to the odor of fish in various stages of spoilage would solve the problem of the nonstandard reference sample.

Odors different from those occurring during normal spoilage of fresh fish did not appear to reduce the overall performance of the panel. Results of testing irradiated and frozen haddock and cod fillets showed that the panelists could relate odors of rancidity and irradiation to the time scale with good agreement among themselves.

CONCLUSIONS

Despite the problems attendant upon the use of this system for evaluating the overall quality of fish samples, it has a number of advantages that merit its consideration as a testing instrument.

1. It is simple — panelists can be selected and trained easily and relatively quickly. Our entire selection and training procedure took only 2 months.

2. It is objective and unambiguous — panelists are trained to make decisions based on standard quality characteristics rather than on personal bias or preference. The decisions are expressed in terms of the storage age of the sample, which is objectively determinable for controls, rather than in abstract terms or in numbers that express degrees of some abstract quality.

3. It is comprehensive and direct — panelists compare the quality of the sample with the entire spectrum of quality for the particular species rather than having to relate the quality of the sample to a single reference control — namely, the very best fish that they can remember. All that is required is an estimation of storage age according to their experience — a realistic value.

4. The panelists themselves develop the scale and the scoresheet based on their training experience. Theoretically, panels could be trained for quality evaluations of almost any fishery product, provided a standard scale showing definite increments of spoilage through time can be developed that can be assimilated by the panelists. Thus, although such problems are associated with the use of this system of evaluation, the overall concept of evaluating the quality of test samples on a sample-age scale has merit. In general, the system is simple to use, panels can be developed with a minimum of resources, and a good panel can provide a reliable analytical tool for the researcher.

ACKNOWLEDGMENT

Wilma Hill and Vincent Ampola aided in the development, training, and testing of the panels. The laboratory personnel who took part in the testing, especially the final panelists selected, contributed greatly to this research.

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DEMERSAL FISH RESOURCES: COMPOSITION, DISTRIBUTION, AND COMMERCIAL POTENTIAL OF THE CONTINENTAL SHELF STOCKS OFF SOUTHEASTERN UNITED STATES

by

Paul Struhsaker

ABSTRACT

A 5-year study of the demersal fish resources of the Continental Shelf off Southeastern United States resulted in the occupation of 956 exploratory trawling stations in the 6- to 100-fathom depth range. The study showed that the region can be divided into five general habitat types — coastal, open-shelf, live-bottom, shelf-edge, and lower-shelf — each harboring a distinctive association of demersal fishes.

The coastal habitat, which has a smooth, sandy-mud bottom out to depths of 8 to 10 fathoms, has well-known and abundant resources of bottomfishes. Increased use of these stocks (mostly drums and croakers) seems to depend on market development, rather than on additional exploratory fishing.

The open-shelf habitat, which has a smooth sand bottom to depths of about 10 to 25 or 30 fathoms, has poor potential for a trawl fishery for food fishes. Occasional large catches of scup and filefish indicate, however, that these species may be abundant enough to support a small industrial fishery for bottomfish.

The live-bottom habitats, which are small areas of broken relief and a rich sessile invertebrate fauna within the open-shelf habitat, have the best food-fish potential for commercial utilization. During exploratory fishing, moderate to large catches of snappers, groupers, porgies, and ecologically associated species were taken consistently with New England-type otter trawls. The best areas were off Northeastern Florida and South Carolina, but other productive areas were found along most of the Southeastern Coast.

The shelf-edge habitat, which has a smooth to highly broken bottom and runs along the edge of the Continental Shelf at depths of about 30 to 60 fathoms, also has large concentrations of snappers, groupers, and porgies in certain localities. Although trawling was often impractical in the rougher portions of this habitat, the fishery resources of these areas can be harvested by handlines and traps.

The lower-shelf habitat has a smooth mud bottom from about 60 to at least 100 fathoms; the limited explorations indicate the presence of large concentrations of butterfish, spotted hake, and perhaps groupers in this habitat.

A fishing log and chart of 50 stations where catches of commercial size were made is provided. A list of demersal fishes taken during the explorations is given, along with notations on their occurrences in the trawl catches and habitat occupation.

Author: Paul Struhsaker, *Fishery Biologist*, Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Station, St. Simons Island, Georgia 31522 (present address: Hawaii Institute of Marine Biology, University of Hawaii, Honolulu, Hawaii 96822).

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INTRODUCTION

Commercial fishermen are understandably reluctant to venture from known fishing localities even when fishing is poor on the usual grounds. The increased expense, the possibility of even poorer catches, and the likelihood of losing gear deter the individual fisherman from exploring unfamiliar areas. As a consequence, governmental agencies have assumed responsibility for many of the fishery explorations in distant or previously unexplored regions. These explorations have often discovered valuable latent resources.

Since 1950, the Fish and Wildlife Service, Bureau of Commercial Fisheries, and other agencies have explored the waters bordering the Southeastern United States (Figure 1). These explorations are one part of a long-range program to strengthen the commercial fishing industry of the United States and to gather knowledge for the wise use of available resources in the marine environment. Powell (1950) and Buller (1951) described bottomfish explorations by the Fish and Wildlife Service off North Carolina. Anderson (1956) carried out winter explorations for brown shrimp over the outer Continental Shelf in 1940. Taylor (1956) and Lunz (1957) described offshore investigations by the State of South Carolina. Bullis and Rathjen (1959) reported offshore and deepwater shrimp explorations by the Bureau of Commercial Fisheries during 1956-58.

In addition to the fishery surveys by the foregoing agencies, the Fish and Wildlife Service used the research vessel *Theodore N. Gill* in a 2-year study of the physical, chemical, and biological environment off the Southeastern Coast. The results of this effort were reported by Anderson, Gehringer, and Cohen, 1956a and 1956b; Anderson and Gehringer, 1957a, 1957b,

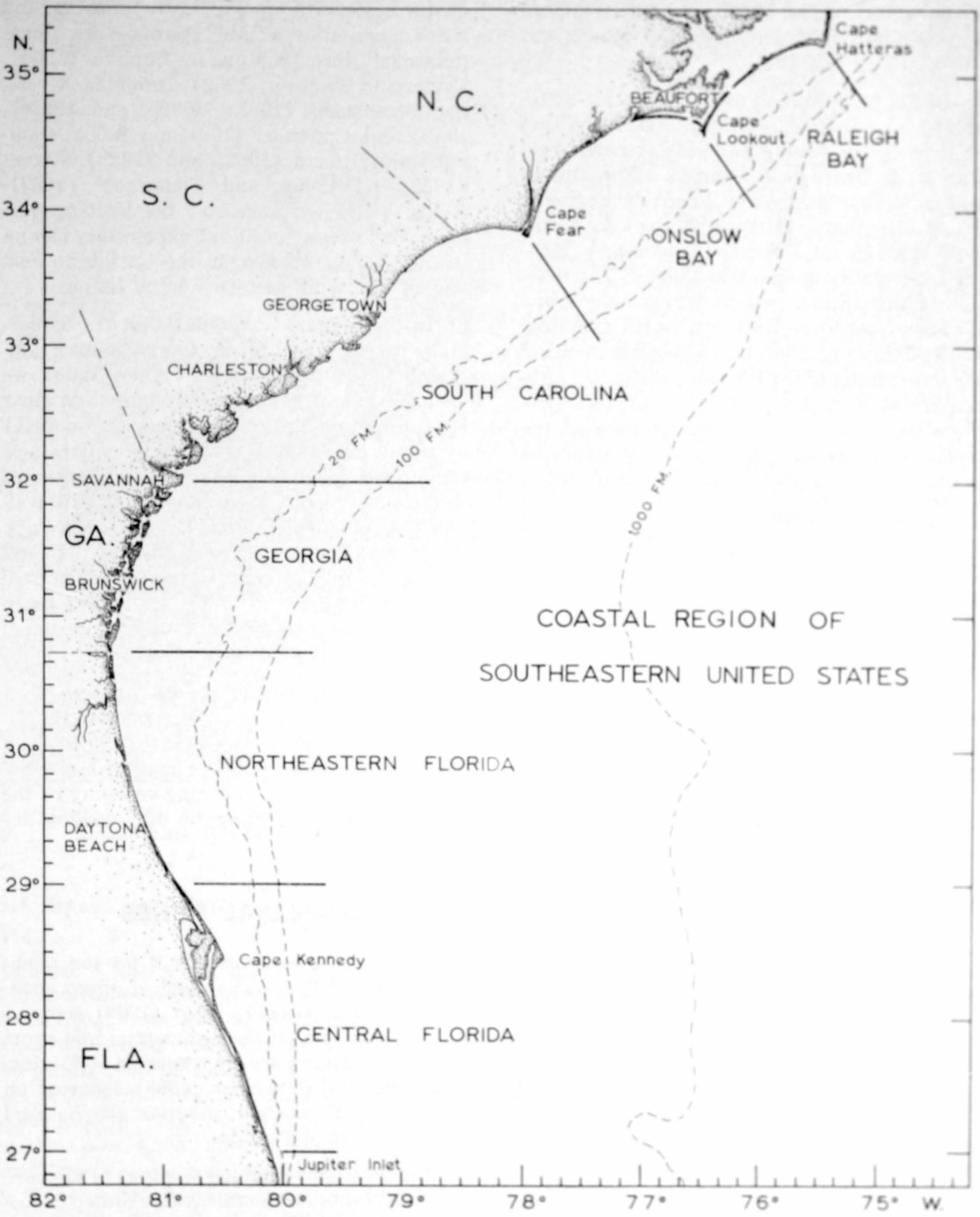


Figure 1.—The Southeastern Coastal Region of the United States and the six subregions considered in this report.

1958a, 1958b, 1959a, 1959b, and 1959c; Moore and Gorsline, 1960; and Anderson, Moore, and Gordy, 1961a and 1961b.

In 1959, the Bureau used funds made available by the Saltonstall-Kennedy Act to establish an exploratory fishing and gear research field station at Brunswick, Georgia. The station was administered by the Bureau's Region 2 (Gulf and South Atlantic States) and was supervised by the Bureau's Exploratory Fishing Base at Pascagoula, Mississippi. The function of this station was to survey extensively the area from Cape Hatteras, North Carolina, to the Straits of Florida. These surveys had the cooperation of the Bureau's Biological Laboratory at Brunswick. The aim of initial explorations was to assess the commercial potential and availability of offshore stocks of shrimps, clams, scallops, and demersal fishes.

These explorations were reported upon in several ways. At the completion of each exploratory fishing cruise, the results were evaluated quickly and given in a report distributed to members of the commercial fishing industry and other interested persons. Thus the fishermen were quickly and effectively informed about the findings of each cruise. Occasionally, favorable fishing results were radioed directly to the commercial fishing fleet. After enough information on a particular phase of the survey was accumulated and evaluated, a more comprehensive report was published, usually in a journal directed to the commercial fishing industry. Reports on exploratory fishing and related activities off the Southeastern Coast published since 1959 are by Captiva (1960), Porter and Chestnut (1962), Cummins, Rivers, and Struhsaker (1962a, 1962b, and 1962c), Bullis and Cummins (1961 and 1963), Cummins and Rivers (1962a and 1962b), Rivers (1962 and 1966), and Thompson[1] (1967). Bullis (1964) summarized the history, purposes, and present status of exploratory fishing in the Gulf of Mexico, in the Caribbean Sea, and off the Southeastern United States.

In the 5 years (1959-64) that the exploratory fishing vessel *Silver Bay* (Figure 2) operated off the Southeastern United States, we (Staff at the Exploratory Fishing and Gear Research Field Station at Brunswick, Georgia) expended much effort on trawling explorations for offshore demersal fishes. The purpose of the present report is to summarize and evaluate the results of these surveys. Although this report is directed primarily to the commercial fishing industry, I hope that it will also aid in planning other investigations in this region and contribute towards a rational use of the area's offshore resources.

Because the primary purpose of the explorations was to determine the commercial potential of the offshore demersal fish stocks, I shall discuss their past and present contribution to the commercial-fishing economy of the region before reporting on the exploratory trawling.

I. COMMERCIAL USE OF OFFSHORE DEMERSAL FISHES

"Offshore fishes," as used in this paper, are fishes that normally occur in depths of greater than 10 fathoms and that are not taken incidentally in the shrimp-trawl fishery. Not all of these offshore fishes are reported upon here. The offshore winter-trawl fishery of Raleigh Bay, North Carolina, for example, is not included in the following discussion, because the species of fishes taken in that fishery are the same as those taken by the inshore shrimp fishery (Pearson, 1932). The offshore fishery of the Southeastern Coast is now limited to handlining and traps, and the catch is composed mainly of black sea bass, snappers, and groupers (see Appendix B for the scientific names of these fishes and of others mentioned in this paper). Moe (1963) comprehensively evaluated the commercial and sport use of the offshore fishery resources of Florida. Anderson and Gehringer (1965) reported on the use of the marine resources off the East Coast of Central Florida.

Figure 3 shows annual landings of offshore demersal fishes for Southeastern United States since 1902. The importance of the once active

[1] Thompson, John R. 1963. The bathyalbenthic caridean shrimps of the Southeastern North Atlantic. Ph.D. Thesis, Department of the Zoology, Duke University, 504 pages.

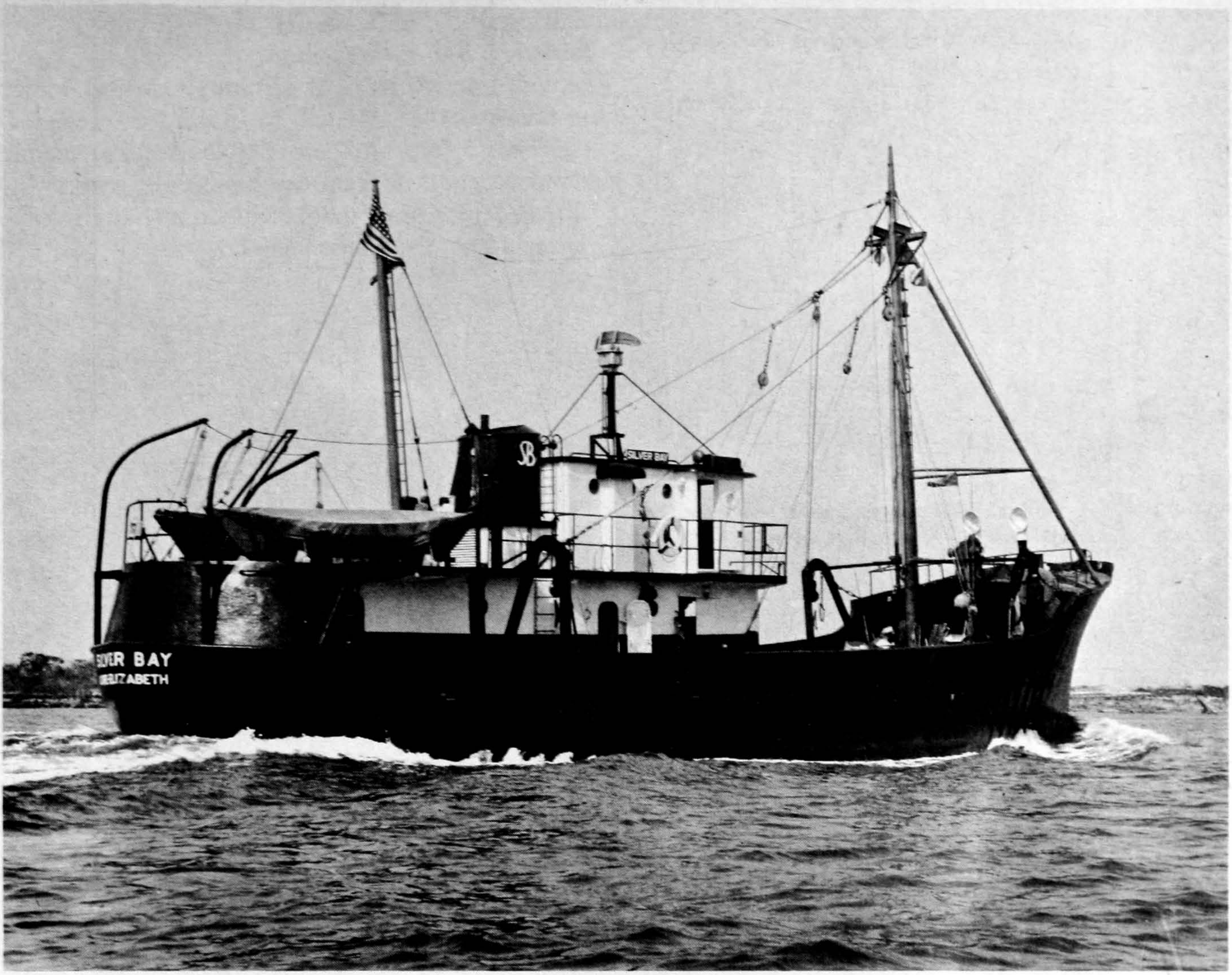


Figure 2.—The *Silver Bay*, a North Atlantic steel-hulled side trawler used for bottomfish explorations off Southeastern United States, 1959-64.

shark fishery in 1937-45 is evident from the data.

Figure 4 shows the annual value of the catch of offshore demersal fishes for the Southeastern Coast from 1950 to 1964. During this period, the values ranged from $250,000 in 1955 to $525,000 in 1963. Although the offshore bottomfishes usually contribute less than 1 percent of the total landings for the Southeastern Coast (300 million to 475 million pounds per year), they represent between 2 and 3 percent of the total monetary value of the landings ($17 million to $23 million per year). Increased production of these more valuable offshore species therefore would substantially increase the income to the area, although would not greatly increase the total fishery landings.

Although the offshore fishery takes about 20 species of fish, a relatively few species dominate the landings. In recent years, the black sea bass has been the primary catch. The establishment of a winter-trap fishery for this species in North and South Carolina (Rivers, 1966) is the reason for the increased landings since 1961 (Figure 5). The second most valuable species is the red snapper, about 850,000 pounds of which are caught annually at a value of about $260,000 (Figure 6). Groupers are the next most abundant group of fishes, now yielding slightly over 500,000 pounds per year (Figure 7). The remaining four species

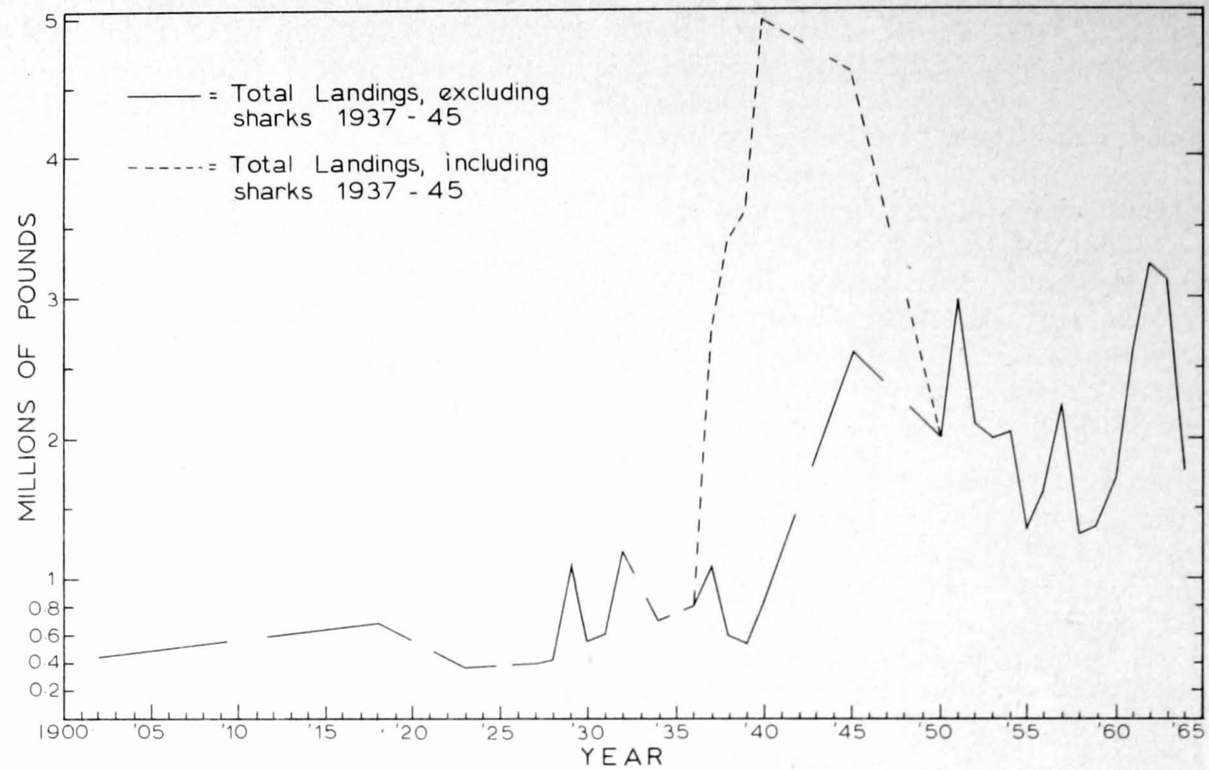


Figure 3.—Annual landings of offshore demersal fishes for Southeastern United States, 1902-64. Sources: Fishery industries of the United States and Fishery statistics of the United States.

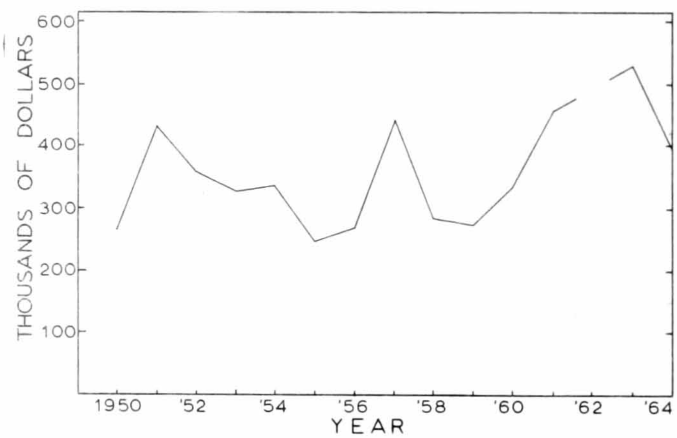
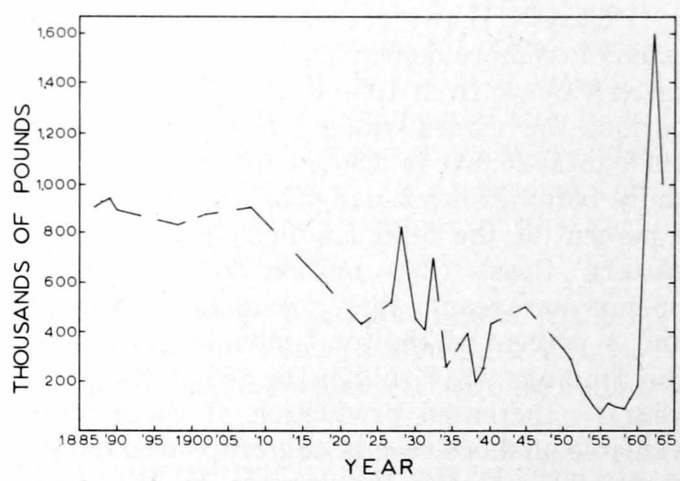


Figure 4.—Annual values of the offshore demersal fish catch for Southeastern United States, 1950-64. Source: Fishery statistics of the United States.

Figure 5.—Annual landings of black sea bass for Southeastern United States, 1886-1964. Sources: Fishery industries of the United States and Fishery statistics of the United States.



of snappers are the fourth most abundant group (Figure 8). Along the Southeastern Coast, the bulk of the snapper and grouper catches comes from the East Coast of Florida, whereas the catch of black sea bass comes almost exclusively from off the Carolinas. Other less abundant commercial species from offshore areas include amberjack, cobia, grunt, hogfish, scup, sharks, spadefish, and gray triggerfish.

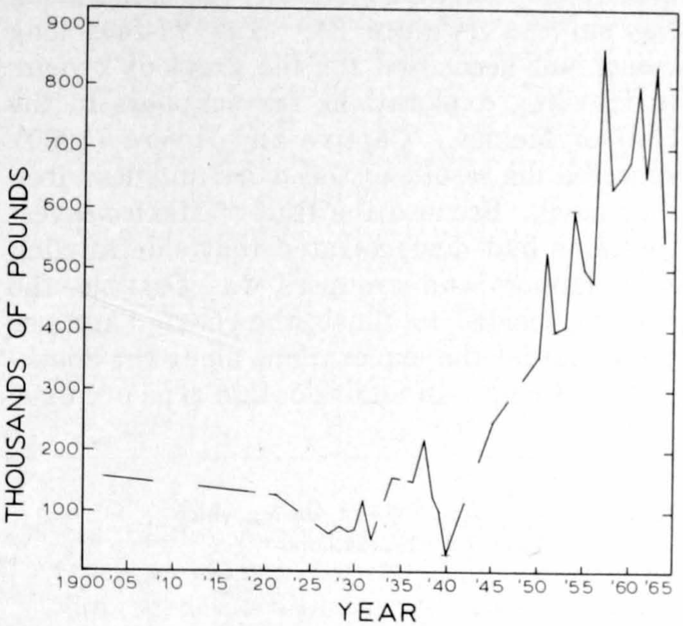


Figure 6.—Annual landings of red snapper for Southeastern United States, 1902-64. Sources: Fishery industries of the United States and Fishery statistics of the United States.

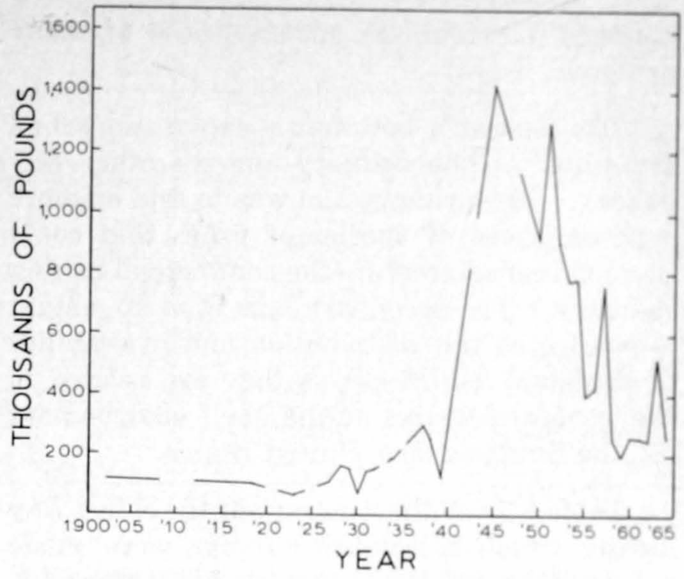


Figure 7.—Annual landings of grouper for Southeastern United States, 1902-64. Sources: Fishery industries of the United States and Fishery statistics of the United States.

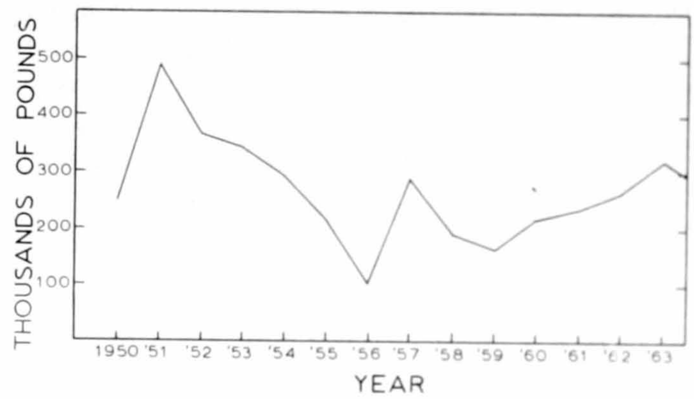


Figure 8.—Annual combined landings of yellowtail, gray, mutton, and vermilion snappers for Southeastern United States, 1950-64. Source: Fishery statistics of the United States.

II. EXPLORATORY TRAWLING FOR OFFSHORE DEMERSAL FISHES

Because the total survey program involved various other surveys — such as explorations for clams, scallops, and shrimps — the surveys for demersal fishes were usually made along with those for other resources. As a result, the exploratory fishing efforts are not evenly distributed throughout any region or season.

A nonsystematic approach such as this has certain disadvantages, especially when the aim of the survey is to obtain data that can be treated statistically, but a survey based on a pattern of stations established at preselected locations and depths also has certain disadvantages. Such a survey is valid only for a nearly homogeneous environment, which does not prevail on the Continental Shelf regions of the world. In little-known regions such as those off the Southeastern Coast of the United States, an initial program of sampling at preselected sites has the inherent danger of obscuring the real abundance of a species, especially when dealing with animals that have clumped distributions, such as those of many demersal fishes.

The Bureau's bottomfish explorations had two aims — one primary and the other secondary. The primary aim was to find offshore concentrations of species of fishes that could be used immediately by the commercial fishing industry. The secondary aim was to obtain a picture of the distribution and availability of demersal fish stocks as they are related to the general features of the shelf environment off the Southeastern United States.

Table 1 gives the itinerary of the *Silver Bay* during which bottomfish surveys were made out to depths of 100 fathoms; Tables 2 and 3, the distribution of exploratory fish- and shrimp-trawling stations by depth range and latitude. Most of the trawling was in depths of less than 41 fathoms. The shallower depths received greater attention because most of the Continental Shelf of the Southeastern United States lies in depths less than 35 fathoms and because the conventional shrimp-trawling vessels in the region cannot fish at greater depths easily (Knake, Murdock, and Cating, 1958). For this report, however, all survey findings to the 100-fathom isobath are included. I feel that the initial exploratory results have provided data that enable us to assess the resources of bottomfishes in this region and to generally relate their distributions to the environmental factors of temperature, depth, and bottom type.

In the following sections the survey methods and results are described.

A. SURVEY METHODS

The *Silver Bay*, a conventional North Atlantic steel-hulled side trawler, was used during the surveys (Figure 2). The 97-foot long vessel had been used for the previous 2 years in trawling explorations for snappers in the Gulf of Mexico. Captiva and Rivers (1960) reported the results of this work and described the vessel. Because the Gulf-of-Mexico investigations had demonstrated that sidetrawling for snappers and groupers was feasible, the Bureau decided to renew the charter and use the vessel for the explorations along the Southeastern Coast. In addition, this type of vessel

Table 1.—Itinerary of *Silver Bay* off the Southeastern United States, 1959-64, during which demersal fish explorations were made in depths of less than 101 fathoms

Cruise number	Dates	Offshore area explored	Trawling stations occupied
			Number
18	31 Aug. to 28 Sept. 1959	Cape Fear, S. C., to Cape Hatteras, N. C.	104
19	14-29 Oct. 1959	Brunswick, Ga., to Cape Fear, N. C.	70
20	21 Nov. to 13 Dec. 1959	Onslow and Raleigh Bays, N. C.	31
21	13-29 Jan. 1960	Georgia and Northern Florida	38
22	16 Feb. to 18 Mar. 1960	Brunswick, Ga., to Cape Hatteras, N. C.	89
23	4-5 May 1960	Off St. Augustine, Fla.	13
24	12-13 June 1960	St. Augustine to Jacksonville, Fla.	13
25	13-30 July 1960	Savannah, Ga., to Cape Hatteras, N. C.	67
27	1-16 Dec. 1960	Savannah, Ga. to Cape Fear, N. C.	22
28	18 Jan. to 10 Feb. 1961	Ft. Pierce to Jacksonville, Fla.	27
29	1-20 Mar. 1961	Onslow and Raleigh Bays, N. C.	11
30	17-22 Apr. 1961	St. Augustine, Fla., to Brunswick, Ga.	40
31	19-20 July 1961	St. Augustine to Jacksonville, Fla.	10
32	8-22 Aug. 1961	Savannah, Ga., to Cape Lookout, N. C.	27
35	8-14 Dec. 1961	Savannah, Ga., to Cape Lookout, N. C.	14
37	23 Feb. to 5 Mar. 1962	St. Augustine, Fla., to Savannah, Ga.	15
39	26 May to 10 June 1962	Savannah, Ga., to Cape Hatteras, N. C.	4
40	22 July to 6 Aug. 1962	Onslow Bay, N. C.	32
45	17-30 Jan. 1963	Savannah, Ga., to Cape Fear, N. C.	34
48	8-18 May 1963	Jacksonville, Fla., to Savannah, Ga.	30
52	4-17 Dec. 1963	Georgia	34
53	11-22 Jan. 1964	South Carolina	22
55	26 Feb. to 13 Mar. 1964	St. Lucie Inlet to St. Augustine, Fla.	78
56	30 Mar. to 20 Apr. 1964	Cape Romain, S. C., to Cape Hatteras, N. C.	78
57	30 Apr. to 19 May 1964	St. Augustine, Fla., to Cape Romain, S. C.	53
	Total		956

Table 2.—Fish-trawl stations occupied by the *Silver Bay* off Southeastern United States, 1959-64

Geographical location	Stations occupied and time fished at: 6-10 fathoms		11-20 fathoms		21-30 fathoms		31-40 fathoms		41-50 fathoms		51-60 fathoms		61-80 fathoms		81-100 fathoms		Total stations occupied
Latitude North	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No.*
35°00′-35°20′	1	2	2	3	1	2	1	2	--	--	--	--	--	--	2	2	7
34°00′-34°59′	39	44	48	52	7	7	11	15	2	2	2	2	1	1	4	5	114
33°00′-33°59′	28	37	63	79	32	40	13	17	8	9	3	5	3	4	1	2	151
32°00′-32°59′	4	5	33	38	30	32	11	18	6	9	--	--	5	6	--	--	89
31°00′-31°59′	--	--	6	8	22	25	25	37	3	4	4	5	6	7	--	--	66
30°00′-30°59′	2	2	46	51	16	19	5	5	3	5	--	--	--	--	1	1	73
29°00′-29°59′	1	1	49	65	16	23	11	13	2	3	2	3	1	2	1	2	83
28°00′-28°59′	7	9	11	14	4	4	2	2	--	--	1	1	1	2	1	1	27
27°00′-27°59′	4	5	14	18	7	10	5	6	2	3	2	4	1	2	--	--	35
Total stations occupied . . .	86		272		135		84		26		14		18		10		645

Table 3.—Shrimp-trawl stations occupied by the *Silver Bay* off Southeastern United States, 1959-64

Geographical location	Stations established and time fished at: 6-10 fathoms		11-20 fathoms		21-30 fathoms		31-40 fathoms		41-50 fathoms		51-60 fathoms		61-80 fathoms		81-100 fathoms		Total stations occupied
Latitude North	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No. Sta.*	*Hours fished*	*No.*
35°00′-35°20′	1	1	--	--	--	--	3	3	1	1	--	--	--	--	2	2	7
34°00′-34°59′	41	45	40	45	14	16	2	2	1	1	--	--	1	2	2	4	101
33°00′-33°59′	25	25	38	39	12	13	1	1	3	2	3	4	--	--	--	--	82
32°00′-32°59′	23	22	21	21	4	4	4	5	1	1	1	1	--	--	--	--	54
31°00′-31°59′	11	11	18	18	4	4	--	--	--	--	--	--	--	--	1	1	34
30°00′-30°59′	8	9	11	12	5	5	--	--	--	--	--	--	--	--	--	--	24
29°00′-29°59′	2	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2
28°00′-28°59′	4	3	--	--	--	--	--	--	--	--	--	--	2	4	1	2	7
Total stations occupied . .	115		128		39		10		6		4		3		6		311

was readily adaptable to other types of gear (such as shrimp trawls, scallop dredges, and clam dredges) and permitted investigators to remain at sea for long periods and to fish during bad weather.

During the first year of the survey, an introduction to the offshore resources of shrimp and demersal fishes was gained by using shrimp trawls with headropes 40 to 65 feet long (Bullis, 1951). Our primary emphasis during this time was to get a general picture of the region, and to accomplish this purpose, we made 1-hour tows along onshore-offshore transects. This method resulted in a more-or-less random distribution of exploratory fishing stations over most of the Continental Shelf. Although we obtained good data on the offshore distribution and abundance of commercial species of shrimps, we felt that the real composition and abundance of the demersal fish resources were not reflected by the shrimp-trawl stations.

Accordingly, during subsequent bottomfish surveys, we spent much time searching with depth recorders for concentrations of fishes before we began sampling with conventional New England-type roller-rigged otter trawls. We supplemented this type of sampling by a number of "blind sets" (that is, we made the sets even though we detected no fish schools on the fish finder), again with otter trawls, to sample the fish fauna of an entire area. All of the trawls had stretched-mesh webbing varying from 4 to 5½ inches in the wings and body and from 1½ to 2½ inches in the cod ends. We made most of the explorations with trawls having a 54-foot headrope and a 74-foot footrope, because such gear is readily used by the conventional shrimp trawlers of the region. We also used trawls with 50-foot headrope and 70-foot footrope, 70-foot headrope and 90-foot footrope, and 80-foot headrope and 100-foot footrope (Knake, 1956 and 1958; Captiva and Rivers, 1960).

The footrope gear of the standard fish trawl consisted of a string of wooden rollers 20 to 24 inches in diameter separated by two to four 6-inch wooden spacers in the bottom bosom section and the first section of each wing of the trawl. The footrope of the terminal section of each wing usually incorporated a string of 6-inch wooden or rubber spacers. In some areas, such as off Northeastern Florida in 13 to 23 fathoms, much of the bottom is trawlable with nets having only 6-inch spacers along the entire footrope. The standard roller-rigged trawl was satisfactory in most rough-bottom areas but was less so in some of the extremely rough areas at the edge of the Continental Shelf.

We located concentrations of fishes by running transects in the selected area of exploration with the aid of a depth recorder incorporating a "white-line" feature. This type of recorder was an essential tool for locating schools of fish; its value is greatly increased when it is used with a cathode-tube scale expander.

On rare occasions, we located schools by noting loggerhead turtles (*Caretta caretta*) that had surfaced after feeding in areas where fishes were concentrated.

Trawling began whenever recordings indicated that sizable concentrations of fish were present on a bottom suitable for trawling. When a school of fish thought to be of suitable size was detected during a transect, the officer on watch signaled for the dropping of a small fishing buoy and anchor near the school. The vessel was then slowed to half speed, and the area around the buoy was surveyed with the depth recorder to determine the size of the school and its location in relation to the buoy.

Because schools of fish are so highly localized in the offshore waters of this coast, a fishing buoy has to be used, particularly inasmuch as the extremely flat topography of the outer shelf precludes the use of a particular depth range or bottom-finding feature as a guide to the location of a school.

After the trawl was retrieved, data on the catch were taken. The fishes and invertebrates in the catch were analyzed for species composition, weight, number, and size. Also recorded were the prevailing meterological and hydrographic conditions. Additional miscellaneous information — such as sex ratios, conditions of gonads, and stomach contents — was occasionally recorded for commercially important species. Fish and invertebrates of value to cooperating taxonomists were routinely collected on each cruise. Personnel from the Bureau's Biological Laboratory at Brunswick, Georgia, identified and catalogued a comprehensive collection of the fishes taken during the explorations.

B. RESULTS

The results from the early phase of the trawling survey were not encouraging and were similar to those reported by Powell (1950), Buller (1951), and Cummins, Rivers, and Struhsaker (1962a).

Trawls are highly selective. For example, off Northeastern Florida, red snapper is the most abundant species caught by the handline fishery in the offshore areas (see Figure 6 and Moe, 1963: 10-18). In this area, trawls took red snapper often but never in large quantities. On the other hand, the same vessel and gear made catches of up to 1,700 pounds of snappers per hour on Campeche Bank (Captiva and Rivers, 1960). At present, the cause of this variation in the catches between the two areas is speculative; for example, differences in abundance and/or behavior of the two populations or variations in trawling techniques during the two surveys could be the explanation.

After the initial phase of the exploratory program, additional fishing with large roller-rigged otter trawls showed that a latent resource of fishes was associated with certain localized bottom habitats. The following subsections present our detailed findings analyzed according to ecology and species of fish caught, catches of commercial size, and geographical subregions explored.

1. Ecology

Of the environmental conditions that govern the distribution of demersal fishes inhabiting continental shelves, those of temperature, topography, and substrate are generally the most influential. Despite their recognized importance in the ecology of commercial species of marine organisms, little information is available concerning the distribution of these critical properties in time and space for most of the continental shelf areas of the world. Since a basic understanding of how these environmental factors vary from area to area is necessary for an understanding of the distribution of bottomfishes, an elementary description is given of these conditions in the region we explored. On the Continental Shelf of the Southeastern United States, the various combinations of these factors give rise to five general types of habitat: namely, coastal, open-shelf, live-bottom, shelf-edge, and lower-shelf. The initial exploratory fishing survey strongly indicates that the distribution of distinctive associations of fishes is correlated with these five habitats (Figure 9).

a. Coastal habitat. — The coastal habitat extends from the sounds and estuaries of the Southeastern States out to depths of 8 or 10 fathoms. The bottom is generally smooth, sandy mud. Because the area is close to estuaries and land masses, temperatures at the bottom fluctuate greatly with the seasons (about 50° to 85° F.). This coastal zone holds the important shrimp and crab fisheries of the Southeastern Coast. The fishes of this habitat are primarily of the drum family — croakers, spot, two species of kingfish, silver perch (yellowtail), sea trouts, star drum, red drum, and banded drum.

Large quantities of fishes suitable for food or industrial purposes were found in the coastal habitat. This area, however, was not explored intensively because the shrimp fishermen of the Southeastern Coast are well aware of the availability of fishes there. Inasmuch as a variety of food fishes incidental to the shrimp fishery are already taken from this zone, increased use of the inshore bottomfish resources is primarily a problem of developing a market for existing stocks.

b. Open-shelf habitat. — Proceeding offshore, we find that the next general area is the open-shelf habitat. Because the boundary between the coastal habitat and the open-shelf habitat is indefinite and gradual, the open-shelf habitat is arbitrarily considered to extend from about the 10-fathom depth curve out to the beginning of the "shelf break" (at about 25

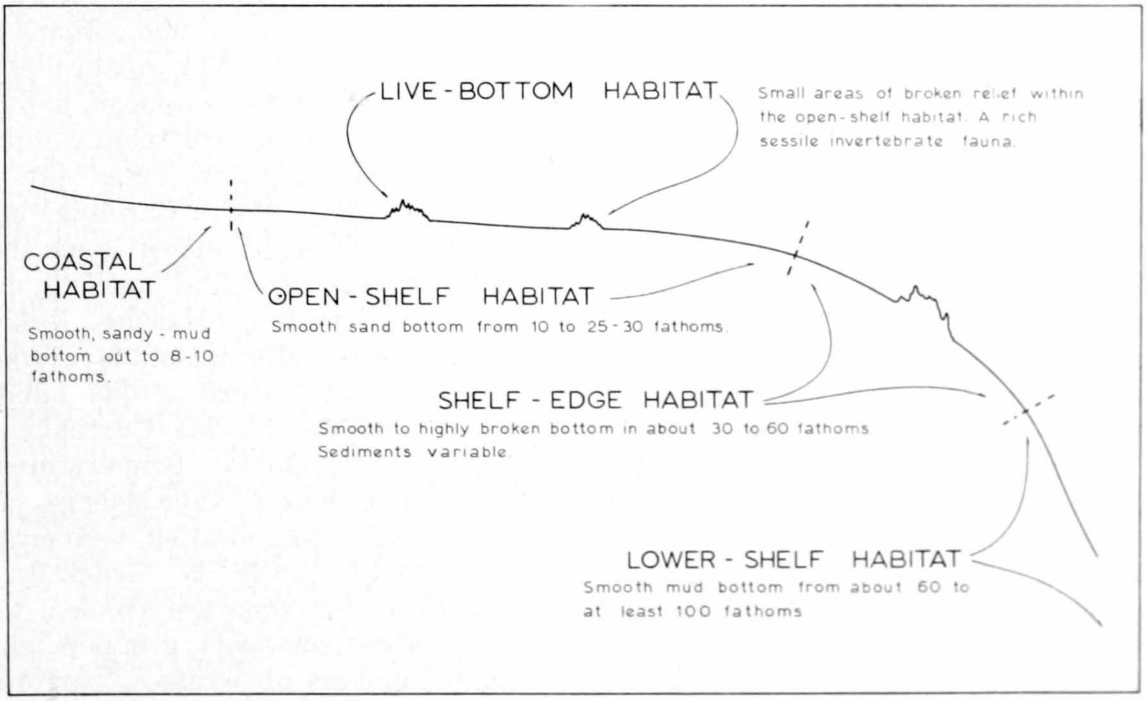


Figure 9.—A schematic section of the Continental Shelf off Southeastern United States showing the five general habitats considered in this report.

to 35 fathoms). This habitat comprises most of the offshore shelf area. Except for some shallow depressions that occur inshore in depths of from 10 to 14 fathoms, it has a very smooth, slightly undulating, sandy bottom that slopes imperceptibly offshore. Compared with those of the coastal habitat, bottom temperatures in this habitat fluctuate less widely, ranging from about 52° to 80° F., and average warmer because much of the area is near the Florida Current (Gulf Stream). This current, which roughly follows the shelf edge, makes for warmer bottom temperatures offshore during the winter. The converse occurs during summer, when bottom temperatures are warmest in the coastal regions. In general, this habitat is relatively unproductive; the fish fauna are preponderantly small numbers of scup, orange filefish, searobins, inshore lizardfish, and sand perch. Occasionally, large numbers of planehead filefish are also found.

During random trawling over the open-shelf habitat, we took many small catches of food and industrial bottomfishes; occasionally interspersed were large catches that approached commercial size. The large catches were not made frequently enough, however, to cause us to classify the average catch as large. For example, 33 random drags with large otter trawls (having 50- to 80-foot headropes) over the open-shelf habitat in depths of from 13 to 23 fathoms off Northeastern Florida and South Carolina averaged only about 350 pounds of fish per hour.

c. Live-bottom habitat. — At various locations, the Continental Shelf is interspersed with "islands" of broken relief. These areas are referred to as the live-bottom habitat and appear to consist of outcrops of rock that are heavily encrusted with such sessile invertebrates as sponges and sea fans. The outcrops seem to be more numerous off Northeastern Florida but are also scattered over most of the shelf. Temperatures are similar to those for the open-shelf habitat. The live-bottom areas harbor a rich association of subtropical and tropical species of fishes and are the basis for the productive handline fishery off Northeastern Florida. Most live-bottom areas are at depths of greater than 15 fathoms, but numerous scatterings of such areas are at depths of from 9 to 14 fathoms, especially off the Carolinas. Generally, snappers, groupers, and porgies pervade the live-bottom habitats off Northeastern Florida and the offshore areas of Georgia and the Carolinas near the Florida Current. The live-bottom areas inshore near the 10-fathom curve have a less-rich invertebrate fauna and are occupied largely by black sea bass and scup. A trap fishery catches sea bass on these inshore grounds in winter and spring (Rivers, 1966).

Commercial quantities of snappers, groupers, porgies, and ecologically related species were consistently caught when the live-bottom areas were fished. The most productive areas were found off Northeastern Florida and South Carolina at depths of from 13 to 23 fathoms. For example, 83 drags in the live-bottom areas of these areas averaged about 1,225 pounds per hour (as contrasted with about 350 pounds per hour over the open-shelf habitat of the same regions).

d. Shelf-edge habitat. — The fourth area is the shelf-edge habitat, which is a more-or-less continuous zone along the entire edge of the Continental Shelf; its depths extend from about 25 or 35 fathoms to 60 fathoms. The bottom types are more diverse in this zone and vary from smooth mud bottoms to bottoms that are characterized by great relief and heavy encrustations of coral, sponge, and other predominantly tropical invertebrate animals. Some of these broken-bottom areas (at least those off Onslow Bay, North Carolina) may represent the remains of ancient reefs that existed when the sea level was lowered during the last glacial period (Menzies, Pilkey, Blackwelder, Dexter, Huling, and McCloskey, 1966). The dominant feature of this habitat is the presence of the Florida Current. Owing to this current, annual temperatures average higher than those further inshore. Depending on the season and location, temperatures vary from about 55° to 78° F. Generally, the fishes inhabiting this zone are tropical types, such as the basses, snappers, groupers, and porgies. Small numbers of wrasses, parrotfishes, and damselfishes are also present. The fishes generally are rather diffuse in this zone, but often they concentrate in aggregations over broken-bottom areas and form associations similar to those formed further inshore at lesser depths.

e. Lower-shelf habitat. — The fifth area is the lower-shelf habitat, which, geologically, is a part of the upper Continental Slope. It is characterized by depths of about 60 to at least 100 fathoms and a predominantly smooth mud bottom. Temperatures in this zone vary from about 51° to 57° F. The most numerous fishes are the cold-water and high-latitude forms such as the hakes, flatfishes, butterfish, and John Dory. This habitat and its association of fishes roughly marks the transition between the fauna of the Continental Shelf and the fauna of the upper Continental Slope. The latter appears to be a distinct and rich association of animals in the Southwestern North Atlantic, which has been the object of considerable investigation by the Bureau (for example, Bullis and Rathjen, 1959).

Little exploratory work was done on the lower-shelf habitat, because it is largely inaccessible to the type of vessels fishing in the region. The results of the limited trawling in this zone, however, are included in the discussion of each subregion.

These typical associations of fish cannot be considered as being completely stable groups of animals, for they are changing (within limits) constantly and subtly. Factors such as spawning success and seasonal migration patterns often complicate the picture. For example, many of the coastal fishes, such as spot, move into the deeper waters of the offshore habitats during winter. Conversely, spotted hake, which normally inhabit lower-shelf and upper-slope zones, move into the coastal habitat during winter. The spiny dogfish is found in the coastal habitat during winter but apparently withdraws to the area north of Cape Hatteras during summer (Bearden, 1965). Moe (1963) concluded that snappers and groupers move inshore off the East Coast of Florida during summer and offshore during winter. He attributed the movements to changes in temperature.

In general, on the Southeastern Coast, most of the groups of fishes that inhabit the offshore Continental Shelf (not including those that occupy the lower-shelf habitat) have tropical affinities, whereas those that inhabit the inshore coastal areas are the groups that reach their greatest abundance off the Middle Atlantic States and in the Northern Gulf of Mexico (Ginsburg, 1952).

Longhurst (1965) evaluated the results of exploratory fishing in the Gulf of Guinea and concluded that the fish fauna there occurs in distinct associations that can be correlated with particular types of habitat. He, too, based his classification of habitats primarily on bottom types and temperatures. But because of the differences in the environment of the two regions, his classification is quite different from that presented here.

2. Catches of Commercial Size

A fishing log (Appendix A) was compiled of 50 stations arbitrarily selected where commercial-size catches of demersal fishes were made. This log serves as a general guide to some of the better fishing areas and an indication of the predominant species available. All catches were made with roller-rigged otter trawls having headrope lengths of from 50 to 80 feet. Each station has a number that refers to its general location as shown in Figure 10. Most of the catches were made in the productive live-bottom and shelf-edge areas. One station in the log frequently represented an area where several catches of commercial importance were made.

3. Species of Fishes

Appendix B is a list of the demersal fishes taken by the *Silver Bay* in depths of less than 101 fathoms off the Southeastern Coast (latitude 35°20′ N. to latitude 27°10′ N.) from 1959 to 1964. This compilation is based on more than 21,000 field and laboratory identifications. Most of the common and scientific names used follow those promulgated by the American Fisheries Society (1960); some common names are those used by the Bureau of Commercial Fisheries but not by American Fisheries Society. Cooperating ichthyologists identified the rare species of complex groups from materials

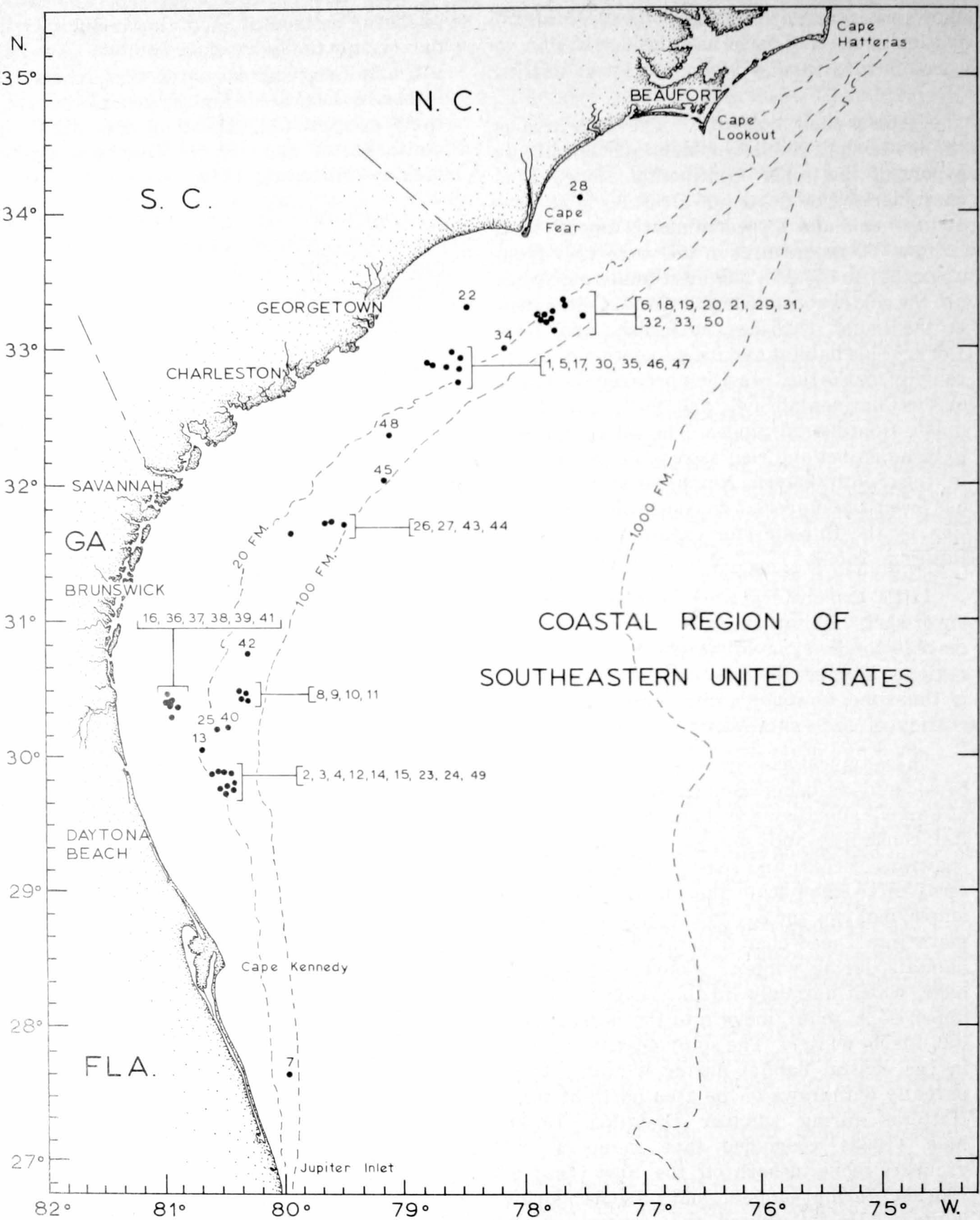


Figure 10.—Locations of 50 exploratory fishing stations where commercial quantities of demersal fishes were taken. Each number refers to a particular station listed in the fishing log (Appendix A).

collected during the explorations. The material ranges from 850 records of the ubiquitous dusky flounder to 2 records of *Chorististium eukrines* (Serranidae), recently described by Starck and Courtenay (1962).

All identifications of fishes and invertebrates have been programmed for automatic data processing at the Bureau's Exploratory Fishing and Gear Research Base, Pascagoula, Mississippi. Summaries of these records are reported periodically (Springer and Bullis, 1956; Bullis and Thompson, 1965). Specific, timely information from the system is also available to biologists and members of the commercial fishing industry.

In addition to presenting a list of the fishes taken, I have attempted to indicate how frequently each species was captured by trawls fished in the primary habitat of the species. The category "very common" indicates that a species was present in over 50 percent of the tows, whereas "common" or "rare" indicates that a species appeared in about 10 to 50 percent or in less than 10 percent of the tows, respectively. I have also made notations about the primary habitat of each species and have occasionally commented on the abundance and distribution of the species. The most accurate appraisals are those for species taken in the most intensely explored area — that is, for those taken in the 10- to 40-fathom depth range.

The list is not intended to be a complete tabulation of all offshore fishes of the Southeastern Coast; rather it is intended as an introduction to the demersal species occurring in the region and their relative abundance and basic patterns of distribution as indicated by the material collected only by the *Silver Bay*.

4. Geographical Subregions

The exploratory trawl catches were analyzed according to the following geographical subregions: Raleigh Bay, North Carolina, Onslow Bay, North Carolina; South Carolina; Georgia; Northeastern Florida; and Central Florida (see Figure 1).

a. North Carolina. — As was just indicated, two subregions off the North Carolina Coast were explored: Raleigh Bay and Onslow Bay.

(1) Raleigh Bay. — About 100 fish- and shrimp-trawl stations were established in Raleigh Bay at depths of from 5 to over 100 fathoms. The five exploratory cruises were timed to sample the fish available at every season of the year. Raleigh Bay was not sampled as inclusively as were other subregions of the Southeastern Coast because the trawl fishery now operating there usually covers the area in depths of less than 30 fathoms.

(a) *Coastal and open-shelf habitats.* —Dragging in the coastal and open-shelf habitats did not reveal any resources of demersal fishes that are not now being used. Catches taken were generally small (100 to 200 pounds per hour), but occasionally moderate to large catches (500 to 2,800 pounds per hour) were taken of northern puffer, croaker, spot, sea trouts, kingfish, searobins, summer flounder, and butterfly rays. All these explorations were completed by mid-1960.

(b) *Live-bottom habitat.* — No live-bottom areas were found in the Raleigh Bay subregion during the survey.

(c) *Shelf-edge habitat.* — We did not make additional explorations for bottomfishes in Raleigh Bay until April 1964 when, despite bad weather, we established 21 trawling and handline stations. Although the results of the inshore drags in the coastal and open-shelf habitats were similar to those obtained in 1960, echo-sounding transects over the shelf-edge zone revealed large concentrations of bottomfishes in three areas of broken relief between 30 and 40 fathoms; these stocks are not commercially used at present.

The first of these areas, a small spot of broken bottom, in 37 fathoms, is at latitude 34°59.5′ N., longitude 75°24′ W. (loran bearings 1H6-1113, 1H7-4765). A trawl was badly damaged during an attempt to sample this area — the catch remaining in the cod end was 35 pounds of medium-sized black sea bass and miscellaneous invertebrates.

The second area, a 4-mile-long ridge that shoals to 30 fathoms from a depth of 37 fathoms, lies due east of Drum Inlet (Figure 11).

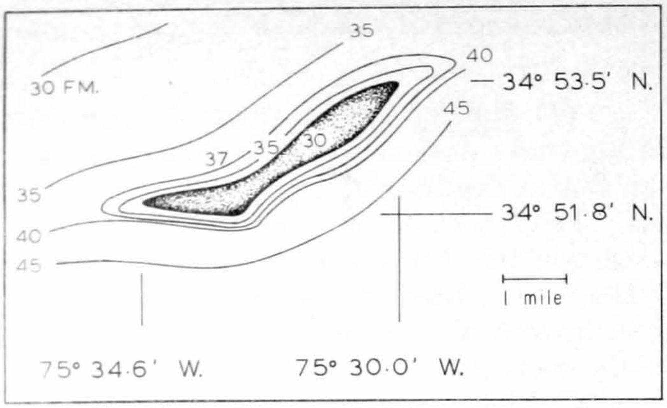


Figure 11.—A 4-mile-long ridge in 37 fathoms due east of Drum Inlet, N.C., where heavy concentrations of bottomfishes were recorded.

The depth recorder showed heavy concentrations of bottomfishes along the sides and over much of the top of this ridge (Figure 12). The bottom was not trawlable with the exploratory gear used, but trawls and handlines took small catches of black sea bass, red snapper, and pink porgy.

The third area, about 8 miles long formed by a sharp dropoff in the bottom from the 35- to 40-fathom depth contour, lies due east of Cape Lookout (Figure 13). We recorded heavy concentrations of fish shoals between 37 and 40 fathoms along the entire length of the ridge. Again, although trawling conditions were difficult, we took red snapper, pink porgy, and small vermilion snapper in small amounts.

These limited observations indicate that large unharvested stocks of snapper, sea bass, porgies, and ecologically related species inhabit the rough-bottom grounds off Raleigh Bay. The depth recordings show some of the heaviest and most extensive concentrations of fish encountered on the entire Southeastern Coast during the 5-year survey. Although trawling in these areas damaged the gear heavily, the damage might have been lessened if the trawls had been equipped with a full set of rollers. These stocks could probably be taken with handlines despite the strong Florida Current in the area.

Because of bad weather, the remainder of the shelf-edge habitat in Raleigh Bay, which is the habitat located due east of Cape Lookout and extending southwest along the shelf edge to an imaginary line running southeast

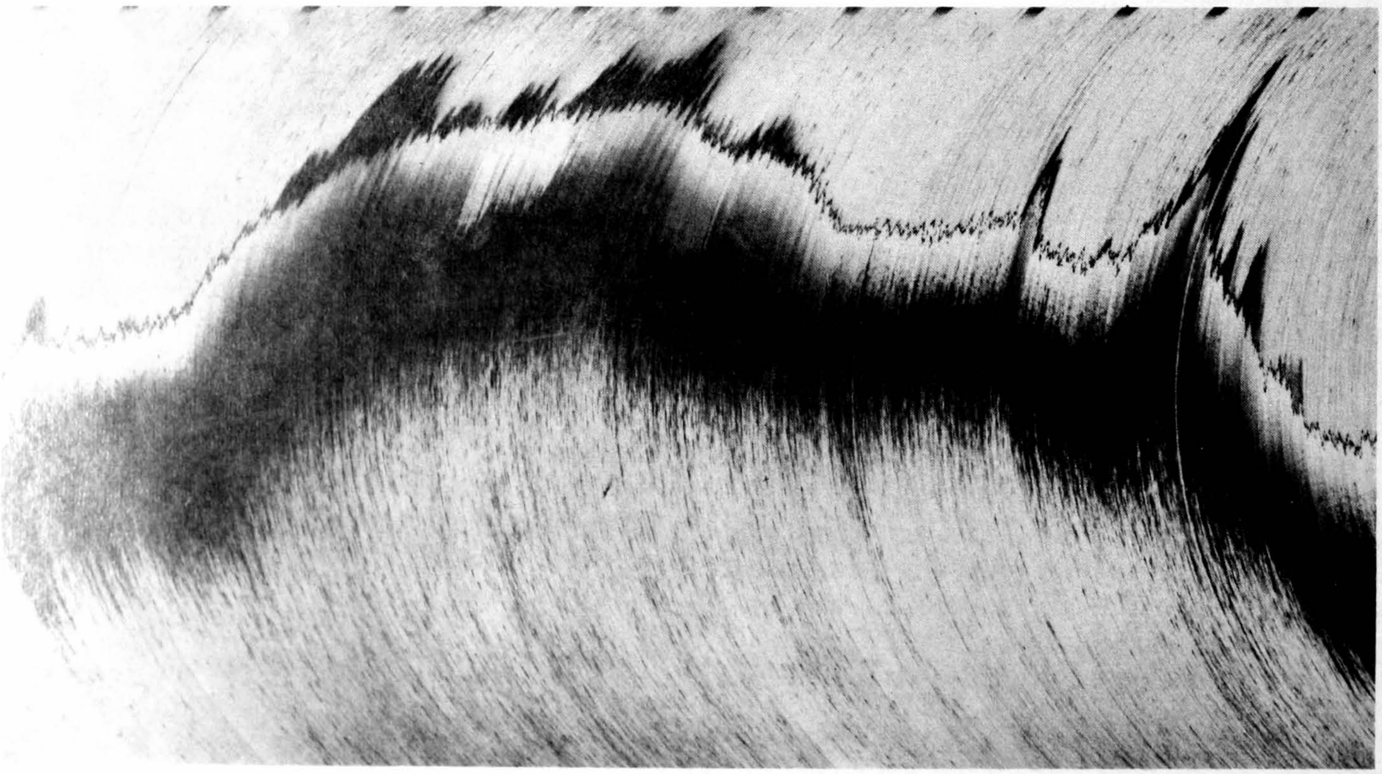


Figure 12.—Fathometer recording of a transect across the 4-mile-long ridge east of Drum Inlet showing concentrations of bottomfishes (see Figure 11 also).

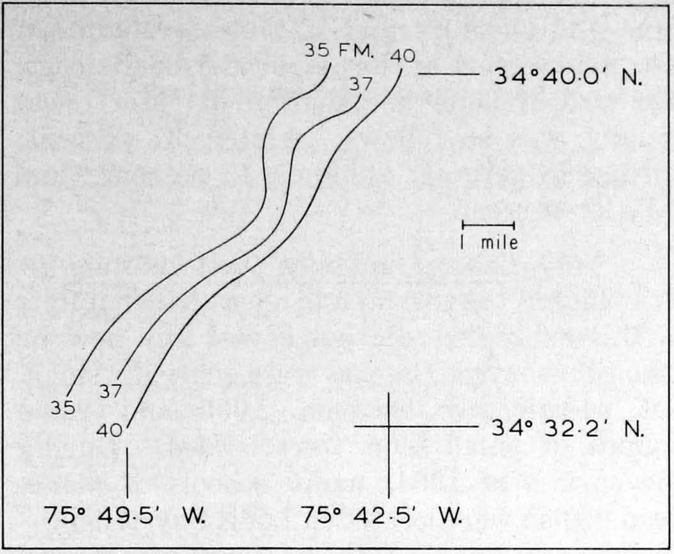


Figure 13.—An 8-mile-long ridge east of Cape Lookout, N.C., in about 37 fathoms, along which substantial concentrations of bottomfishes were recorded.

from Cape Lookout, was not explored during the last cruise in the area. Further exploration in this area is warranted.

(d) *Lower-shelf habitat.* — Our very limited exploration of the lower-shelf habitat produced catches of up to 1,800 pounds of small butterfish and 500 pounds of squid per drag. After 1960, we did not explore this habitat further.

(2) Onslow Bay. — The Onslow Bay subregion lies between Cape Lookout and Cape Fear. Substantial amounts of foodfishes are taken incidentally in the coastal shrimp-trawl catches in the bay. An offshore trawl fishery does not exist here because local fishermen generally consider the region untrawlable, owing to extensive areas of slab rock.

Because of the sizable shrimp- and fish-trawling fleet in the region, an assessment of the trawlability and the fishery resources in Onslow Bay could but be valuable to the commercial fishing industry of the region. Accordingly, 213 fish- and shrimp-trawling stations were occupied during nine cruises, covering every season. The distribution of exploratory effort was relatively uniform for each season except winter, when adverse weather curtailed the work. Most stations were established in the open-shelf habitat (10 to 25 fathoms) and the coastal habitat. Only a moderate amount of trawling was done in the shelf-edge habitat, and very little in the lower-shelf habitat. We found that most of Onslow Bay is trawlable. The fully roller-rigged otter trawls suffered relatively little damage, although more nets were torn up in the open-shelf habitat of this subregion than in any other open-shelf habitat explored during the survey.

(a) *Coastal habitat.* — Drags in the coastal habitat caught from 2,000 to 3,000 pounds per hour of small croaker, spot, kingfish, scup, sea trout, grunt, Spanish mackerel, and flounder. Most catches made farther offshore, in from 9 to 12 fathoms, were smaller, but an occasional drag would yield 2,500 or 3,000 pounds per hour of small butterfish and croakers.

(b) *Open-shelf habitat.* — The catches were variable both in amount and in species taken. Small catches, running from 100 to 600 pounds per drag, made in the open-shelf zone (10 to 25 fathoms) were composed of scup, filefish, lizardfish, searobins, and miscellaneous flatfishes. Larger catches ranging from 2,500 to 3,500 pounds were occasionally made; they consisted of small- to medium-sized scup, pinfishes, and northern puffers. Although black sea bass were taken often on irregular bottom between 11 and 15 fathoms, the quantity never exceeded 125 pounds per drag. During the spring of 1964, large schools of planehead filefish were caught along the outer open-shelf at depths of between 20 and 25 fathoms; some of the drags yielded up to 4,000 pounds each.

The echo sounder often recorded extensive schools of midwater and near-bottom fish over the open-shelf zone of Onslow Bay. The catches of scad (often as high as 900 pounds per drag) suggested that this fish constituted a large part of the recorded schools. Moderate numbers of herrings, such as threadfin, shad, and round herring, were also taken.

(c) *Live-bottom habitat.* — No extensive areas of live-bottom habitat were found in Onslow Bay. In limited areas of broken relief, a few small catches, ranging from 20 to 150 pounds, of red snappers and groupers were made in depths of from 14 to 25 fathoms. Because these catches were made during summer and fall, I surmise that the fish belonged to transient schools that had moved inshore from the shelf edge to occupy small patches of broken bottom during the warm months. The echo sounder showed no large concentrations of fishes in these areas, nor did trawling produce catches of commercial sizes.

(d) *Shelf-edge habitat.* — Data from about 30 trawl stations in the shelf-edge habitat (30 to 60 fathoms) indicated that this area is most promising for future fishery development. During 1956 and 1957, a small flourishing handline fishery landed 355,000 pounds of red snapper and 135,000 pounds of grouper. The fishery failed when fish became scarce after a massive mortality. At the time of the mortality, local fishermen reported large numbers of dead fish to me and believed that an incursion of cold water into the shelf-edge zone was the cause. Although our trawls made no large catches of snappers and groupers, depth recorder and trawling transects showed concentrations of fishes over broken relief. For example, quantities of fishes were found in 30 fathoms on a lump southeast of Frying Pan Lightship at latitude 33°15′ N., longitude 77° 22′ W. (loran bearings 1H6-2760, 1H7-4740). Trawling was comparatively unsuccessful in this restricted area, but small catches made by trawls and handlines took red snapper, grouper, hogfish, and amberjack.

The entire shelf-edge habitat in Onslow Bay, especially the northeastern sector, should be explored more intensely.

(e) *Lower-shelf habitat.* — The exploratory fishing effort expended in the lower-shelf habitat was inadequate to permit an immediate appraisal of the bottomfish resources.

b. **South Carolina.** — The South Carolina subregion lies between the latitude 32° N. and an imaginary line extending southeast from Cape Fear. It thus includes Long Bay, the northern span of which extends along the coast of North Carolina. Because this subregion has more Continental Shelf area than any other region that we explored, we needed about 295 fish- and shrimp-trawl stations to obtain an adequate picture of the potential fishery stocks. The proportional distribution of effort seasonally was as follows: winter, 37 percent; spring, 26 percent; summer, 15 percent; and fall, 22 percent.

(1) Coastal and open-shelf habitats. — Trawling in the coastal and open-shelf habitats in this subregion did not reveal any new or unused resource. Catches were generally small, but occasionally between 2,000 and 2,500 pounds of small scup were landed. During the spring of 1964, many schools of planehead filefish were located in Long Bay at depths of from 20 to 25 fathoms; catches ranged up to 9,000 pounds per drag.

(2) Live-bottom habitat. — Exploratory trawling showed that the live-bottom area had extensive stocks that were relatively unused. Concentrations of snappers, groupers, porgies, and ecologically related species were found at between 13 and 25 fathoms in widely scattered live-bottom habitats throughout the subregion. Some of the large catches included over 1,000 pounds of vermilion snapper and groupers. Pink porgy and groupers predominated in other drags. Selected catches are listed in the fishing log (Appendix A); locations are shown in Figure 10.

A large part of the fishes caught by trawl from the live-bottom areas off South Carolina is salable. Table 4 shows the species composition of trawl catches from the live-bottom habitat. The species that lead in the weight percentages, calculated from a total catch of 69,516 pounds, are listed for 40 stations. All stations lay in live-bottom areas at depths of between 13 and 23 fathoms; the catches were made during various cruises from August 1961 to January 1963. Small scup (3 to 6 per pound) predominated in these catches, making up 16.4 percent by weight of all species. The planehead filefish, of no commercial importance now, was the next most abundant fish, constituting 15.6 percent of the total weight. The four next most abundant fishes (vermilion snapper, pink porgy, tomtate, and gray triggerfish) are commercial species and constituted collectively 36.4 percent of the total weight. Other commercially important but

Table 4.—Proportionate species composition of 69,516 pounds of fishes taken in 40 *Silver Bay* trawl catches in live-bottom areas off South Carolina, 1960-63

Species	Proportionate weight
	Percent
Scup	16.4
Planehead filefish	15.6
Vermilion snapper	13.1
Pink porgy	9.2
Tomtate	7.1
Gray triggerfish	7.0
Thorny (roughtail) stingray	6.2
Scamp	5.1
Gag	2.3
Sand shark	2.3
Knobbed porgy	1.9
Amberjack	1.7
Hogfish	1.3
Orange filefish	1.3
Requiem sharks	1.1
Remaining species	8.4

less abundant species [such as scamp and gag (groupers), knobbed porgy, amberjacks, and hogfish] made up 12.3 percent of the total catch.

We simulated a commercial fishing operation during January 1963, when we found a large school of mixed fishes in 20 to 24 fathoms at latitude 33°45′ N., longitude 78° 33.5′ W. Using an otter trawl with an 80-foot headrope, we made nine consecutive drags in this area. The drags yielded 21,348 pounds, of which 72 percent consisted of commercial species (Table 5). Pink porgy, groupers, and gray triggerfish were the most abundant fishes in the catches; knobbed porgy, snappers, and hogfish appeared in lesser amounts.

In this general region, many small live-bottom habitats were found where catches were so insignificant that they are not listed in the log. For example, at a depth of 24 fathoms (latitude 32°40′ N., longitude 78°34′ W., loran bearing 1H6-3558, 1H7-4820), the echogram recorded extensive shoals of fish, but trawling yielded only small catches of pink porgy, red snapper, red grouper, scamp, and gag.

(3) Shelf-edge habitat. — The exploratory fishing efforts that have been completed in the shelf-edge habitat are only preliminary. We fished many of the trawling stations between 26 and 60 fathoms with inefficiently rigged trawls;[2] however, we found indications of commercial quantities of bottomfishes at scattered locales throughout the entire shelf-edge habitat. For example, at latitude 33°11′ N., longitude 77°11′ W. (see *Silver Bay* Station 5655 in log) in 29 fathoms, two drags with less efficient gear took 790 pounds of groupers, 500 pounds of gray triggerfish, 180 pounds of various snappers, 100 pounds of hogfish, and miscellaneous other species of commercial importance. At another location (32°21′ N., 79° 02′ W., loran bearing 1H6-3872, 1H-4793) in depths between 31 and 34 fathoms, 3 hours of handlining caught 915 pounds of speckled hind, 342 pounds of large red snapper weighing from 25 to 36 pounds each, and 168 pounds of amberjack. I conclude that the shelf-edge

[2] Occasionally the Vigneron-Dahl rig was not used; instead, the doors were attached to the trawl with 15-foot legs. This arrangement required fewer fishermen to handle the trawl and permitted trawling on a 24-hour basis.

Table 5.—Species composition, by weight, at nine *Silver Bay* stations with an 80-foot (headrope) otter trawl off South Carolina, January 1963

Station number	Weight of predominant commercial species									Total weights of:	
	Pink porgy	Groupers	Gray triggerfish	Knobbed porgy	Hogfish	Scup	Vermilion snapper	Red snapper	Grunts	Commercial species	All species
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
4667	390	645	460	110	125	45	50	--	20	1,845	2,850
4668	510	360	240	90	70	75	65	30	20	1,460	2,680
4669	--	645	170	50	40	10	40	25	15	995	1,600
4670	1,000	1,180	470	110	75	20	40	150	12	3,057	4,518
4671	250	162	210	75	20	110	125	4	--	956	1,300
4672	320	685	260	125	70	125	30	50	25	1,690	1,900
4673	720	465	290	140	85	60	75	65	70	1,970	2,500
4674	950	260	240	85	45	45	65	65	25	1,780	2,100
4675	790	260	245	165	48	60	30	25	20	1,643	1,900
Total weight	4,930	4,662	2,585	950	578	550	520	414	207	15,396	21,348

habitat of South Carolina has a high potential and will eventually prove to be extremely productive in snappers, groupers, and porgies, all of which are associated with grounds characterized by broken relief.

(4) Lower-shelf habitat. — We did little trawling in the lower-shelf habitat; however, 40-foot shrimp trawls caught up to 600 pounds per drag of spotted ling (450 pounds) and spot (150 pounds). At the same time, at depths of between 100 and 130 fathoms, the trawls also caught small amounts of groupers — an indication of a deepwater grouper population. Catches of up to 350 pounds per drag of red grouper were made here in depths of from 85 to 152 fathoms by the Bureau's *Albatross III* (Buller, 1951) and *Delaware* in 1958.[3]

c. **Georgia.** — The Georgia subregion lies between latitudes 30°45′ N. and 32°00′ N. All but 9 of the 136 exploratory trawling stations in this subregion were fished during winter and spring.

(1) Open-shelf habitat. — Although we made extensive fish-detection and trawling transects over the open-shelf habitat, we found no promising resources of demersal fishes. Catches usually contained typical open-shelf fauna, except for an occasional large amount of planehead filefish. During a 1-hour drag in 24 fathoms east of Sapelo Island (see Station 4961 in log), however, we caught about 4,000 pounds of large croakers (2 to 3 pounds each). These fish were taken in a "blind set" and were absent from the catches when trawling was repeated in the area. Evidently, a moving school had been sampled.

[3] Unpublished data. Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base, State Fish Pier, Gloucester, Massachusetts 01930.

(2) Live-bottom habitat. — It seemed reasonable to assume that areas of broken relief would be found off Georgia, because such topographic features are present off South Carolina and Northeastern Florida at depths of between 13 and 25 fathoms. Extensive bottom-sounding transects, however, showed only a few scattered areas of broken relief between 10 and 14 fathoms, and some few others in deeper water. None of these areas had any substantial stocks of bottomfishes during the winter and spring surveys.

The best signs of broken bottom were located in the region off Cumberland Island, in less than 25 fathoms. Here, a few small patches of broken relief are scattered about a 45-square-mile area between latitudes 30°45′ and 30°53′ N. and longitudes 80°07′ and 80°15′ W. at from 20 to 25 fathoms. In this area we made some promising catches (see Station 4938 in the log). Most likely, these specks of live bottom are structurally related to those off Northeastern Florida.

(3) Shelf-edge habitat. — As in the previous subregions considered, we obtained some of the best exploratory results on the shelf edge (26 to 60 fathoms), where trawling produced varying amounts of snappers, groupers, porgies, and ecologically related species. Handlining also yielded good catches at three locations during June 1963; positions and predominant species taken are given in Table 6.

We found the best trawling from latitude 31°45′ N. to 32°05′ N. (slightly outside of the subregion) in depths of from 30 to 50 fathoms. Here, the shelf-edge zone drops off gradually, making for a large area of smooth, trawlable bottom. Thus, little modification of the trawl footrope was necessary. Catches contained large croaker, pink porgy, red snapper, group-

Table 6.—Weight of principle fishes caught by handline at three *Silver Bay* stations off the Georgia Coast, June 1963

Station number	Position of station				Depth of water	Weight of fishes caught:			
	Geographic coordinates		Loran bearing						
	Latitude North	Longitude West	1H6	1H7		Amberjack	Groupers	Pink porgy	Red snapper
					Fathoms	*Pounds*	*Pounds*	*Pounds*	*Pounds*
4939	30°45′	80°06′	4113	3737	25-26	30	290	95	200
4946	31°29.5′	79°56.5′	4115	4003	27-30	--	155	80	43
4950	31°29.5′	79°56.5′	4120	4298	28-30	165	580	80	500

ers, and related species. Sampling over a 2-year period indicated that the composition of bottomfishes in this area changed with the seasons.

Our most comprehensive survey was made in December 1963, when, using a fish trawl rigged with a 50-foot headrope, we dragged the area bounded by latitudes 31°45′ N. and 32°00′ N. Eight exploratory drags between 35 and 40 fathoms yielded 8,365 pounds of bottomfishes (Table 7). Pink porgy was the principal commercial species in the area at that time. Limited explorations and data from other sources indicate that this area may be important wintering ground for large croakers. This area is the most promising one found off Georgia.

Table 7.—Species composition by weight of eight exploratory drags from latitudes 31°45′N. to 32°00′N. (Georgia) in 35 to 40 fathoms with a 50-foot (headrope) fish trawl, December 1963

Species	Weight
	Pounds
Pink porgy	3,420
Planehead filefish	2,578
Thorny (roughtail) stingray	575
Knobbed porgy	570
Vermilion snapper	511
Groupers	141
Amberjack	113
Red snapper	102
Grunt (tomtate)	58
Blackbar drum	47
Remaining species	250
Total	8,365

(4) Lower-shelf habitat. — We did little trawling in the lower-shelf habitat. Two 1-hour blind sets east of Savannah in from 75 to 80 fathoms took 3,000 and 4,000 pounds of small butterfish (12 per pound). Bad weather at the time prevented any additional sampling of the size and distribution of this population.

d. Florida.—We explored two subregions off the Florida Coast: Northeastern Florida and East Central Florida.

(1) Northeastern Florida. — The Northeastern Florida subregion lies between latitude 29°00′ N. and the Florida-Georgia State line at about latitude 30°45′ N. During 10 cruises in this subregion, we established 137 fish- and shrimp-trawling stations. Their proportional distribution seasonally was: winter, 30 percent; spring, 53 percent; summer, 17 percent; and fall, 0 percent.

(a) *Coastal and open-shelf habitats.* — We made few explorations in depths of less than 12 fathoms or of greater than about 26 fathoms. Trawling in the open-shelf habitat of this subregion produced small catches of scup, lizardfish, and orange filefish. We frequently detected extensive schools of planehead filefish; catches ranged from 4,000 to 9,000 pounds per drag.

(b) *Live-bottom habitat.* — The live-bottom habitat was one of the most productive that we found during the 5-year survey. Live-bottom habitats are extensive in the 10- to 25-fathom depth range; here exploratory trawling consistently caught commercial quantities of salable foodfishes. Selected catches are listed in the fishing log (Appendix A); locations are shown in Figure 10.

Forty-three drags of the live-bottom habitat yielded 62,980 pounds of fishes (Table 8). The species caught in the live-bottom habitat off Northeastern Florida differed slightly from the bottomfishes caught in the live-bottom areas off South Carolina. Vermilion snapper was the predominant species caught off Northeastern Florida, constituting 27.5 percent of the total catch; it was followed by thorny (roughtail) stingray and scup. Other commercial

Table 8.—Proportionate species composition of 62,980 pounds of fish taken in 43 *Silver Bay* trawl catches in live-bottom areas off Northeastern Florida, 1960-63

Species	Proportionate weight
	Percent
Vermilion snapper	27.5
Thorny (roughtail) stingray	16.8
Scup	15.4
Pink porgy	6.4
Tomtate	6.1
Gray triggerfish	5.5
Knobbed porgy	3.5
Blue angelfish	3.0
Orange filefish	2.5
Red snapper	1.9
Gray snapper	1.3
Atlantic spadefish	1.3
Remaining species	8.8

species (such as pink porgy, tomtate, gray triggerfish, knobbed porgy, and snappers) contributed 24.7 percent of the total catch. The selectivity of the trawls over the live-bottom habitat was apparent — although a commercial handline fishery in this area relies almost entirely upon groupers and red, gray, mangrove, and yellowtail snappers, these fishes made up only about 5 percent of our trawl catches.

(c) *Shelf-edge habitat.* — Trawl catches of snappers and groupers and the commercial handline catches indicate that extensive, relatively unused stocks of bottomfishes inhabit the shelf edge off Northeastern Florida. Although the broken relief of the shelf-edge habitat in this subregion makes trawling difficult or impossible, further explorations are warranted to define the untrawlable areas and the availability of bottomfishes to other gear.

(d) *Lower-shelf habitat.* — Several trawl hauls in the lower-shelf habitat produced small catches of butterfish, spotted hake, and spot only.

(2) Central Florida. — The east Central Florida subregion lies between latitudes 27°00′ N. and 29°00′ N. and, aside from Southeastern Florida, is the least explored area along the Southeastern Coast. Only 92 fish- and shrimp-trawl stations were established here, and most of them were in winter and spring. As a result, our knowledge of the Central Florida fish resources is fragmentary.

(a) *Coastal and open-shelf habitats.* — The coastal and inshore open-shelf habitats near Cape Kennedy were fairly productive. Catches of butterfish, croaker, spot, and banded drum ranged from 1,500 to 2,500 pounds per drag. Small amounts of kingfish were also caught. Most of the shelf between 14 and 30 fathoms consists of a smooth, sand-shell-gravel bottom; here the calico scallop (*Pecten gibbus*) is the principal species. Large beds of scallops were found over much of the shelf during extensive dredging explorations by the *Silver Bay* (Bullis and Cummins, 1961). In contrast, exploratory trawling for fishes was generally unproductive on these grounds.

(b) *Live-bottom habitat.* — Commercial and sport fishermen take full advantage of the few small live-bottom habitats available in this subregion. Small catches of snapper and grouper were made on several patches of live bottom, but echograms indicated that live-bottom areas and associated concentrations of fish were not extensive.

(c) *Shelf-edge habitat.* — Although concentrations of fishes were not located in the shelf-edge habitat during the most extensive survey, in the spring of 1964, additional work is needed in this region. Commercially important stocks of bottomfishes undoubtedly use this habitat, but the extremely broken nature of the bottom along much of the shelf edge may preclude trawling in depths of from 40 to 60 fathoms.

(d) *Lower-shelf habitat.* — Trawling in the lower-shelf habitat produced small amounts of butterfish and spotted hake only.

The need for additional trawling in this subregion was shown by some exploratory work completed by the Bureau's research vessel *Oregon* in the spring of 1965. At that time, moderate concentrations of large (13 to 25 tails per pound) brown and pink shrimps (*Penaeus aztecus* and *P. duorarum*) were found at depths of from 30 to 38 fathoms between Bethel Shoal and Cape Kennedy. Catches of spots and croakers ranged from 200 to 1,400 pounds per hour when a 40-foot trawl was used.

CONCLUSIONS

On the basis of the initial exploratory survey reported here, some general statements may be made about the resources of demersal fishes of the Continental Shelf of the Southeastern United States, particularly in the 10- to 40-fathom range. Most of the open-shelf habitat is relatively unproductive of bottomfishes when compared with the shelf fisheries of the temperate and boreal regions of the North Atlantic. Trawl catches in the open-shelf zone, with few exceptions, are small, and the potential for developing a trawl fishery for foodfishes in this habitat seems to be poor. Occasional catches of up to about 5,400 pounds of small scup and 9,000 pounds of planehead filefish indicate, however, that these species may occur locally in sufficient abundance to support an industrial bottom fishery for fishes used for pet food, mink food, crab bait, or fish meal.

Both the live-bottom and shelf-edge habitats were productive. Restricted live-bottom areas within the open-shelf habitat have the best potential for commercial fishing. Moderate to large catches of snappers, groupers, porgies, and ecologically associated species can be consistently made with roller-rigged, New England-type fish trawls. The most productive grounds are off Northeastern Florida and South Carolina, but additional isolated areas occur along most of the Southeastern Coast. Sizable catches can also be made on broken bottom of the shelf-edge habitat. Although we carried out most of our explorations with large fish trawls, all the resources located in the live-bottom and shelf-edge habitats can be harvested by conventional handlining methods. I would conservatively estimate that proper use of these resources would at least double the present annual landings of snappers and groupers in the Southeastern Region.

The coastal habitat of the Southeastern Region has abundant resources of demersal fishes that shrimp fishermen already know well. Use of these fishes (mostly members of the drum family) seems to be dependent upon developing a market for these species rather than upon additional exploratory fishing. Limited explorations in the lower-shelf habitat indicated that concentrations of butterfish, spotted hake, and perhaps groupers, are available.

With the exception of the fish stocks occupying the Northeastern Florida Subregion, the present commercial utilization of these recently explored offshore stocks of fish is small. Several vessels have trawled successfully in the live-bottom habitats off Florida and South Carolina but discontinued their operations for various reasons. A conservative estimate of the total landings from these trial operations is about 200,000 pounds of snappers, groupers, porgies, and large croakers. In addition, a few Florida handline vessels have fished some of the live-bottom habitats off Georgia; however, at present no vessel trawls throughout the year for offshore bottomfishes in this region.

The quality of trawl-caught fishes varies somewhat with the size and composition of the catch. In general, the quality of most fishes is excellent; however, when a catch includes large numbers of loggerhead sponges that crush and distort the fishes, the market value of these fishes will be reduced.

A hazard of trawling in these waters involves the frequent capture of fire sponge (*Tedania ignis*), whose skeletal structure is composed of small spicules that cause dermatitis when they contact the human skin. Extreme discomfort follows exposure. The hazard may be reduced if fishermen handling the catch wear protective clothing over exposed skin surfaces and wash the catch thoroughly before handling it.

RECOMMENDATIONS

I feel that several lines of investigation require further exploratory trawling effort. For example, the availability of black sea bass to trawls in the inshore live-bottom areas during winter should be studied. A study should also be made to determine if planehead filefish and small scup could sustain a fishery for industrial products. Since preliminary explorations show that the shelf-edge habitat harbors a rich community of snappers, groupers, and ecologically related species, the distribution and availability of these species to trawls and other gear should be determined with greater precision. Finally, the resources of demersal fishes of the lower-shelf habitat (60 to 100 fathoms) and a part of the upper-slope habitat (100 to 150 fathoms) should be surveyed sufficiently to permit assessment of the stocks of butterfish, hake, flatfish, and grouper there.

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Appendix A.—Fishing log - selected trawl stations where commercial quantities of fishes were taken during M/V *Silver Bay* bottomfish explorations off Southeastern Coast, 1959-64

Chart guide No.	*Silver Bay* station No.	Date	Position: Lat. N.	Position: Long. W.	Loran: 1H6	Loran: 1H7	Subregion	Depth	Time fished	Total catch	Predominant species in catch: Vermilion snapper	Scup	Red, gray, and mutton snappers	Triggerfish	Grouper	Grunt	Black sea bass	Pink porgy	Croaker	Planehead filefish	Spadefish	Butterfish	Amberjack	Hogfish
								Fm.	*Min.*	*Lbs.*	*Thousands of pounds*													
1	1360	10/20/59	32°51′	78°32′	3498	4840	S. C.	21	60	1,715	.1	.9	--	--	--	--	--	--	--	--	--	--	--	--
2	2078	5/4/60	29°45′	80°26′	4090	2965	NE. Fla.	24	105	1,205	.7	--	--	.2	.03	--	--	--	--	--	--	--	--	--
3	2084	5/5/60	29°53′	80°34′	4120	3072	NE. Fla.	22	90	1,500	1.0	.1	--	--	.04	.2	--	--	--	--	--	--	--	--
4	2144	6/13/60	29°52′	80°26′	4112	3055	NE. Fla.	20	60	939	.6	--	--	.2	--	.4	--	--	--	--	--	--	--	--
5	2533	12/4/60	32°55′	78°31′	3468	4860	S. C.	21	70	767	.3	--	--	.2	--	--	--	--	--	--	--	--	--	--
6	2537	12/5/60	33°08′	77°46′	3000	4757	S. C.	30	60	2,200	.4	--	--	--	--	.9	--	--	--	--	--	--	--	--
7	2721	2/1/61	27°40′	79°58′	3924	1446	Central Fla.	50	60	558	--	--	--	--	.4	--	.04	--	--	--	--	--	--	--
8	2994	4/19/61	30°28′	80°21′	4133	3495	NE. Fla.	21	135	394	--	--	.3	--	.04	--	--	--	--	--	--	--	--	--
9	2996	4/19/61	30°28′	80°21′	4133	3495	NE. Fla.	20	60	580	.3	.2	--	--	--	--	--	--	--	--	--	--	--	--
10	2998	4/20/61	30°25′	80°25′	4140	3471	NE. Fla.	19	60	6,000	--	5.4	--	--	--	--	--	--	--	--	--	--	--	--
11	3000	4/20/61	30°29′	80°27′	4148	3508	NE. Fla.	21	60	3,400	.6	--	--	.6	--	--	--	--	--	--	--	--	--	--
12	3005	4/21/61	29°45′	80°28′	4097	2965	NE. Fla.	18	60	1,152	.6	--	.1	.1	.1	--	--	--	--	--	--	--	--	--
13	3016	4/22/61	30°04′	80°40′	4145	3200	NE. Fla.	19	120	825	.2	--	.1	--	--	.4	--	--	--	--	--	--	--	--
14	3307	7/19/61	29°52′	80°32′	4113	3054	NE. Fla.	21	90	792	.6	--	.1	--	--	--	--	--	--	--	--	--	--	--
15	3308	7/19/61	29°52′	80°32′	4113	3054	NE. Fla.	19	90	1,570	1.1	--	--	--	--	.4	--	--	--	--	--	--	--	--
16	3311	7/20/61	30°19′	80°55′	4190	3373	NE. Fla.	13	60	1,274	.4	--	.1	.3	--	.4	--	--	--	--	--	--	--	--
17	3324	8/11/61	32°53′	78°44′	3588	4903	S. C.	14	54	2,100	.3	1.6	--	--	--	--	--	--	--	--	--	--	--	--
18	3330	8/13/61	33°15′	77°50′	2982	4808	S. C.	17	105	1,000	.1	.5	.1	.1	.1	--	--	--	--	--	--	--	--	--
19	3348	8/17/61	33°20′	77°40′	----	----	S. C.	13	95	1,600	1.0	--	.04	--	.1	--	--	--	--	--	--	--	--	--
20	3649	12/11/61	33°17′	77°46′	2948	4795	S. C.	18	90	1,028	.3	--	.04	--	.1	--	--	--	--	--	--	--	--	--
21	3650	12/12/61	33°15′	77°51′	3000	4806	S. C.	18	107	1,477	.6	--	--	.2	.03	--	--	--	--	--	--	--	--	--
22	3652	12/13/61	33°18′	78°27′	3283	4937	S. C.	14½	90	2,195	--	.5	--	--	--	.8	.1	--	--	--	--	--	--	--
23	3753	2/23/62	29°43′	80°27′	4096	2969	NE. Fla.	19	90	4,482	.2	1.0	.3	.3	--	--	--	--	--	--	--	--	--	--
24	3754	2/23/62	29°45′	80°27′	4096	2969	NE. Fla.	19	90	4,183	--	1.0	.3	.4	--	--	--	--	--	--	--	--	--	--
25	3760	2/25/62	30°13′	80°31′	4137	3313	NE. Fla.	19	90	2,900	.8	--	.1	.2	--	--	--	--	--	--	--	--	--	--
26	3766	3/1/62	31°45′	79°36′	4093	4457	Ga.	35	72	1,025	.2	--	--	--	--	--	.1	.2	--	--	--	--	--	--
27	3767	3/1/62	31°44′	79°38′	4105	4450	Ga.	30	92	1,232	.1	.5	--	--	.2	--	--	--	--	--	--	--	--	--
28	4174	7/24/62	34°07′	77°31′	2473	----	Onslow	11	90	2,300	--	1.8	--	--	--	--	.3	--	--	--	--	--	--	--
29	4181	7/28/62	33°21′	77°40′	2872	----	S. C.	14	60	900	.6	--	--	--	--	--	--	--	--	--	--	--	--	--
30	4646	1/17/63	32°52′	78°38′	3548	4905	S. C.	17/18	90	7,500	.7	--	--	.2	--	--	--	--	--	5.5	--	--	--	--
31	4652	1/25/63	33°15′	77°51′	3000	4837	S. C.	17	60	2,100	.4	.7	--	--	--	.4	--	--	--	--	--	--	--	--
32	4653	1/25/63	33°12′	77°50′	3010	4820	S. C.	17	60	560	.5	--	--	--	--	--	--	--	--	--	--	--	--	--
33	4655	1/25/63	33°15′	77°51′	3000	4837	S. C.	17	60	2,000	--	1.8	--	--	--	--	--	--	--	--	--	--	--	--
34	4659	1/26/63	33°00′	78°08′	3238	4830	S. C.	18	60	2,300	--	2.0	--	--	--	--	--	--	--	--	--	--	--	--
35	4664	1/27/63	32°45′	78°33′	3543	4844	S. C.	18/19	90	1,275	.7	.4	--	--	--	--	--	--	--	--	--	--	--	--
36	4920	5/8/63	30°23′	80°52′	4190	3450	NE. Fla.	15/17	60	4,400	1.5	--	--	--	--	--	--	--	--	--	1.2	--	--	--
37	4924	5/9/63	30°23′	80°53′	4191	3451	NE. Fla.	18/20	60	2,500	--	2.0	--	--	--	--	--	--	--	--	--	--	--	--
38	4926	5/9/63	30°28′	80°58′	4205	3506	NE. Fla.	15/16	60	2,000	1.6	--	--	--	--	--	--	--	--	--	--	--	--	--
39	4927	5/10/63	30°28′	80°58′	4205	3506	NE. Fla.	15/16	60	2,200	1.6	--	--	--	--	.2	--	--	--	--	--	--	--	--
40	4929	5/10/63	30°13′	80°29′	4133	3348	NE. Fla.	18/19	91	2,200	.9	.8	--	--	--	--	--	--	--	--	--	--	--	--
41	4935	5/13/63	30°28′	80°58′	4205	3506	NE. Fla.	15/17	60	4,500	1.5	2.1	--	--	--	--	--	--	--	--	--	--	--	--
42	4938	5/14/63	30°45′	80°15′	4140	3740	Ga.	21	60	3,200	.2	2.7	--	--	--	--	--	--	--	--	--	--	--	--
43	4955	5/17/63	31°47′	79°38′	4110	4507	Ga.	34	60	585	--	--	--	--	--	--	--	.5	--	--	--	--	.04	--
44	4961	5/18/63	31°39′	79°56′	4168	4415	Ga.	24	60	4,530	--	--	--	--	--	--	--	--	4.0	--	--	--	--	--
45	5397	12/7/63	32°01′	79°10′	3950	4627	S. C.	75/80	60	4,020	--	--	--	--	--	--	--	--	--	--	--	4.0	--	--
46	5427	1/14/64	32°53′	78°46′	3615	4940	S. C.	15	90	2,040	.5	1.2	--	--	--	--	--	--	--	--	--	--	--	--
47	5437	1/16/64	32°58′	78°36′	3490	4923	S. C.	16	60	3,075	.2	2.0	--	--	--	--	--	.1	--	--	--	--	--	--
48	5447	1/21/64	32°21′	79°07′	3918	4817	S. C.	25/27	60	2,730	--	2.6	--	--	--	--	--	--	--	--	--	--	--	--
49	5585	3/12/64	29°41′	80°28′	4094	2948	NE. Fla.	19½	60	8,719	--	--	.5	--	--	--	--	--	--	8.0	--	--	--	--
50	5655	4/12/64	33°11′	77°30′	2850	4745	S. C.	29	90	1,225	--	--	.1	.3	.4	--	--	--	--	--	--	--	--	.1

Appendix B.—Common and scientific names of bottomfishes taken by the M/V *Silver Bay* in depths less than 101 fathoms off the Southeastern Coast, 1959-64.

["Occurrence" refers to the appropriate percentage of trawling stations a species was taken when fishing in the primary habitat(s) of the species.]

Family and common name	Scientific name	Occurrence: Very common >50%	Occurrence: Common 10-50%	Occurrence: Rare <10%	Primary habitat(s) occupied and other remarks
CARCHARIIDAE — Sand Sharks					
Sand shark	*Carcharias taurus*		X		Coastal, live-bottom, and shelf-edge
SCYLIORHINIDAE — Cat Sharks					
Chain dogfish	*Scyliorhinus retifer*			X	Lower-shelf
CARCHARHINIDAE — Requiem Sharks					
Blacknose shark	*Carcharhinus acronotus*			X	Coastal and open-shelf
Silky shark	*Carcharhinus falciformis*			X	Shelf-edge — rarely taken in trawls, but one of the most abundant sharks
Sandbar shark	*Carcharhinus milberti*			X	Coastal and open-shelf
Tiger shark	*Galeocerdo cuvieri*			X	Only one capture (17 fm.)
Lemon shark	*Negaprion brevirostris*			X	Coastal and occasionally in offshore habitats
Atlantic sharpnose shark	*Scoliodon terraenovae*			X	Coastal
TRIAKIDAE — Smoothhounds					
Smooth dogfish	*Mustelus canis*		X		Coastal (winter only ?) and occasionally open-shelf
SPHYRNIDAE — Hammerhead Sharks					
Hammerheads	*Sphyrna* spp.			X	Coastal, open-shelf, live-bottom, and shelf-edge — infrequently taken
SQUALIDAE — Dogfish Sharks					
Spiny dogfish	*Squalus acanthias*		X		Coastal (winter)
SQUATINIDAE — Angel Sharks					
Atlantic angel shark	*Squatina dumerili*		X		All habitats, but North Carolina only
RHINOBATIDAE — Guitarfishes					
Atlantic guitarfish	*Rhinobatos lentiginosus*			X	Coastal
TORPEDINIDAE — Electric Rays					
Lesser electric ray	*Narcine brasiliensis*		X		Coastal and open-shelf — most common off Florida
RAJIDAE — Skates					
Clearnose skate	*Raja eglanteria*	X			Coastal and frequently offshore
Rosette skate	*Raja garmani*	X			Lower-shelf
DASYATIDAE — Stingrays					
Southern stingray	*Dasyatis americana*			X	Coastal (offshore during winter?)
Thorny (roughtail) stingray	*Dasyatis centroura*		X		Live-bottom, open-shelf, and shelf-edge during winter — most individuals apparently migrate north during the warm seasons, but a few occur in the coastal habitat
Atlantic stingray	*Dasyatis sabina*	X			Coastal
Bluntnose stingray	*Dasyatis sayi*		X		Coastal but frequently offshore

Appendix B.—Continued

Family and common name	Scientific name	Occurrence			Primary habitat(s) occupied and other remarks
		Very common >50%	Common 10-50%	Rare <10%	
GYMNURIDAE — Butterfly Rays					
Spiny butterfly ray	*Gymnura altavela*		X		Open-shelf, shelf-edge — not taken south of lat. 33° N.
Smooth butterfly ray	*Gymnura micrura*			X	Coastal, open-shelf — not taken south of lat. 33° N.
MYLIOBATIDAE — Eagle Rays					
Spotted eagle ray	*Aetobatus marinari*			X	Coastal
Bullnose ray	*Myliobatis freminvillei*		X		Coastal and occasionally open-shelf
RHINOPTERIDAE — Cownose Rays					
Cownose ray	*Rhinoptera bonasus*		X		Coastal — very rarely offshore
ACIPENSERIDAE — Sturgeons					
Atlantic sturgeon	*Acipenser oxyrhynchus*			X	Two records off North Carolina, coastal
CLUPEIDAE — Herrings					Although pelagic, following bearings are taken frequently in bottom trawls
American shad	*Alosa sapidissima*	--	--	--	Coastal
Menhaden	*Brevoortia* sp.	--	--	--	Coastal and open-shelf
Atlantic herring	*Clupea harengus*	--	--	--	Coastal
Atlantic round herring	*Etrumeus sadina*	--	--	--	Coastal, open-shelf, and shelf-edge
Atlantic thread herring	*Opisthonema oglinum*	--	--	--	Coastal and open-shelf
Spanish sardine	*Sardinella anchovia*	--	--	--	Coastal
ENGRAULIDAE — Anchovies					Although pelagic, anchovies are frequently taken in bottomfishing trawls
Striped anchovy	*Anchoa hepsetus*	--	--	--	Coastal
Bay anchovy	*Anchoa mitchilli*	--	--	--	Coastal
ARGENTINIDAE — Argentines					
Argentine	*Argentina striata*			X	Lower-shelf
--	*Glossanodon pygmaeus*			X	Lower-shelf
SYNODONTIDAE — Lizardfishes					
Largescale lizardfish	*Saurida brasiliensis*			(?)X	Lower-shelf
Shortjaw lizardfish	*Saurida normani*		(?)X		Lower-shelf
Inshore lizardfish	*Synodus foetens*	X			Coastal, open-shelf, and shelf-edge — very common
Sand diver	*Synodus intermedius*			X	Lower-shelf
Offshore lizardfish	*Synodus poeyi*			X	Lower-shelf
Red lizardfish	*Synodus synodus*			X	Open-shelf and shelf-edge
Snakefish	*Trachinocephalus myops*	X			Open-shelf

Appendix B.—Continued

Family and common name	Scientific name	Occurrence			Primary habitat(s) occupied and other remarks
		Very common >50%	Common 10-50%	Rare <10%	
SUDIDAE — Greeneyes					
Greeneye	*Chloropthalmus agassizi*			X	Lower-shelf
ARIIDAE — Sea Catfishes					
Gafftopsail catfish	*Bagre marinus*	X			Coastal
Sea catfish	*Galeichthys felis*	X			Coastal
MURAENIDAE — Morays					
Pygmy moray	*Anarchias yoshiae*			X	One record (40 fm.)
Spotted moray	*Gymnothorax moringa*		X		Live-bottom
Blackedge moray	*Gymnothorax nigromarginatus*			X	Live-bottom
CONGRIDAE — Conger Eels					
Bandtooth conger	*Ariosoma impressa*			X	Coastal and lower-shelf
Conger eel	*Conger oceanicus*			X	Open-shelf
--	*Hoplumnis tenuis*			X	Lower-shelf and open-shelf
OPHICHTHIDAE — Snake Eels					
Shorttail snake eel	*Callechelys perryae*			X	One record off central Florida (20 fm.)
Sailfin eel	*Letharchus velifer*			X	Coastal, open-shelf, live-bottom, and shelf-edge
Speckled worm eel	*Myrophis punctatus*			X	Coastal — one record
Spotted spoon-nose eel	*Mystriophis intertinctus*		X		Live-bottom
Palespotted eel	*Ophichthus ocellatus*		X		Live-bottom and open-shelf
Finless eel	*Verma kendalli*			X	Lower-shelf
GADIDAE — Codfishes and Hakes					
Silver hake	*Merluccius bilinearis*		X		Lower-shelf
Carolina hake	*Urophycis earlli*			X	Shelf-edge, apparently coastal and open-shelf also
Southern hake	*Urophycis floridanus*		X		Primarily lower-shelf, but also coastal and open-shelf
Spotted hake	*Urophycis regius*	X			Primarily lower-shelf, but also coastal, open-shelf, and shelf-edge
AULOSTOMIDAE — Trumpetfishes					
Trumpetfish	*Aulostomus maculatus*			X	Live-bottom
FISTULARIIDAE — Cornetfishes					
Cornetfish	*Fistularia petimba*		X		Live-bottom
Cornetfish	*Fistularia tabacaria*			X	Live-bottom

Appendix B.—Continued

Family and common name	Scientific name	Occurrence: Very common >50%	Occurrence: Common 10-50%	Occurrence: Rare <10%	Primary habitat(s) occupied and other remarks
MACRORHAMPHOSIDAE — Snipefishes					
Longspine snipefish	*Macrorhamphosus scolopax*		X		Lower-shelf
SYNGNATHIDAE — Pipefishes and Seahorses					
Whitenose pipefish	*Corythoichthys albirostris*			X	One record off Florida (24 fm.)
Spotted seahorse	*Hippocampus erectus*		X		Live-bottom
Northern pipefish	*Syngnathus fuscus*			X	Coastal and open-shelf
Chain pipefish	*Syngnathus louisianae*			X	Coastal and open-shelf
Bull pipefish	*Syngnathus springeri*			X	Open-shelf
POLYMIXIIDAE — Beardfishes					
Beardfish	*Polymixia lowei*		X		Lower-shelf
HOLOCENTRIDAE — Squirrelfishes and Soldierfishes					
--	*Corniger spinosus*			X	Shelf-edge and live-bottom
Squirrelfish	*Holocentrus ascensionis*		X		Live-bottom
Deepwater squirrelfish	*Holocentrus bullisi*		X		Shelf-edge and live-bottom
Longspine squirrelfish	*Holocentrus rufus*			X	One record off Florida (35 fm.)
Dusky squirrelfish	*Holocentrus vexillarius*			X	One record off Florida (35 fm.)
Blackbar soldierfish	*Myripristis jacobus*			X	Live-bottom
Bigeye soldierfish	*Ostichthys trachypomus*	--	--	--	This species may occur in the region only as pelagic juveniles
Cardinal soldierfish	*Plectrypops retrospinis*			X	One record shelf-edge (40-50 fm.)
ZEIDAE — Dories					
American John Dory	*Zenopsis ocellata*		X		Lower-shelf
GRAMMICOLEPIDAE					
--	*Xenolepidichthys dalgleishi*			X	Lower-shelf
CAPROIDAE — Boarfishes					
Deepbody boarfish	*Antigonia capros*		X		Lower-shelf and shelf-edge
Shortspine boarfish	*Antigonia combatia*		X		Lower-shelf and shelf-edge
SERRANIDAE — Sea basses					
Mutton hamlet	*Alphestes afer*			X	One record off North Carolina (24 fm.)
Crimson bass	*Anthias asperilinguis*		X		Shelf-edge and rarely lower-shelf
Bank sea bass	*Centropristis ocyurus*	X			Live-bottom and open-shelf
Rock sea bass	*Centropristis philadelphicus*			X	Live-bottom
Black sea bass	*Centropristis striatus*	X			Live-bottom, especially inshore
--	*Chlorististium eukrines* Stark and Courtenay			X	Two records, shelf-edge

Appendix B.—Continued

Family and common name	Scientific name	Occurrence: Very common >50%	Common 10-50%	Rare <10%	Primary habitat(s) occupied and other remarks
Dwarf sand perch	*Diplectrum bivittatum*			X	Three records (13-78 fm.) — possibly more common than these records indicate
Sand perch	*Diplectrum formosum*	X			Open-shelf in small numbers — the most common member of the genus in the region
--	*Diplectrum radiale*			X	Three records, coastal and open-shelf — possibly more common than these records indicate
Speckled hind	*Epinephelus drummondhayi*			X	Live-bottom and shelf-edge — rarely taken in trawls but readily available locally to handlines
Yellowedge grouper	*Epinephelus flavolimbatus*			X	Shelf-edge
Red grouper	*Epinephelus morio*		X		Live-bottom and shelf-edge
Warsaw grouper	*Epinephelus nigritus*			X	Shelf-edge and live-bottom
Snowy grouper	*Epinephelus niveatus*			X	Shelf-edge and live-bottom
Red barbier	*Hemanthias vivanus*			X	Two records, shelf-edge
Gag	*Mycteroperca microlepis*	X			Live-bottom and shelf-edge
Scamp	*Mycteroperca phenax*		X		Live-bottom and shelf-edge — the yellowmouth grouper, *M. interstitialis*, also possibly occurs off this coast
Roughtongue bass	*Ocyanthias martinicensis*			X	One record, shelf-edge
Blackear bass	*Paracentropristes pomospilus*			X	One record (13 fm.)
Creole-fish	*Paranthias furcifer*			X	Two records, shelf-edge
Streamer bass	*Pronotogrammus aureorubens*			X	Shelf-edge and lower-shelf
Soapfishes	*Rypticus* spp.			X	Live-bottom
Pygmy sea bass	*Serraniculus pumilio*			X	Coastal and open-shelf
Orangeback bass	*Serranus annularis*			X	Shelf-edge
Lantern bass	*Serranus baldwini*			X	Two records, open-shelf
Saddle bass	*Serranus notospilus*			X	Shelf-edge
Tattler	*Serranus phoebe*	X			Shelf-edge
Belted sandfish	*Serranus subligarius* (Cope)			X	Open-shelf
LUTJANIDAE — Snappers					
Mutton snapper	*Lutjanus analis*	X			Live-bottom and shelf-edge
Red snapper	*Lutjanus aya*		X		Live-bottom and shelf-edge
Blackfin snapper	*Lutjanus buccanella*			X	Live-bottom and shelf-edge
Gray snapper	*Lutjanus griseus*		X		Live-bottom — Florida only
Lane snapper	*Lutjanus synagris*			X	Live-bottom
Yelloweye or silk snapper	*Lutjanus vivanus*			X	Shelf-edge
Yellowtail snapper	*Ocyurus chrysurus*			X	Live-bottom and shelf-edge

Appendix B.—Continued

Family and common name	Scientific name	Occurrence: Very common >50%	Common 10-50%	Rare <10%	Primary habitat(s) occupied and other remarks
Wenchman	*Pristipomoides aquilonaris*		X		Shelf-edge
Vermilion snapper	*Rhomboplites aurorubens*	X			Live-bottom and shelf-edge
PRIACANTHIDAE — Bigeyes					
Bigeye	*Priacanthus arenatus*		X		Live-bottom and shelf-edge
Glasseye snapper	*Priacanthus cruentatus*			X	Shelf-edge — few records
Short bigeye	*Pseudopriacanthus altus*	X			Live-bottom and shelf-edge
APOGONIDAE — Cardinalfishes					
Cardinalfishes	*Apogon* spp.			X	Live-bottom
--	*Synagrops bella*		X		Lower-shelf
BRANCHIOSTEGIDAE — Tilefishes					
Tilefish	*Caulolatilus* sp.			X	Lower-shelf and shelf-edge
Tilefish	*Lopholatilus* sp.			X	Lower-shelf and shelf-edge
POMATOMIDAE — Bluefishes					
Bluefish	*Pomatomus saltatrix*		X		Coastal — rarely offshore
RACHYCENTRIDAE — Cobias					
Cobia	*Rachycentron canadum*		X		Live-bottom
CARANGIDAE — Jacks, Scads, and Pompanos					
African pompano	*Alectis criniti* s			X	Coastal — rarely live-bottom
Jacks	*Caranx* spp.		X		Coastal
Bumper	*Chloroscombrus chrysurus*	X			Coastal
Round scad	*Decapterus punctatus*		X		Coastal and open-shelf — pelagic and near-bottom
Bigeye scad	*Selar crumenophthalmus*			X	Coastal and open-shelf — pelagic and near-bottom
Lookdown	*Selene vomer*	X			Coastal
Greater amberjack	*Seriola dumerili*		X		Live-bottom and shelf-edge
Amberjack	*Seriola rivoliana*		X		Live-bottom and shelf-edge
Banded rudderfish	*Seriola zonata*			X	Live-bottom
Pompanos	*Trachinotus* spp.			X	Coastal
Rough scad	*Trachurus lathami*		X		Open-shelf — pelagic and near-bottom
Atlantic moonfish	*Vomer setapinnis*		X		Coastal
GERRIDAE — Mojarras					
Mojarras	*Eucinostomus* spp.		X		Coastal
POMADASYIDAE — Grunts					
Sargo (porkfish)	*Anisotremus virginicus*			X	Live-bottom — Florida

Appendix B.—Continued

Family and common name	Scientific name	Occurrence			Primary habitat(s) occupied and other remarks
		Very common >50%	Common 10-50%	Rare <10%	
Tomtate	*Haemulon aurolineatum*	X			Live-bottom and shelf-edge
White grunt	*Haemulon plumieri*		X		Live-bottom
Pigfish	*Orthopristis chrysopterus*		X		Coastal and open-shelf
SCIAENIDAE — Drums					
Silver perch (yellowtail)	*Bairdiella chrysura*	X			Coastal
Sand sea trout	*Cynoscion arenarius*			X	Coastal
Spotted sea trout	*Cynoscion nebulosus*	X			Coastal
Silver sea trout	*Cynoscion nothus*	X			Coastal
Weakfish	*Cynoscion regalis*	X			Coastal and live-bottom
Jackknife-fish	*Equetus lanceolatus*		X		Live-bottom
Banded drum	*Larimus fasciatus*	X			Coastal
Spot	*Leiostomus xanthurus*	X			Primarily coastal — withdraws to shelf-edge and lower-shelf during winter
Southern kingfish	*Menticirrhus americanus*	X			Coastal
Northern kingfish	*Menticirrhus saxatilis*		X		Coastal — frequently open-shelf and live-bottom
Atlantic croaker	*Micropogon undulatus*	X			Primarily coastal — open-shelf and shelf-edge
Black-bar drum	*Pareques* sp. (undescribed)		X		Shelf-edge
Black drum	*Pogonias cromis*			X	Coastal
Red drum	*Sciaenops ocellata*			X	Coastal
Star drum	*Stellifer lanceolatus*	X			Coastal
MULLIDAE — Goatfishes					
Red goatfish	*Mullus auratus*	X			Live-bottom and shelf-edge
Spotted goatfish	*Pseudupeneus maculatus*		X		Live-bottom
Dwarf goatfish	*Upeneus parvus*			X	Live-bottom and shelf-edge
SPARIDAE — Porgies					
Sheepshead	*Archosargus probatocephalus*		X		Coastal but commonly live-bottom
Jolthead porgy	*Calamus bajonado*			X	Occasionally encountered in moderate numbers on the live-bottom areas off Northeastern Florida
Whitebone porgy	*Calamus leucosteus*		X		Open-shelf, inshore live-bottom, and occasionally coastal
Knobbed porgy	*Calamus nodosus* Randall and Caldwell 1966	X			Live-bottom and shelf-edge
Littlehead porgy	*Calamus proridens*			X	Live-bottom
Spottail pinfish	*Diplodus holbrooki*		X		Live-bottom off North Carolina and South Carolina
Pinfish	*Lagodon rhomboides*	X			Coastal, open-shelf, and live-bottom
Pink porgy, red porgy	*Pagrus sedecim*	X			Live-bottom and shelf-edge
Scup	*Stenotomus chrysops*	X			Open-shelf, live-bottom, and coastal

Appendix B.—Continued

Family and common name	Scientific name	Occurrence: Very common >50%	Occurrence: Common 10-50%	Occurrence: Rare <10%	Primary habitat(s) occupied and other remarks
EPHIPPIDAE — Spadefishes					
Atlantic spadefish	*Chaetodipterus faber*		X		Coastal and live-bottom — large schools occasionally encountered offshore
CHAETODONTIDAE — Butterflyfishes					
Bank butterflyfish	*Chaetodon aya*		X		Shelf-edge and occasionally live-bottom
Spotfin butterflyfish	*Chaetodon ocellatus*	X			Live-bottom and shelf-edge
Reef butterflyfish	*Chaetodon sedentarius*	X			Live-bottom and shelf-edge
Banded butterflyfish	*Chaetodon striatus*			X	Three records, live-bottom
Blue angelfish	*Holacanthus bermudensis*	X			Live-bottom
Queen angelfish	*Holacanthus ciliaris*			X	Live-bottom
Rock beauty	*Holacanthus tricolor*			X	Three records, live-bottom — Florida
French angelfish, black angelfish	*Pomacanthus arcuatus*			X	Live-bottom — Florida
Gray angelfish	*Pomacanthus aureus*			X	Live-bottom — Florida
POMACENTRIDAE — Damselfishes					
Yellowtail reef-fish	*Chromis enchrysurus*			X	Live-bottom
Gray reef-fish	*Chromis insolatus*			X	One record, live-bottom
Beaugregory	*Eupomacentrus leucostictus*		X		Live-bottom and occasionally shelf-edge
LABRIDAE — Wrasses					
Spotfin hogfish	*Bodianus pulchellus*			X	Live-bottom
Creole wrasse	*Clepticus parrai*			X	One record, live-bottom
Red hogfish	*Decodon puellaris*			X	Two records, shelf-edge
Greenband wrasse	*Halichoeres bathyphilus*			X	Two records, live-bottom
Slippery dick	*Halichoeres bivittatus*			X	Two records, live-bottom
Painted wrasse	*Halichoeres caudalis*			X	One record, North Carolina
Blackear wrasse	*Halichoeres poeyi*			X	Two records, open-shelf — Florida
Pearly razorfish	*Hemipteronotus novacula*		X		Primarily open-shelf
Hogfish	*Lachnolaimus maximus*		X		Live-bottom — occasionally shelf-edge, most common off South Carolina
Tautog	*Tautoga onitis*			X	Coastal
SCARIDAE — Parrotfishes					
Bluelip parrotfish	*Cryptotomus roseus*			X	One record
Emerald parrotfish	*Nicholsina usta*			X	Three records — open-shelf and live-bottom
Bucktooth parrotfish	*Sparisoma radians*			X	Three records, live-bottom

Appendix B.—Continued

Family and common name	Scientific name	Occurrence: Very common >50%	Occurrence: Common 10-50%	Occurrence: Rare <10%	Primary habitat(s) occupied and other remarks
ACANTHURIDAE — Surgeonfishes					
Blue tang	*Acanthurus coeruleus*			X	Two records, live-bottom
Doctorfish	*Acanthurus chirurgus*			X	Live-bottom
TRICHIURIDAE — Cutlassfishes					
Atlantic cutlassfish	*Trichiurus lepturus*		X		Coastal and rarely lower-shelf
SCOMBRIDAE — Mackerels and Tunas					
Chub mackerel	*Scomber colias*	--	--	--	Pelagic but frequently taken in bottom trawls in the coastal and open-shelf habitats
King mackerel	*Scomberomorus cavalla*	--	--	--	Pelagic but occasionally taken in coastal and live-bottom habitats
Spanish mackerel	*Scomberomorus maculatus*	--	--	--	Pelagic but very commonly taken in bottom trawls in the coastal and live-bottom habitats
SCORPAENIDAE — Scorpionfishes					
Longfin scorpionfish	*Scorpaena agassizi*		X		Lower-shelf and shelf-edge
Barbfish	*Scorpaena brasiliensis*	X			Open-shelf, coastal, live-bottom, and shelf-edge
Smoothhead scorpionfish	*Scorpaena calcarata*			X	Open-shelf
Hunchback scorpionfish	*Scorpaena dispar*			X	One record
TRIGLIDAE — Searobins					
Shortfin searobin	*Bellator brachychir*			X	Lower-shelf
Streamer searobin	*Bellator egretta*			X	Shelf-edge and lower-shelf
Horned searobin	*Bellator militaris*	X			Shelf-edge
Spiny searobin	*Prionotus alatus*			X	Shelf-edge and lower-shelf
Northern searobin	*Prionotus carolinus*	X			Primarily open-shelf — also live-bottom and shelf-edge
Striped searobin	*Prionotus evolans*		X		Open-shelf and shelf-edge
Blackwing searobin	*Prionotus pectoralis*			X	Open-shelf
Bluespotted searobin	*Prionotus roseus*	X			Open-shelf
Shortwing searobin	*Prionotus stearnsi*			X	Shelf-edge and lower-shelf
PERISTEDIIDAE — Armoured Searobins					
Armoured searobins	*Peristedion* spp.			X	Lower-shelf
DACTYLOPTERIDAE — Flying Gurnards					
Flying gurnard	*Dactylopterus volitans*		X		Live-bottom and shelf-edge
OPISTHOGNATHIDAE — Jawfishes					
Longtail jawfish	*Opisthognathus lonchurus*			X	One record, shelf-edge
Mottled jawfish	*Opisthognathus maxillosus*			X	One record off Florida (15 fm.)

Appendix B.—Continued

Family and common name	Scientific name	Occurrence: Very common >50%	Common 10-50%	Rare <10%	Primary habitat(s) occupied and other remarks
URANOSCOPIDAE — Stargazers					
Southern stargazer	*Astroscopus y-graecum*		X		Coastal and open-shelf
Freckled stargazer	*Gnathagnus egregius*			X	One record (65 fm.)
Lancer stargazer	*Kathetostoma albigutta*	X			Lower-shelf and shelf-edge
DACTYLOSCOPIDAE — Sand Stargazers					
Sand stargazer	*Gillelus* sp.			X	Two records, open-shelf — Florida
BROTULIDAE — Brotulas					
Bearded brotula	*Brotula barbata*			X	One record off Florida (35 fm.)
OPHIDIIDAE — Cusk-Eels					
Fawn cusk-eels	*Lepophidium cervinum*		X		Lower-shelf
Mottled cusk-eel	*Lepophidium jeannae*		X		Open-shelf and shelf-edge
Bank cusk-eel	*Ophidion holbrooki*	X			Open-shelf and live-bottom
Gray's cusk-eel	*Otophidium grayi*			X	Open-shelf
Polka-dot cusk-eel	*Otophidium omostigmum*			X	Open-shelf
Striped cusk-eel	*Rissola marginata*		(?)X		Coastal
CARAPIDAE — Pearlfishes					
Pearlfish	*Carapus bermudensis*			X	Commensal with sea cucumbers — one record
STROMATEIDAE — Butterfishes					
Silver-rag	*Cubiceps nigriargenteus*		X		Lower-shelf
Southern harvestfish	*Peprilus alepidotus*		X		Coastal
Northern harvestfish	*Peprilus paru*		X		Coastal
Butterfish	*Poronotus triacanthus*	X			Coastal and lower-shelf
Spotted driftfish	*Psenes regulus*			X	Live-bottom — sometimes abundant locally
SPHYRAENIDAE — Barracudas					
Great barracuda	*Sphyraena barracuda*			X	Coastal and live-bottom
Northern sennet	*Sphyraena borealis*		X		Coastal
Guaguanche	*Sphyraena guanchancho*			X	Coastal
ATHERINIDAE — Silversides					
Atlantic silverside	*Menidia menidia*			X	Coastal
BOTHIDAE — Lefteye Flounders					
Three-eye flounder	*Ancylopsetta dilecta*		X		Lower-shelf
Ocellated flounder	*Ancylopsetta quadrocellata*	X			Open-shelf — occasionally coastal, live-bottom, shelf-edge, and lower-shelf
Eyed flounder	*Bothus ocellatus*		X		Open-shelf and live-bottom

Appendix B.—Continued

Family and common name	Scientific name	Occurrence: Very common >50%	Occurrence: Common 10-50%	Occurrence: Rare <10%	Primary habitat(s) occupied and other remarks
Gulf Stream flounder	*Citharichthys arctifrons*		X		Lower-shelf
Spotted whiff	*Citharichthys macrops*	X			Open-shelf — most often taken in small numbers by dredges
Bay whiff	*Citharichthys spilopterus*			X	Coastal
Spotfin flounder	*Cyclopsetta fimbriata*		X		Open-shelf and live bottom — occasionally shelf-edge
Fringed flounder	*Etropus crossotus*		X		Open-shelf
Smallmouth flounder	*Etropus microstomus*		X		Coastal, open-shelf, and shelf-edge
Gray flounder	*Etropus rimosus*		X		Coastal, open-shelf, and shelf-edge
Shrimp flounder	*Gastropsetta frontalis*			X	Shelf-edge
Fourspot flounder	*Hippoglossina oblonga*	X			Lower-shelf
--	*Monolene* spp.			X	Lower-shelf
Gulf flounder	*Paralichthys albigutta*		X		Coastal
Summer flounder	*Paralichthys dentatus*	X			Open-shelf, coastal, and live-bottom
Southern flounder	*Paralichthys lethostigma*		X		Coastal
Broad flounder	*Paralichthys squamilentus*			X	Shelf-edge and lower-shelf
Windowpane	*Scophthalmus aquosus*		X		Coastal
Dusky flounder	*Syacium papillosum*	X			Open-shelf and live-bottom — rarely coastal and shelf-edge
PLEURONECTIDAE — Righteye Flounders					
--	*Poecilopsetta beani*			X	One record off Florida (97 fm.)
SOLEIDAE — Soles					
Naked sole	*Gymnachirus melas* Nichols		X		Open-shelf and coastal
Hogchoker	*Trinectes maculatus*	X			Coastal
CYNOGLOSSIDAE — Tonguefishes					
Offshore tonguefish	*Symphurus civitatus*			(?)X	Open shelf?
Spottedfin tonguefish	*Symphurus diomedianus*	X			Open-shelf and shelf-edge
Largescale tonguefish	*Symphurus minor*		(?)X		Apparently primarily open-shelf
Blackcheek tonguefish	*Symphurus plagiusa*	X			Coastal
Spottail tonguefish	*Symphurus urospilus*			(?)X	Open-shelf?
ECHENEIDAE — Remoras					
Sharksucker	*Echeneis naucrates*		X		Often taken trawling over live-bottom
TRIACANTHODIDAE — Spikefishes					
Jambeau	*Parahollardia lineata*			X	Lower-shelf
BALISTIDAE — Triggerfishes					
Gray triggerfish	*Balistes capriscus*	X			Live-bottom and shelf-edge
Queen triggerfish	*Balistes vetula*			X	Live-bottom and shelf-edge

Appendix B.—Continued

Family and common name	Scientific name	Occurrence: Very common >50%	Occurrence: Common 10-50%	Occurrence: Rare <10%	Primary habitat(s) occupied and other remarks
MONACANTHIDAE — Filefishes					
Dotterel filefish	*Alutera heudelotii*			X	Live-bottom and shelf-edge
Unicorn filefish	*Alutera monoceros*			X	Live-bottom and shelf-edge
Orange filefish	*Alutera schoepfi*	X			Open-shelf
Scrawled filefish	*Alutera scripta*			X	Open-shelf, live-bottom
Fringed filefish	*Monacanthus ciliatus*			X	Live-bottom
Planehead filefish	*Stephanolepis hispidus*	X			Open-shelf and live-bottom — semipelagic
OSTRACIIDAE — Trunkfishes					
Honeycomb cowfish	*Acanthostracion polygonius*			X	Live-bottom
Scrawled cowfish	*Acanthostracion quadricornis*	X			Live-bottom
Trunkfish	*Lactophrys trigonus*			X	Live-bottom
Spotted trunkfish	*Rhinesomus bicaudalis*			X	Live-bottom
CANTHIGASTERIDAE — Sharpbacked Puffers					
Sharpnose puffer	*Canthigaster rostrata*			X	Two records (23-24 fm.)
TETRAODONTIDAE — Puffers					
Smooth puffer	*Lagocephalus laevigatus*		X		Coastal, open-shelf, live-bottom, and shelf-edge
—	*Sphaeroides cutaneus*			X	Live-bottom
Marbled puffer	*Sphaeroides dorsalis*		X		Open-shelf
Northern puffer	*Sphaeroides maculatus*	X			Coastal and open-shelf
Southern puffer	*Sphaeroides nephelus*			X	Coastal and open-shelf
Bandtail puffer	*Sphaeroides spengleri*		X		Live-bottom
DIODONTIDAE — Porcupinefishes					
Web burrfish	*Chilomycterus antillarum*			X	One record (17 fm.)
Spotted burrfish	*Chilomycterus antinga*			X	Live-bottom
Striped burrfish	*Chilomycterus schoepfi*	X			Live-bottom
Balloonfish	*Diodon holacanthus*			X	Live-bottom
BATRACHOIDIDAE — Toadfishes					
Leopard toadfish	*Opsanus pardus*			X	Live-bottom and shelf-edge
Oyster toadfish	*Opsanus tau*		X		Coastal
Atlantic midshipman	*Porichthys porosissimus*	X			Very widespread — coastal, open-shelf, live-bottom, shelf-edge, and lower-shelf
LOPHIIDAE — Goosefishes					
American goosefish	*Lophius americanus*		X		Open-shelf off North Carolina — lower-shelf to the southward

Appendix B.—Continued

Family and common name	Scientific name	Occurrence			Primary habitat(s) occupied and other remarks
		Very common >50%	Common 10-50%	Rare <10%	
ANTENNARIIDAE — Frogfishes					
Ocellated frogfish	*Antennarius ocellatus*			X	Open-shelf and live-bottom
Singlespot frogfish	*Antennarius radiosus*		X		Lower-shelf
Splitlure frogfish	*Antennarius scaber*			X	Open-shelf
CHAUNACIDAE					
Sackfish	*Chaunax pictus*			X	Lower-shelf
OGCOCEPHALIDAE — Batfishes					
--	*Dibranchus atlanticus*			X	Lower-shelf
Spiny batfish	*Halieutichthys aculeatus*		X		Lower-shelf and shelf-edge
Batfishes	*Ogcocephalus* spp.	X			Two to four species of *Ogcocephalus* commonly taken in the live-bottom, coastal open-shelf, and shelf-edge habitats

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BRANCH OF TECHNOLOGY

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Technological Laboratory
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Laboratory Director
Bureau of Commercial Fisheries
Technological Laboratory
2725 Montlake Boulevard East
Seattle, Washington 98102

Laboratory Director
Bureau of Commercial Fisheries
Technological Laboratory
Emerson Avenue
Gloucester, Massachusetts 09131

Branch of Technology
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U.S. Fish and Wildlife Service
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Laboratory Director
Bureau of Commercial Fisheries
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