466

ECOLOGY OF THE GULF OF MEXICO COMMERCIAL SPONGES AND ITS RELATION TO THE FISHERY

by John F. Storr

SPECIAL SCIENTIFIC REPORT-FISHERIES No. 466

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

This work was financed by the Bureau of Commercial Fisheries under Contract No. 14-19-008-2486 with funds made available under the Act of July 1, 1954 (68 Stat. 376), commonly known as the Saltonstall-Kennedy Act.

UNITED STATES DEPARTMENT OF THE INTERIOR
Stewart L. Udall, *Secretary*
James K. Carr, *Under Secretary*
Frank P. Briggs, *Assistant Secretary for Fish and Wildlife*
FISH AND WILDLIFE SERVICE, Clarence F. Pautzke, *Commissioner*
BUREAU OF COMMERCIAL FISHERIES, Donald L. McKernan, *Director*

ECOLOGY OF THE GULF OF MEXICO COMMERCIAL SPONGES AND ITS RELATION TO THE FISHERY

by

John F. Storr

Contribution No. 192 from the Marine Laboratory, Institute of Marine Science, University of Miami

United States Fish and Wildlife Service
Special Scientific Report--Fisheries No. 466

Washington, D.C.
March 1964

CONTENTS

Page

ECOLOGY OF THE GULF OF MEXICO COMMERCIAL SPONGES AND ITS RELATION TO THE FISHERY

by
John F. Storr, Ph.D.
Department of Biology
State University of New York
Buffalo, New York

ABSTRACT

The results of 2 years of study on the ecology of the commercial sponges and the relationship of sponge ecology to the commercial sponge fishery are discussed. A review and fiber analysis of the various commercial sponge species are presented. Reproduction of sponges is reviewed, and the effects of temperature and population concentration on reproduction are discussed. Data on the growth rate of wool sponges are presented, and a growth formula calculated. Temperature, salinity, depth of water, water currents, dispersion, population concentration, disease, commensalism, rock bar communities, and other environmental relationships are discussed. The sponge fishery from 1936 to 1958 is reviewed along with an analysis of take per unit of effort, sponging methods, and relationship of fishing and take to the sponge ecology. Present status of the industry is reviewed, and recommendations made that might assist in increasing the harvest of sponges. Projected increases in sponge population and sponging areas are analyzed.

INTRODUCTION

Although the first record of sponge taking in Florida dates from 1822, it was not until 27 years later (1849) that domestic sponges became a commercially valuable product in the United States. By the time diving gear was in use for sponging in 1905, concern was already being expressed about conservation of this valuable resource. This concern resulted in 4 years of extensive research (Moore, 1910a, 1910b) on sponge cultivation methods. His reports also included descriptions of sponging methods, the sponge grounds, and the commercial species of sponges.

No other major investigation of the Florida sponges was undertaken until the outbreak of the sponge disease in 1938. The results of this investigation was reported by Galtsoff (1942) and Smith (1941). In 1947 and 1948, the State of Florida Board of Conservation authorized the University of Miami Marine Laboratory to make limited surveys of the Florida sponge grounds between Key West and Carrabelle. This resulted in the published accounts of the economic history of the industry (Smith, 1949; Storr, 1956), a report of the expeditions (Dawson and Smith, 1953), and a description of the commercial and noncommercial sponges collected (de Laubenfels, 1953). Meanwhile, by 1951, production had fallen to less than 3 percent of the 1936 peak and the dollar returns had declined to less than 3 percent of the 1946 value when more than $3 million worth of sponges were sold.

Because of this drastic decline in abundance of sponges, the Sponge and Chamois Institute of America and the sponge producers at Tarpon

Note.--The study was made during 1955-57 while author was at the University of Miami Marine Laboratory.

Springs, Fla., requested the U.S. Fish and Wildlife Service to make an investigation. The Service contracted with the Marine Laboratory of the University of Miami in 1955 to carry out a scientific investigation of the commercial sponges of Florida. The investigations were financed with funds made available under the Act of July 1, 1954 (68 Stat. 376), commonly known as the Saltonstall-Kennedy Act.

Purposes of the investigations were to learn more facts about the sponges themselves, to study the relationships between sponges and other organisms, and between sponges and their environment, to study the ways in which these relationships affect sponge abundance and harvest, and to make recommendations leading to an increase in abundance of sponges and their harvest. The principal results of the investigations and a review of the status of the industry are presented in this paper.

Sponges constitute one of the principal divisions of the animal kingdom. They live and grow exclusively underwater, both fresh and salt.

Sponges are simple multicellular animals made up of several specialized types of cells. Differentiation into definite tissues is incomplete; consequently, there are little cooperation and coordination among parts of the body. The several types of cells are supported by the skeleton.

Sponge skeletons are of spicules or a network of pale brown fibers. Elasticity of the fiber skeleton gives rise to the familiar term "spongy." Sponges are of all sizes and shapes, and the living sponges have many colors. The striking characteristic, yielding the scientific name *Porifera*, is the abundance of small inhalent openings (pores) through the surface. Other apertures, called oscules (oscula), are exhalent; these are usually larger in size and fewer in number than the pores. Water containing both food and oxygen is taken in through the pores and discharged through the oscules.

Reproduction is by several means. Sponges have a high ability to restore lost parts by regeneration; a whole new sponge can grow from just a small piece. All fresh-water and some marine sponges reproduce asexually by means of gemmules; these embryos are formed simply by assembly of a few amoebocyte cells. Reproduction is also accomplished sexually by the union of sperm and egg cells.

THE COMMERCIAL SPONGES

Commercial sponges are taken in the United States only along the coast of Florida, from depths of 1 to 150 feet. Sponges may be able to live at even greater depths. The principal coastal areas of distribution prior to the disease of 1938 were from Carrabelle to Tampa Bay in the upper Gulf; Cape Romano, Ten Thousand Islands, Cape Sable, and Florida Bay areas on the southwestern Florida coast; and in the Keys area from the Dry Tortugas to Biscayne Bay.

Sponge Species

Of the eight or nine species of marketable sponges within these coastal areas, only five have any commercial value at the present time. These are described below in order of importance together with the approximate yearly percentage of total take and value based on the 1955 and 1956 landings. A number of these sponges are also shown in figure 1 and listed in table 1.

Four commercial sponges have been described and assigned specific names for the first time by de Laubenfels and Storr in 1958. This new naming appears to clarify the relationships of the Florida commercial sponges.

Wool sponge (*Hippiospongia lachne* de Laubenfels 1936).--The wool sponge is rounded, with a diameter to height ratio of from 2: 1 to 1: 1. When alive the sponge is black, the color changing to a light gray at the base. Wool sponges that grow in shallow water are much darker than those found in deeper water. The surface of this sponge is usually covered with blunt points, and the sides of the sponge have a number of small inhalent openings, the oscules (the large openings on the top), varying from 1/2 to 1-1/4 inches in diameter. Commonly the oscules are surmounted by thin-walled chimneys up to 2 inches in height, and are normally larger in shallow-water sponges. The average size (used throughout this paper as measurement of the diameter) of this sponge being taken

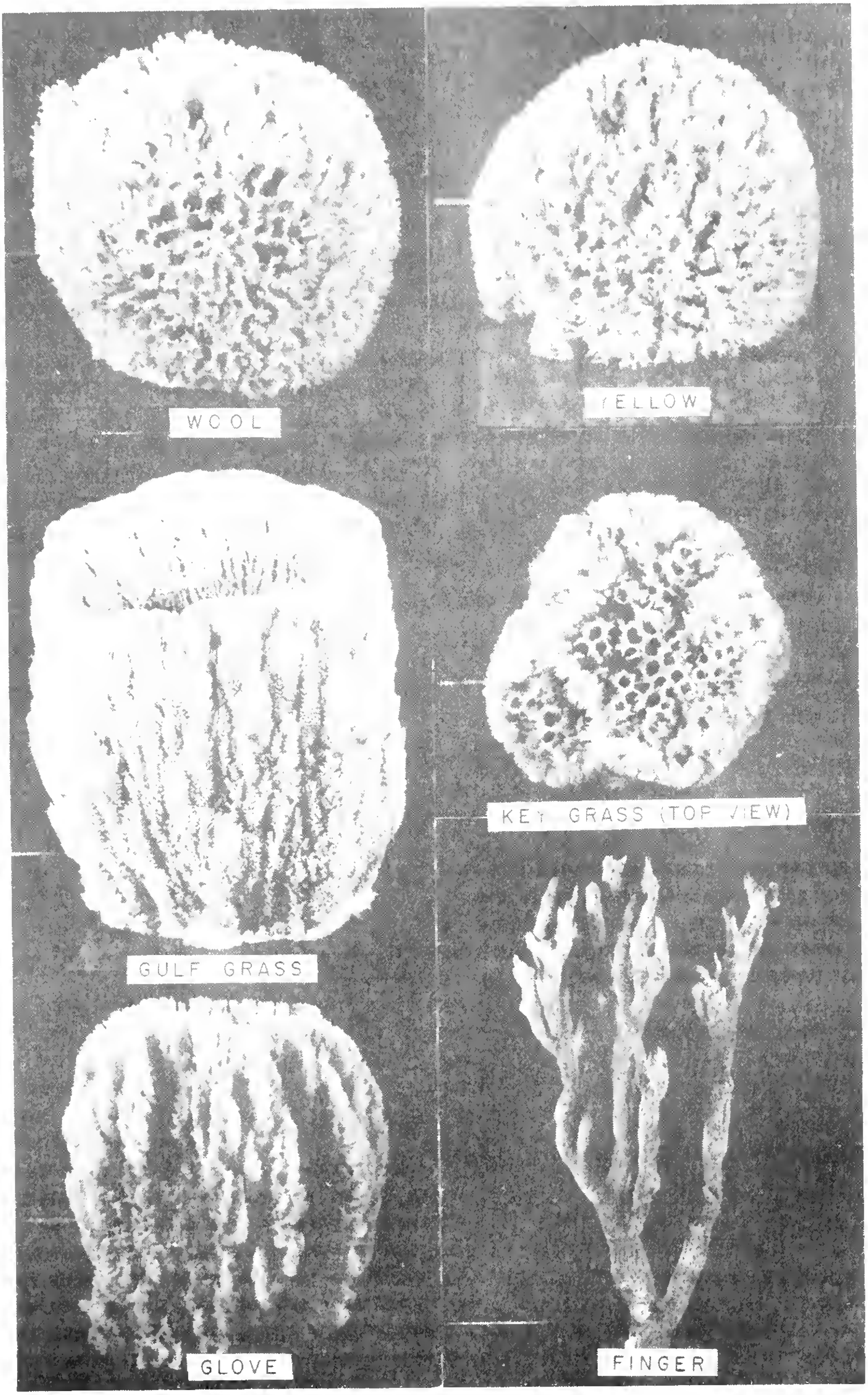

Figure 1.--Six species or subspecies of dried and cured American commercial sponges.

Table 1.--Comparison of commercial sponges

Common name	Scientific name	Color (in life)	Shape	Average		Distribution[1]	Value[3]
				Height	Diameter		
				Inches	*Inches*		*Cents*
Wool	*Hippiospongia lachne*	Black	Rounded	7	9	All areas	70
Velvet	*H. gossypina*	Black	Rounded	6-8	7-10	None	None
Anclote yellow	*Spongia anclotea*	Black	Hemisphere	4	6	D.	35
Yellow	*S. barbara*	Creamy tan to black	Rounded	5	7	All areas	35
Glove	*S. cheiris*	Black	Beehive	7	6	D, G.	20
Key grass	*S. graminea*	Black	Inverted cone	6	6	G.	None
Gulf grass	*S. graminea tampa*	Light drab	Thick-walled vase	12	10	A to F.	35
Reef	*S. obliqua*	Black	Rounded with flat surfaces	4	3	SE Bahamas	None
Wire	*S. sterea*	Brown	Lumpy mass	8	12	A, B.[2]	None
Finger	*Axinella polycapella*	Orange red	Bushlike	20	1/2" Branches	All areas	15

[1] See fig. 15 and appendix A for areas indicated by letter.
[2] Only in water more than 40 feet deep.
[3] Average value of one sponge to the fisherman in 1953.

at the present time is about 7 inches. When cleaned and cured the wool sponge is light tan.

The wool sponge is the basic sponge of commerce making up 90 percent or more of the entire take of sponges on a per piece[1] basis and about 95 percent of the cash returns. Average value per piece is close to 70 cents.

Yellow sponge (*Spongia barbara* Duchassaing and Michelotti 1864).--This sponge is black, dark brown, or creamy tan in color depending on the area and depth from which it is taken. The smooth rounded shape is much like that of the wool sponge with the exception that the oscules are never surmounted by chimneys as is common in the wool sponges. When cleaned the fibers are yellowish in appearance, hence the name.

[1] Per piece is a trade method of referring to an individual sponge. Sponges have been sold by the pound, but are normally bought from the sponge fishermen by the bunch. This refers to a number of sponges strung on a line and tied to form a ring. The number of sponges on a ring may vary according to the size of the sponge and the kind of sponges.

The yearly take of yellow sponges is at present less than 6 percent of the total take by pieces and the value per piece one-half of that of the average price for wool sponges.

Anclote yellow sponge (*Spongia anclotea* de Laubenfels and Storr 1958).--This sponge is of very minor commercial importance. Its color and the appearance of its surface fibers are quite like the yellow sponge. Its entire surface, however, is thrown up into a number of distinct lobes, each with an oscule. It is commonly found north of Anclote Key in shallow water.

Key grass sponge (*Spongia graminea* Hyatt 1877)[2].--This sponge was originally described as the Florida grass sponge, but it differs greatly from the one found in the Gulf. It is usually 5 to 6 inches in height, is black, and lives in shallow water of less than a few fathoms. The top of the sponge is flat or

[2] De Laubenfels (1936) may be in error in identifying the grass sponge, rather than the glove sponge, as *Spongia graminea*. If so then the designation of the glove sponge as *Spongia cheiris* (de Laubenfels and Storr, 1958) is also in error.

concave and is usually made up of a number of oscules up to one-quarter of an inch in diameter. When cleaned, the edges of the oscules are quite thin and feathery and in most cases form chimneys an inch or so in height.

In Biscayne Bay and the Bahamas this sponge, or a variant, grows into a rounded form with very tall chimneys. These latter sponges are light in weight and have little total spongin fiber material. Numbers of this type now appear on the market but bring a very low price.

Gulf grass sponge (*Spongia graminea tampa* de Laubenfels and Storr 1958).--In life the Gulf grass sponge has a smooth surface and a light drab color. It is roughly vase-shaped, but under good growth conditions the inside of the vase is almost completely filled in. Sponges of this latter form have a fine texture and good market value. When cleaned the color is light tan.

The number of grass sponges taken every year varies considerably but is usually between 4 to 6 percent of the total take. The value is about the same as that of the yellow sponge.

Finger sponge (*Axinella polycapella* de Laubenfels 1953).--The finger sponge has a bushlike shape in which each of the branches is about one-half inch in diameter (fig. 1). The color in life is bright orange-red. These sponges grow from 2 to 3 feet high. This is the only commercial sponge containing spicules. It is harvested in very limited quantity although it is common in the Gulf.

When cleaned, the sponge is pale tan to cream in color. It is used in making swab applicators for liquid shoe polish or for similar purposes. A good-sized sponge sells for about 15 cents. There are no records of the number taken or the total value for this sponge.

Glove sponge (*Spongia cheiris* de Laubenfels and Storr 1958).--This sponge is almost black in color, subconical in shape with the skeleton thrown up into perpendicular folds or ridges on the sides. The top of the sponge contains one large oscule. When cleaned the sponge is also light tan in color.

The sponge has very poor quality and is easily torn. The yearly take is normally less than 0.5 percent of the total production. Value of the sponge per piece over the years has been from 4 to 12 cents with an average value of about 6 cents. The glove sponge and the finger sponge together probably make up less than 1 percent of the total value of all sponges taken. It is found in the Anclote Key area and along the Florida Keys.

Other commercial sponge species.--The wire sponge (*Spongia sterea* de Laubenfels and Storr 1958), which was formerly of minor commercial importance, is now no longer in demand although a few are found in the Gulf northwest of Cedar Keys at depths of 40 feet or more. In deep water they grow to 30 inches in diameter.

The reef sponge (*S. obliqua* Duchassaing and Michelotti 1864) is probably not taken commercially at present; there is no official record of its having survived the disease periods in Florida waters.

The velvet sponge (*Hippiospongia gossypina* Duchassaing and Michelotti 1864) was found principally in the waters off the Keys. The usual habitat was in living coral areas at depths of 3 to 25 feet. At one time this sponge made up a large portion of the take from this zone and also from the Bahamas where the favorable ecological conditions produced a grade of sponge almost equivalent to that of the wool. The 1938 fungal disease appears to have destroyed this species. None have been reported in the Bahamas since the disease.

Sponge Fibers

The basic desirable qualities--ability to hold water, compressibility, resiliency, and toughness--of a sponge are all dependent upon its fiber pattern and structure. The sponge fiber is composed of a kind of keratin, spongin, closely related to the collagens. Keratin itself is made up of iodine and amino acids--lysine, arginine, cystine, phenylallnine, and glycine. (Block and Bolling, 1939).

The ability to hold water and compressibility are a result of both pattern and size of the fibers. Von Lendenfeld (1889) showed that:

1. Compressibility of the sponges is partly dependent upon the shape of the meshwork. The more regularly polygonal the meshes

the harder the sponge. The greater number of simple branching of the fibers, the softer and more absorbent the sponge.

2. The sponges with connecting fibers of about .02 mm. thickness appear to be the most elastic. The thicker the fiber, the more rigid the sponge. Finer the fibers, softer the sponge.

3. If any of the fibers of the sponge contain foreign bodies, these fibers are readily crushed when the sponge is compressed and the sponge loses its elasticity.

4. The more numerous the fibers per unit of volume, the greater the capillary action and the more water the sponge can hold.

The above fiber characteristics are of interest because of the differences between the fiber structure of the main commercial species of sponges and the differences between the fiber structure of wool sponges growing in different ecological conditions. The series of photomicrographs in figure 2 illustrate the variations.

In the wool sponge fibers, figure 2a, the individual fibers are very fine, about .02 mm. in diameter. By comparison with other sponges the meshes are much smaller; this property gives the wool sponge the ability to hold much larger quantities of water than any other sponge and also makes it softer to the touch. All fibers are much the same size, and in the area of the conules, as shown in the photograph, the fibers tend to be clumped together, giving greater support at the sponge's surface.

Two distinct kinds of fibers are found in the yellow sponge and all others of the genus *Spongia*. The ascending or principal fibers are normally oriented perpendicular to the sponge surface. These usually contain bits of fine sand or spicule particles from other sponges as inclusions within the fibers (fig. 2b). The mesh, or secondary, fibers may be two or three times as thick as the thickest fibers of the wool sponge. The meshwork also contains more interconnections than that of the wool sponge.

The looser meshwork of the yellow sponge does not make it possible for this sponge to hold as much water as the wool and allows the sponge to be torn more easily. With the heavy fibers perpendicular to the surface, the sponge is torn into segments under any hard usage.

In figure 2c of the grass sponge fibers, the coarseness of the individual fibers and the fairly regular pattern make this sponge feel hard. The large size of the meshes prevents this sponge from holding much water.

The arrangement of the fibers of the glove sponge, figure 2d, is much the same as the yellow sponge although the meshwork is finer. Unfortunately the entire sponge is arranged in narrow perpendicular columns (fig. 1) with deep clefts between so that the sponge is very weak and easily torn into sections.

The fiber arrangement of the wire sponge, figure 2e, is latticelike, the meshes very regular and entire in shape. This arrangement combined with the large mesh size makes the sponge incapable of holding water and renders it almost valueless commercially; however, it would serve as good insulating material.

The fibers of the finger sponge, figure 2f, are arranged very differently than those of the other sponges. The core is made up of a regular meshwork of fibers arranged in line with the branch. In the outer part the fibers are perpendicular to the branch and are fairly loosely grouped.

Sponge Grading

The desirable commercial qualities possessed by a sponge such as softness, fineness, absorptiveness, toughness, elasticity, and durability depend on: (1) the species of sponge and (2) the type of physical environment in which the sponge grows. Considerable skill (and honesty) is attributed to sponge graders who separate the wool sponges into a number of grades. Other species of sponges are not usually graded at present because of the small take. The method of grading has at times been very complex.

Sponge grade is determined by texture, shape, and solidity.

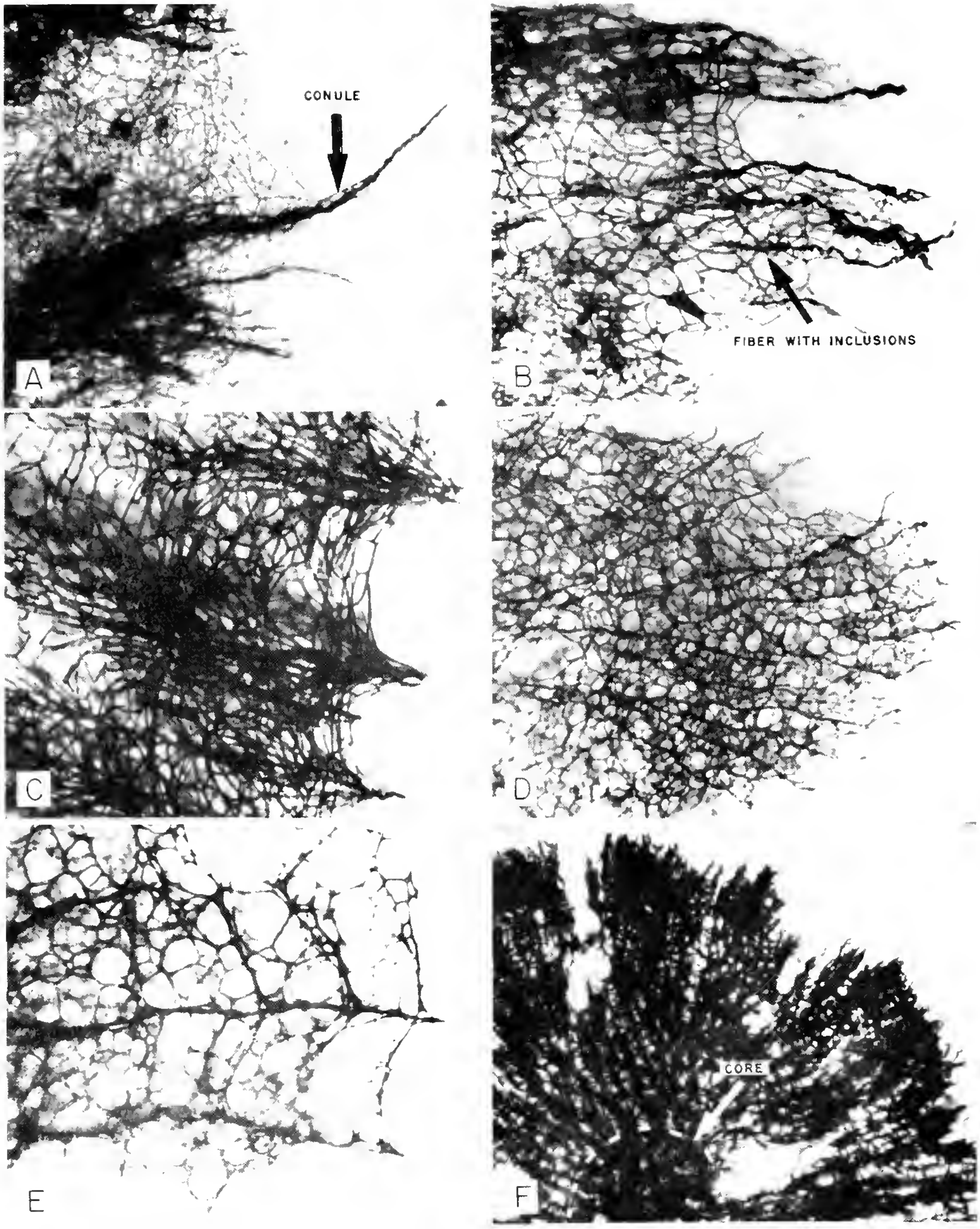

Figure 2.--Photomicrographs of fibers of the principal American commercial sponges. a. Wool sponge fibers. b. Yellow sponge fibers. c. Fibers from Pepperfish Keys grass sponge. d. Fibers of glove sponge from the Gulf of Mexico. e. Fibers of wire sponge from north of Cedar Keys. f. Cross section of one branch of a finger sponge.

REPRODUCTION OF SPONGES

Little is known about the embryology of commercial species of sponges although considerable work has been done with noncommercial species closely related to commercial types. Similarity of the reproduction process in the various orders studied suggests that the basic pattern of reproduction found applies to most sponge species. The present study concentrated on the gross examination of wool sponges for larvae and on the reproduction cycle as related to total sponge productivity.

With this consideration in mind, an extensive program of examination of living sponges in the field was carried out. Sponges were collected and preserved every month and examined for larval content. This program was carried on for almost the entire 2-year investigational period. The actual collection and preservation was done by crews of sponge diving boats.

Process of Reproduction

The spermatozoa and ova produced by sponges are similar in structure to those of other members of the animal kingdom. The spermatozoa, about 0.05 mm. in length, are produced in large numbers close to the walls of the smaller excurrent canals. Spermatozoa, when mature, are released into the open water. To effect fertilization the spermatozoon must be taken up by an egg-producing sponge in the incurrent flow of water. Since spermatozoa enter an egg-producing sponge by chance, their concentration in the water influences the number of eggs fertilized and the number of larvae developed.

Once a spermatozoon is in one of the sponge's chambers it is taken in either by one of the choanocytes (collared cells) or by an amoebocyte. The cell picking up the spermatozoon is termed a carrier cell, and in the sponge species studied by Duboscq and Tuzet (1937) this function was fulfilled by either choanocytes or amoebocytes, depending on the species of the sponge. If the spermatozoon is taken up by a choanocyte, this carrier cell loses both its collar and flagellum and takes on the appearance of an amoebocyte. The cell picking up the spermatozoon is usually the one closest to an immature ovum. Once within the carrier cell the spermatozoon loses its tail while the head and body enlarge two to three times.

The presence of the spermatozoon in the carrier cell close by apparently triggers the immature ovum (which at this stage in the reproduction process is about 15 microns in size (Duboscq and Tuzet, 1937) into activity. The ovum fuses with two amoebocytes called the nurse cells; then the ovum enlarges. The actual transfer of the sperm is accomplished through a canal which develops from the outer part of the ovum to the nucleus. The young embryo enlarges to about 0.5 mm. and becomes surrounded by a hyaline capsule. Maturing embryos sometimes occur singly but more often are found in groups of 10 to 15 (fig. 3b).

The color of the fertilized ovum in the early stages of cleavage is whitish. As the embryo matures it becomes a dark olive green with one end more deeply pigmented (fig. 3c). The final stage in development of the larval form is the growth of a crown of cilia at one end. At this point the larva is released into the nearest excurrent canal and expelled into the water where it continues to live as a free-swimming larva for a period of from a few hours to several days.

After being released from the sponge, the larva must come in contact with clean hard bottom to develop successfully into a mature sponge. Some attach to sea grass, sea whips, mollusk shell, bits of coral, etc., and attain some size, but being poorly anchored they are usually washed about and killed.

Observation of a spawning sponge by W. Smith, Nassau, Bahamas, (personal communication) showed that all the embryos in a velvet sponge matured and were released within a 4-week period.

Majority of the eggs and embryos are developed in the lower two-thirds and toward the central part of the wool sponge (fig. 3a) with very few eggs developing in the peripheral portion. One phenomenon associated with the production of eggs is the loss of living material

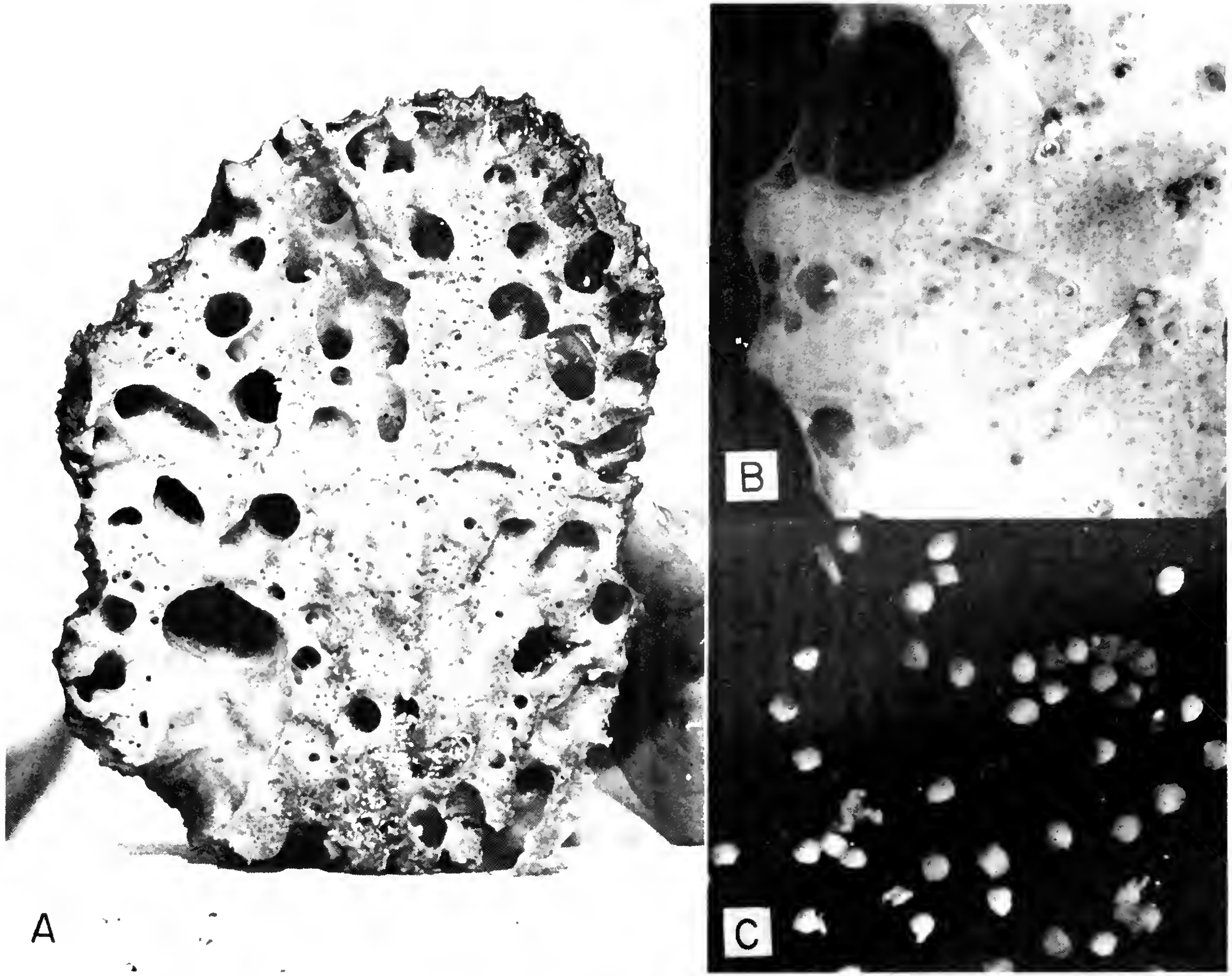

Figure 3.--Maturing larvae in a wool sponge. a. Cross section of a 6-inch diameter wool sponge. The maturing larvae appear as white dots, concentrated in the center and lower two-thirds of the sponge. b. An enlarged portion of the edge of a cross section of a wool sponge. A group of maturing larvae are in the upper right quadrant. In the lower right-hand quadrant is one almost mature larva which has become darker in color. c. A number of larvae removed from a wool sponge.

within the sponge itself so that the skeletal spongin fiber makes up a much larger percentage of the central mass after egg production has actively begun. Loss of living material causes a darkening of the internal portion of the sponge, and the beginning of this darkening can be observed in figures 3a and 3b, which are sections of sponges just attaining egg-producing size.

Relationship Between Sponge Concentration and Larval Production

Field observations of the number of eggs produced by individual sponges and the percentage of sponges producing eggs in any one area point to important relationships between sponge concentration and reproduction. During July 1956, more than 50 test dives of approximately 2 hours each were made. The relative concentration of the sponges on each rock bar was calculated from the number of sponges taken on each dive.

Although the information shown in table 2 does not lend itself to detailed analysis, some tentative conclusions can be obtained from the data gathered, supplemented by direct observation of other sponging areas. Verification of these can be established in future work.

1. There may be a critical density of sponges required for optimum production of larvae.--If the concentration of sponges of 5-1/2 inches or over was of the order of 11 per acre, over 85 percent were producing larvae. Of more significance is the fact that the density of the larvae in these sponges was approximately 500 per cubic inch. At some stations where the concentration of sponges was three or less per acre, only 30 percent or less of the sponges were producing larvae and in these cases the density of the larvae in the sponges was never more than 50 per cubic inch. This would give a total ratio of reproductive potential of the sponges in the two areas of about 30 to 1.

The data must be interpreted with reserve. Concentration of the sponges is not the only factor in assuring optimum fertilization and production of larvae. A sperm-producing sponge is a necessary element in the concentration.

Table 2.--Concentration of wool sponges collected in July 1956 for determination of larval content

[Number of sponges]

Station No.[1]	Total sponges taken per acre	Under 5-1/2" diameter	5-1/2" diameter and over	Total sponges with larvae
	Number	*Number*	*Number*	*Number*
XVII	11	0	11	9
XVIII	1	0	1	0
XXIII	2	2	0	0
XXIV A	14	11	3	3
B	15	8	7	6
C	5	0	5	4
D	4	0	4	4
XXV	4	1	3	2
XXVI A	25	24	1	[2]1
B	5	0	5	4
XXVII	2	0	2	2
XXVIII	20	18	2	[2]2
XXIX	9	6	3	0
XXX	7	6	2	0
XXXII	5	0	5	4
XXXIII A	4	1	3	[2]1
B	3	2	1	0
XXXIV	1	0	1	0

[1] Locations of these stations are shown in figure 10.
[2] Very few larvae in any one sponge.

The process of fertilization of the ova within the wool sponge suggests that for almost every sperm taken in, one egg will be fertilized and mature to the larval stage. The number of embryos produced, therefore, will be in direct ratio to the number of sperm entering the sponge. Further, the number of spermatozoa being taken in will be in direct relationship to the concentration of sperm in the water surrounding the egg-producing sponge.

2. Sponges possibly can reach a size and shape that inhibits the production of eggs and larvae.--Sponge fishermen have observed that when they formerly found densely populated beds of very old doughnut-shaped sponges there were few if any young sponges developing. Doughnut-shaped sponges were obviously past their optimum size of development. Extensive fishing of these beds resulted in the appearance of large numbers of small sponges the following year. (Regrowth of pieces of sponge left on the bottom when the large sponges are torn free could account for the small sponges.) The possibility is suggested that when a wool sponge reaches a 12-inch size and begins to form into a ring, it may be in a period of senescence. (See section on growth for a discussion of this phenomenon.) At this point the food intake may be below the demands of the living tissue, and there may not be sufficient food reserves for the larvae to become vigorous enough to leave the sponge. If they do leave they may not be strong enough to attach and metamorphose into young sponges.

Since small pieces of even the largest sponges can be used successfully in cultivation and these grow into vigorous young sponges, the argument cannot be used that the tissues of the large doughnut-shaped sponges become too old to produce ova.

3. Wool sponges may not be capable of self-fertilization.--If sponges were able to self-fertilize, the sponges found in areas of low sponge concentration would have as many larvae as those in areas of high sponge concentration. At many stations in area D (see appendix) where only few sponges were encountered, none contained developing larvae.

4. Sponges less than 5-1/2 inches in diameter may not be the sperm-producing sponges.--The presence of large numbers of sponges of less than 5-1/2 inches in diameter had no relationship to the percentage of mature sponges that were producing larvae. For example, on one bar, Station XXVIII (table 2), the concentration for all sponges was 20 per acre but only 2 per acre for sponges of mature size. The mature sponges here had very low egg counts.

5. From the evidence gathered there is an indication that only 1 out of every 200,000 or more larvae actually settles on the bottom and grows to maturity.--On five bars, in less than 24 feet of water where intensive work on the ecology and growth of the sponges was carried out, of the 108 sponges measured, the ratio of mature sponges to sponges of less than 5-1/2 inches in diameter, was 1: 3.6. A number of the sponges were obviously regrowths from old torn bases. I assume that the number of mature sponges present was barely enough to maintain the concentration of sponges at the level observed. Since the average mature wool sponge in the area was little more than 6 inches in diameter and sponges of this size produce an estimated 200,000 or so larvae per year, it would appear that this level of egg production in this area is the minimum production per mature sponge required for maintenance of the population. Almost all of the sponges over 6 inches in diameter were being harvested each year in the area. It may be suggested that if the average diameter of the mature sponges in an area is only 6 inches and all sponges over

this size are being steadily removed, insufficient larvae are being produced to bring about an increase in the sponge population. As a result the concentration of sponges will remain at an almost constant level.

Potential Larval Production Related to Volume

The average size of the mature sponges in an area is also an important factor in bringing about an increase in sponge population as well as the concentration of sponges of mature size. On a volumetric basis the ratio of the volume of a 6-inch diameter sponge to sponges of 7 to 11 inches in diameter is revealing.

It is the total volume of reproducing sponge material present in an area and not the number of sponges alone which must be considered. It may be seen from table 3, for example, that an 11-inch sponge may produce more larvae than six 6-inch sponges.

Optimum Temperatures for Larval Production

Larval production cycle throughout the year and the relationship of temperature to this cycle were determined by monthly collections of wool sponges made during most of the 2-year study period. Diving boat crews collected and preserved the sponges for later examination at the Marine Laboratory of the University of Miami. During each of the field trips, large numbers of sponges were also examined for larval production and size of the sponges at maturation. Well over 700 sponges were examined during the study.

Probably the longest and most complete records of sponge larval production were obtained by F. G. Walton Smith (personal communication). These records are for the breeding cycles off Turneffe, British Honduras. Information regarding the larval production cycle in the Bahamas was also available. The combination of three cycles plus parallel records of monthly mean water temperatures from the corresponding areas are presented in figure 4.

The temperature data were obtained from U.S. Department of Commerce Special Publication No. 278 (1955), which gives the surface water temperatures at tide stations along the Atlantic and Gulf of Mexico coasts. Accuracy to within 3° F. is claimed, depending on the location of the tide station on the shore.

Data on larval production are given as the percentage of sponges producing larvae of the total number examined each month. Cedar Keys data are for the area from Tampa Bay to St. Marks. Data from the Bahamas and British Honduras were obtained from F.G. Walton Smith.

The two critical temperatures in the larval production cycles appear to be 73° F. and 84° F. In the Cedar Keys area, larval production begins as soon as the mean monthly temperature rises to about 73° F. and increases

Table 3.--Potential larval production related to volume

Diameter	Ratio to 6" sponge	Potential larvae being developed[1]	Yearly production[2]
Inches		*Number*	*Number*
6	1 : 1	60,000	200,000
7	1.6 : 1	96,000	320,000
8	2.4 : 1	144,000	480,000
9	3.5 : 1	210,000	700,000
10	4.7 : 1	282,000	940,000
11	6.2 : 1	372,000	1,240,000

[1] With the observed number of larvae in a 6 inch sponge being taken as unity.
[2] Based on length of larval production season and length of time for maturation of one larva (4 weeks).

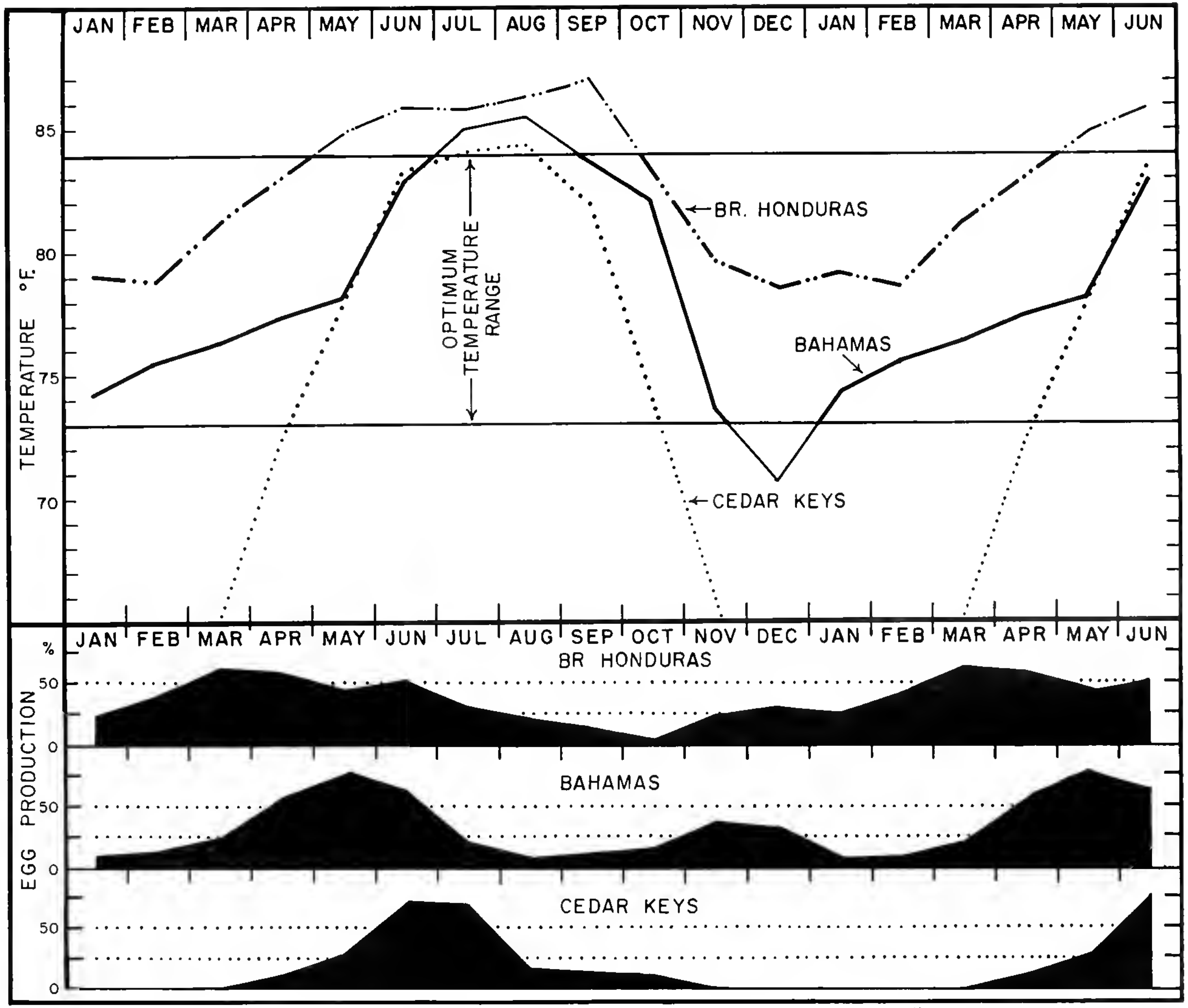

Figure 4.--Optimum temperature for sponge egg production in various areas. In the upper portion the temperature graphs for year and a half periods for three areas are drawn, with the probable optimum temperature range indicated as being between 73° and 84° F. In the lower portion the approximate monthly percentage of wool sponges carrying developing eggs (larvae) for the same three areas is shown.

rapidly until the temperature exceeds 84° F. With a further rise of 2 or 3 degrees in temperature the number of sponges producing larvae falls from 70 percent or more to about 25 percent. Even with a drop in temperature the percentage of sponges producing larvae continues unchanged until the temperature is below 73° F. at which time larval production ceases.

In the British Honduras area the cycle is more complex. Here the monthly mean water temperature never falls much below 79° F. In the late winter and early spring when the temperature is rising, larval production also increases but again, as the temperature goes above 84° F., the number of sponges producing larvae declines and finally tapers off to about 7 percent. As the temperature falls below 84° F., larval production increases but never more than 50 percent of the sponges are gravid. When the temperature again begins to rise in the next yearly temperature cycle, it is accompanied by a rapid increase in larval production.

The production peaks in the Bahamas follow the same pattern, as in British Honduras. The first peak, in April, May, and June, occurs while the temperature is rising. There is a decline when the temperature is above 84° F., with a second peak in larval production in November and December when the temperature again falls below 84° F. This second peak appears to be very slow in starting, and part of the peak actually occurs while the temperature is below 73° F. The temperature data for the Bahamas were obtained from a study by C. L. Smith (1940) and were early morning temperatures.

It would be expected that there would be optimum temperatures which would stimulate the production and release of the sexual products (in this case the sperm) and also increase the receptiveness of the eggs for fertilization. Shortly after the sperm are released, the egg-producing sponges would have enlarging embryos which would be readily visible to the naked eye. Minimum temperature for the release of the sperm appears to be about 73° F. Above 80° F. there apparently is a much stronger stimulus for this release and a much larger percentage of sponges are producing larvae. Above 84° F. either the sperm are not released from the male sponge (or become impotent), or the eggs become unreceptive, for larval production ceases. There seems to be no ready explanation why larval production remains at a very low level after the temperature declines below 84° F. The data from British Honduras and the Bahamas indicate that a long period of time is required by the sponges to recover their ability to reproduce in quantity while temperature is declining. In the Cedar Keys area the temperature declines so rapidly that before this recovery can take place the temperature drops below 73° F. and larval production ceases.

The longer reproductive period of the sponges in British Honduras results in much greater egg production than in the upper Gulf area even though the peak of productivity is higher in the Cedar Keys area than in British Honduras. Total larval production in the Cedar Keys area is only about 63 percent of that in British Honduras (fig. 4). When the size at maturation is taken into account, this discrepancy may be somewhat increased. Sponges as small as 2 inches in diameter will produce eggs in the warmer waters of British Honduras (F. G. Walton Smith, personal communication), while in the upper Gulf eggs are not normally produced by sponges until they are between 5 and 5-1/2 inches in diameter. Thus, if the percentage of sponges producing eggs and larvae in British Honduras is estimated, almost all the sponges would be potential egg producers. In the upper Gulf, on the other hand, only sponges above 5 inches in diameter have been used to obtain the data; and if all sizes of sponges were considered, the actual percentages of egg-producing sponges would be reduced to about one-third of that indicated in figure 4.

Temperature and Size at Maturation

In the Gulf north of Tampa Bay (area D) the minimum diameter of wool sponges producing larvae was 5 inches. North of Cedar Keys (areas A and B) the minimum diameter for mature sponges, generally speaking, was 5-1/2 inches. Only four or five sponges (out of the 700 examined) less than 5-1/2 inches were found to be producing larvae. In the Key Largo area, the minimum size for mature wool sponges was 3 inches; in the Bahamas, W. Smith (personal communication) reported that the minimum size was 4 inches. In British Honduras sponges as small as 2 inches in diameter may produce eggs.

When in each area the size at maturation of the wool sponges was compared with the water temperature, there was a very close relationship between the number of months per year in which the temperature in an area was greater than 80° F. and the minimum size of mature wool sponges (fig. 5). The curve in figure 5 represents a relationship between size at maturation (larval-production size) and the variation of temperature at different geographical points. It is likely that a very similar relationship exists between size at maturation and the variation of temperature with depth of water. Bathythermograph recordings show that in the upper Gulf, for example, temperatures of more than 80° F. are to be found as deep as 120 feet during July. Insufficient data exist to plot the duration of this temperature at various depths throughout the year. It is possible that dispersion of wool sponges to deep water areas in the Gulf may be retarded by the effect of temperature on the sexual maturation of the sponges.

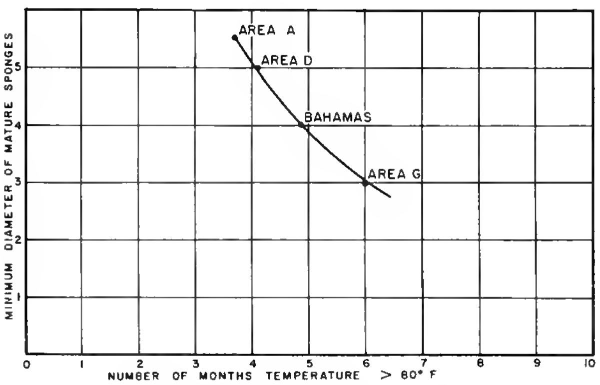

Figure 5.--Temperature - size at maturation relationship for wool sponges in various areas. (See appendix a for areas.)

Since temperature is a factor in the breeding cycle of the wool sponge, variation of water temperature from year to year will affect larval production. It is possible also that long periods of optimum temperature could bring about an earlier maturing of the sponges and total egg productivity would be increased as a result (fig. 5).

GROWTH OF SPONGES

Method of Determining Growth

Sponge growth was studied during the investigation by a series of underwater field tests in the northern Gulf. In all, 108 sponges of the three principal species (wool, grass, and yellow) were measured and tagged for growth rate studies. Eleven were cut off, measured, and tagged for regrowth study. One hundred sponge cuttings were set out to observe their growth rate, and a number of plain cement bricks were placed in the areas to try to obtain sponge settings. Sufficient data were obtained to construct a growth curve only for the wool sponge.

The sponges were tagged by running a stainless steel or Monel wire through the sponge and around a brick. Each cement brick was code numbered by cuts in the edges (fig. 6b). The three dimensions of the attached sponge was then measured with a modified sliding square.

It was necessary to examine seven or eight sponging bars before locating one that had a sufficient number of sponges growing on it to justify establishing a station. When located, each of the five selected stations was positioned by (a) placing a buoy, the most practical method, (b) making compass sightings, (c) timing course runs from stationary objects in the water, e.g., the coastal bird racks (platforms constructed in the shallow water for collecting guano), and (d) laying of wires on the bottom in set directions from the bar for locating by dragging later.

Losing buoys, changing work boats and compasses, taking of sponges by sponge fishermen (even though more or less unintentional), and dying from adverse ecological conditions contributed to our inability to recover a considerable number of tagged sponges. Despite these losses, I obtained enough data to establish a growth rate for the sponges in the Gulf area

Figure 6a.--Measuring sponges underwater during the field studies. Lightweight Navy diving gear was used throughout, air being supplied from the surface.

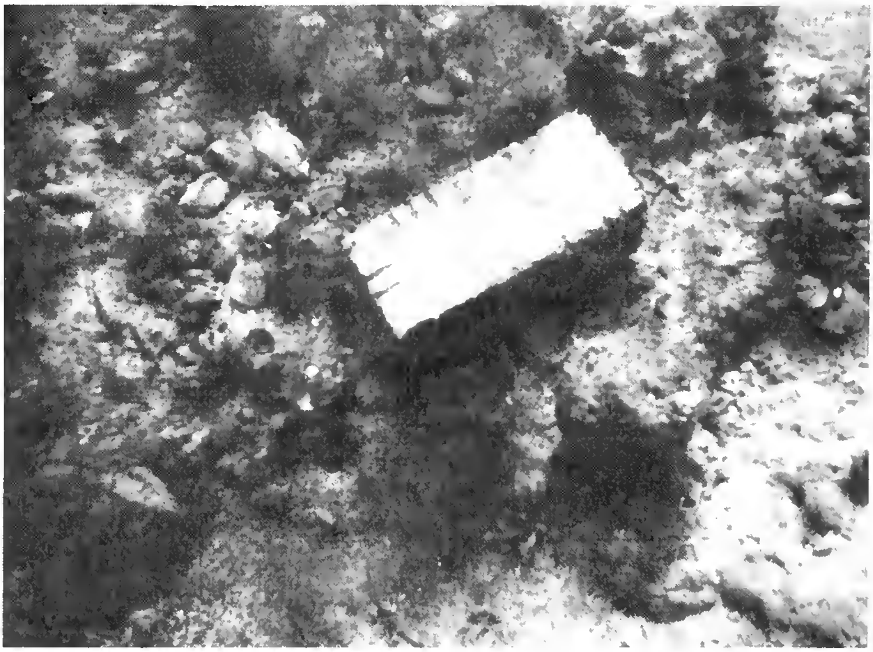

Figure 6b.--A wool sponge measured and tagged for growth studies. The brick is code numbered by the notches on three of the upper edges and attached to the sponge by a Monel metal wire. This sponge was on a rocky bar in the northern Gulf in 20 feet of water. To the left are a number of *Arca* clams, algae, and noncommercial sponges. This is typical rock bar appearance.

north of Piney Point. It is unfortunate that the growth rates of the sponges in the area off Cape Sable in the south could not be established as well, as this would have assisted greatly in understanding the relationship of temperature and sponge growth.

To obtain the growth curve for wool sponges in figure 7a, the growth data from each tagged sponge was recorded individually on a graph and the mean slope between them taken as the average growth rate of the sponges. The results obtained by compilation of the data in this way agreed well with those obtained by Moore (1910b). The data gathered indicated marked variation of growth between sponges on the same bar.

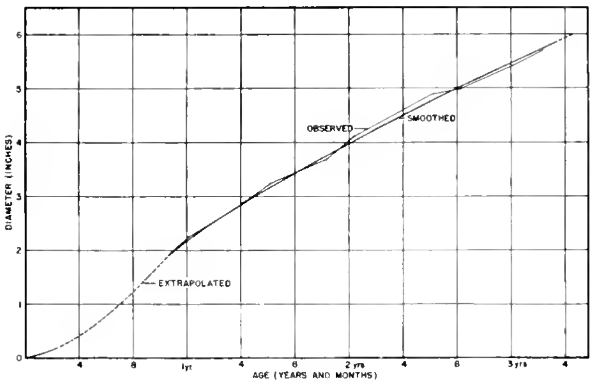

Figure 7a.--Growth rate of wool sponges. The light line is based on observation data of the growth of tagged sponges on bars in the upper Gulf. The heavy line is the modified growth curve, dashed portions extrapolated.

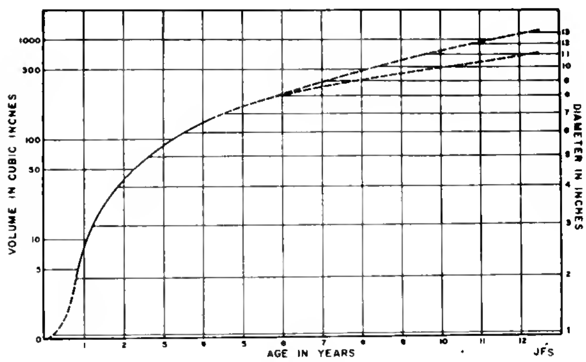

Figure 7b.--Volume-diameter relationships in the wool sponges. Solid line based on observed growth rates. Lower dashed line beyond 6-inch diameter based on the growth formula. The upper dashed line of the growth curve represents the more probable growth rate under natural conditions as discussed in the text.

Moore determined the average yearly increase in diameter of wool sponges to be between 1 and 1.2 inches, beginning with a cutting of 10 cubic inches. For a comparable 4-year period the yearly increase of wool sponges growing naturally on the bottom determined by the short-term experiment during the present investigation was 1.25 inches.

Yearly Growth Factor

Growth may also be expressed in terms of a growth factor, the number of times a sponge increases in volume during a 1-year period. With Moore's method the growth factors determined for the present experiment from the growth curve were:

Second year of growth - 3.2
Third year of growth - 2.0
Fourth year of growth - 1.6

The average growth factor for this 3-year period was 2.3. Moore obtained a growth factor of 1.9 for cultivated sponges in shallow water at Anclote Key for a comparable period and size of sponge. Crawshay (1939), reviewing experiments with sponge cuttings at Turneffe, British Honduras, considered a growth factor of 2.0 or more as adequate and 2.5 as good. He also considered a growth factor of 3 or more as high and suggested that the exceptional accumulation of waste matter which could accompany the high food intake necessary to maintain this growth factor might be unhealthy for the sponge and result in disease. This could happen with any deterioration of optimum growth conditions.

With a growth factor of 2.3 during the first few years of the growth of the sponge found in the upper Gulf, a sponge would require about 3 years to reach the legal size of 5 inches in diameter from the time of attachment of the sponge larva and almost 4 years before the sponge was 6 inches in size. A listing of various growth factors obtained during the past and present experiments show wide variation for comparable growth periods:

Sugar Loaf Key, Florida (Moore, 1910b)	1.86
Anclote Key, Florida (Moore, 1910b)	1.91

Piney Point, Florida (personal observation) 2.27
Abaco Island, Bahamas (Crawshay, 1939)...................................... 2.34
Turneffe, British Honduras (Crawshay, 1939)...................... 2.94

Growth Formula

When the annual rates of increase between units of diameter were plotted, it was found that for growth beyond a diameter of 3-1/2 inches the growth factor could be expressed by the standard formula:

$$y = Ae^{Bx}$$

where y = annual rate of increase - the growth factor
x = radius of the sponge in inches at beginning of a year
and A and B are constants, while e is the base of the Naperian logarithms.

This is assuming a regular spherical shape for the sponge.

For the particular values obtained on the growth rate off the Piney Point area the formula, modified for ease in working, became:

$$y = 1 + 11.2e^{-1.07x}$$

Since the data gathered were for diameters of from 2 to 7 inches, the use of this formula for extrapolation of the curve beyond 7 inches was particularly useful (fig. 8). The formula indicates that growth will almost completely stop when the sponge reaches a 12-inch diameter. This is confirmed in the observed growth of wool sponges by the death of the central portion of the sponge when this diameter is reached. The form of the sponge from then on becomes more and more doughnut in shape. Continued growth beyond a 12-inch diameter suggests that one other growth factor operates as the sponge approaches the limit of growth indicated by the formula. Since the sponge is uniform in structure and the intake of water carrying the food is through the sides, the greatest amount of food uptake is in the

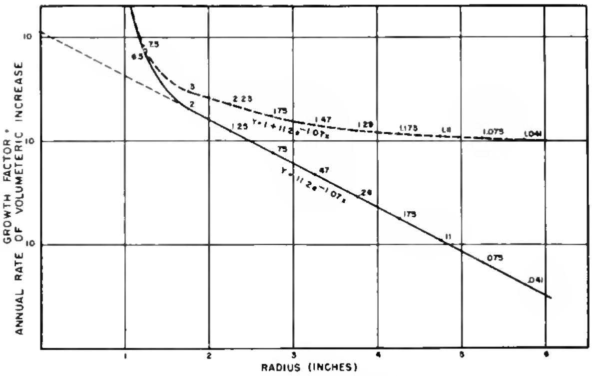

Figure 8.--Growth factor for wool sponges. Radius in inches vs. the logarithm of the growth factor. The upper curved broken line is comprised of the percentage volume increase plus 1, which gives the factor of growth for any size of sponge from 3-1/2 to 12 inches in diameter.

periphery of the sponge. This area, therefore, continues to grow vigorously, but the rate of food intake is not sufficient nor the rate of food transfer through the sponge efficient enough to support active metabolism in the central portion of the sponge when the diameter of the sponge is 12 inches or over. The growth formula obtained would probably be directly applicable to the rate of sponge growth except for this phenomenon of sponge physiology. It has been observed in doughnut-shaped sponges of large size that the ring is little more than 6 to 9 inches thick.

The rate of growth in diameter indicated by the growth formula (fig. 7) appears to be valid for the first 5 or 6 years. Beyond this point the growth rate must be assumed to be somewhat less than indicated by the formula, the increase in diameter gradually approaching a uniform rate as the sponge assumes the doughnut shape.

Life Span

Little is known of the life span of wool sponges although the records have indicated that they can live at least 25 years. Presumably, the limiting factor to continued growth is the capability of the sponge to draw in sufficient food for self-maintenance. Any lack of food intake is counteracted in part by the dying of the central portion of the sponge so that after a certain point in growth in diameter, the volume of the sponge remains a constant in relation to the surface area.

If the size of the sponge were periodically reduced by dividing it into cuttings, it may be that the original sponge material could be kept living indefinitely, assuming favorable growth conditions. This has been done in part in the Bahamas' sponge plantation where sponges have been cut several times from the same base. Some of the bases are close to 16 years of age and are repeatedly developing new upper growths.

Several individual sponges of noncommercial varieties have been observed by me for over 15 years. These sponges had reached 3 feet in diameter when first seen. This may be the maximum size obtainable under the local conditions present, for after a winter when temperatures were unusually cool a decline in size was noted. Similar reductions in size of sponges growing in aquaria were observed when water temperatures dropped suddenly. This reduction in size seems to be related only to temperature changes.

An examination of the ecological conditions existing in each area indicates that food supply, temperature, and water currents are the primary factors affecting the growth rate. The effect of these factors on growth will be discussed in the section on ecology.

Healing and Growth of Cut Surfaces

Part of the field study on growth was experimentation on regrowth of the sponge from the cut base to show the possible value of cutting the sponge from the base rather than using a hook to remove the sponge. Weekly observations were made of the cuttings of wool and yellow sponges attached to cement bricks in aquaria with running salt water. Most closely related to the field experiments were the observations made on the healing of the cut surfaces and the external evidence of reorganization in the canal system of the sponge cuttings.

Initial healing and sealing off of the cut surfaces took place within a few hours after cutting. After 3 days, primary healing of the cut surface had occurred and a new outside surface layer laid down. At the end of 2 weeks the cut surfaces had become black in color, and within the month the exposed internal canals had filled in. A number of small volcanolike oscules had also developed, from which a noticeable current of water passed.

The bases of the sponges in the field study were examined about 3 months after the top of the sponges had been removed by cutting. The appearance of the regrowth from the cut base was essentially that of a number of small coalescing sponges. These bases had retained their original mass and had developed a number of prominent oscules about one-half inch in height scattered over the cut surface. Because of its relatively thin layer of living material on the rock, the sponge had not had sufficient food reserve to fill in all the larger exposed canals and only a dermal layer had been laid down. Beyond the formation of the oscules no real growth had been made in this relatively short period of time.

CULTIVATION OF SPONGES

Aristotle in 350 B.C. noted the regrowth of sponges from torn bases. There are records of experiments of sponge cultivation during the 18th century in the Mediterranean Sea, and many experiments have been carried out since that time in various Mediterranean countries, British Honduras, the Bahamas, and Florida.

From the time that sponging became an important industry in Florida, the harvesting methods have been deplored as destructive and sponge cultivation has been suggested as a remedy to assure an adequate continuing harvest. The most extensive cultivation experiments attempted were by Moore (1910b). In the several cultivation experiments tried in Florida, the sponges were grown on metal spikes, wire, and cane, with cement triangles or discs used as the bases for attachment. All the experiments eventually ended because the sponges were destroyed either by storms or by the spongers, some of whom were opposed to the experiments. Principal source of failure was the poor locality chosen for the experiments.

Sponge Cultivation in the Bahamas

Choice of locality for growing good-quality sponges is of particular importance. In some cases in the Bahamas it was found that a 3-inch sponge cutting would grow to 8 or 10 inches in size within 2 years; however, quality of such sponges was extremely poor. The best grade of sponges was produced by 3-inch cuttings that increased to an 8-inch size in 3 years, a rate of about 1.6 inches per year.

Several attempts at sponge cultivation have been carried out in the Bahamas since the early 1900's with some degree of success. Wilfred Smith of Nassau had about 200,000 velvet and wool sponges "planted" just previous to the 1938 disease that wiped out the entire sponge industry in the Bahamas. The present plantation at Pot Cay, Andros Island, Bahamas, is being maintained by Henry Thorn, and sponges are being grown successfully although not on an active commercial basis.

In an unpublished manuscript on sponge cultivation by W. Smith of Nassau, a complete outline is given for successful sponge cultivation methods. With his permission a very brief summary is given here.

The "wild" sponges to be used as cuttings were gathered by the crew of a small sloop within a 30-mile radius of the plantation. The sponges as gathered were stored or held in the fish well of the sloop or in a fish scow, in either case the sea water having free access to, and circulation around, the sponges. A full load to make 3,000 sponge cuttings could be collected in about a week if the weather was favorable. At the plantation the sponges were strung on wires and fastened to the bottom for a week. This method assured that only healthy sponges were used in planting; the ones that died during the holding period were cleaned for sale.

The planting unit consisted of four men working from three dinghies--the live sponges were kept in the fish well of one dinghy, 8-inch flat dry stones in the second, and the third was used to ferry stones from the shore to the planting unit. In planting, the sponges were cut with a sharp knife into pieces about 3 inches across, tied to the stones with a length of palmetto string made from splitting a palmetto palm leaf and dropped overboard 3 feet apart (fig. 9). Planting was on firm mud bottom in about 6 feet of water where there was a good but not excessive flow of the tide. It was also important that the choice of locality be in an area where the salinity of the water would never fall below 32 ‰ , (see section on salinity relationships for more detail).

Within 2 weeks after planting the raw surfaces of the cuttings had healed over completely and turned black. Within 6 weeks the cuttings had normal color. The second phase in the growth was the withdrawal of living material from the sharp corners of the cuttings, the exposed skeletal material rotting and sloughing away. By the end of the first 6-month period the new sponge was rounded out by new growth.

Advantages and Disadvantages for Cultivation

There have been many advocates of sponge cultivation. Some have even stated that cultivation was an absolute necessity for the survival of the sponge industry. Such a strong opinion can be understood because of the obvious difficulty in obtaining wild sponges, lack of assurance in maintaining a constant supply, the considerable difficulties that have been encountered in trying to bring about an understanding of the need for sound conservation practices, as well as the attractive assets cultivation has been said to offer. The more obvious advantages and disadvantages of sponge cultivation are listed below.

The major advantages would be:

1. The planting operation is a relatively simple one, the basic materials (sponge, rock, and tying strings) can be gathered in the area. This does not rule out the possibility of using an improved base of cast cement and a better grade of tying material.

2. Sponges can be concentrated in a small area. In many places one cutting can be placed per square yard. Loss of time in harvesting is thus minimized.

Figure 9.--Cutting sponges for cultivation. A 2-year-old sponge has been cut from its base, bottom left, and the top part divided into quarters. One of the quarters has been attached to a rock, while another is being threaded on a string of dry palmetto leaf in preparation for tying to a rock.

3. Harvesting of the sponges is a simple and controlled operation, the sponges being taken up only when an order has to be filled. The remaining sponges continue to grow.

4. If the sponges were cut from the rock base rather than pulled or torn off, the remaining base would act as a fresh cutting and the operation of harvesting and planting is thus accomplished at the same time (fig. 9).

5. Growing sponges by cultivation also offers the advantage of some control over quality, size, and shape through the proper selection of the growth area and the growth period. It might be possible to increase quality and value by selecting only the best sponges for cultivation.

6. The heavy concentration of sponges in the cultivation area would result in production of large numbers of eggs and larvae. If the plantation were in the region of good natural sponging ground where the bottom was suitable for attachment of the larvae, large numbers of naturally growing sponges could be expected to set within a 2- or 3-mile radius of the plantation. The harvesting of these sponges would add to the total returns.

The major disadvantages encountered in any attempt at sponge cultivation would be:

1. The lengthy process of selection of a growing area which would assure the development of a good grade of sponge in the shortest possible time. This might require the use of a series of test areas,

over a considerable period of time; or, the plots to be cultivated could be located near areas known to grow superior individuals.

2. A long-term lease of the bottom sponging rights would have to be obtained.

3. The necessity for constantly patrolling and protecting the plantation area from vandalism or theft would be expensive.

4. The possibility of almost complete loss of several years of work by storm is always present.

5. W. Smith (personal communication) stated that during 1938 the sponge disease killed almost all of the sponges in areas where there was a high sponge concentration. On the other hand, a much larger percentage of the sponges in areas of low concentration were able to survive. This at least suggests that with cultivated sponges at concentrations of one per square yard any sponge disease would spread rapidly from one sponge to the other and quickly result in large numbers of free-floating or free-swimming stage of such disease organisms. Once started, therefore, a disease that would normally be only somewhat destructive in natural sponge beds might quickly reach epidemic proportions in a cultivated bed.

6. Because of the slow growth rate of sponges it would not be until the fourth year that any returns could be expected and not until the seventh that the plantation would be fully productive.

A rough schedule for planting and harvesting using the methods described above for the Bahamas would be as follows:

1. Planting would be carried out during a limited part of the year when weather conditions would be most favorable, using a crew of about nine aboard a sloop to collect the sponges and a crew of four to plant the cuttings in the selected area.

2. Under actual conditions as many as 1,500 cuttings can be planted in 1 day by the crew of four, but the problem of gathering stone and sponges to maintain a supply for the planters would become increasingly difficult. Assuming that one good-sized sponge would supply 8 cuttings, about 7,000 "wild" sponges would have to be gathered to plant 50,000 cuttings. A rate of 50,000 plantings per year would have to be maintained for the first 3 years. During the fourth year two planting crews could do all the work, harvesting the first year's planting of cuttings and replanting part of these. Assuming a maximum mortality of 20 percent during the 3 years of growth, 40,000 sponges could be harvested during the fourth year. Since it is possible to cut the sponges from the base and still have a very good product, the 40,000 living sponge bases would be essentially replanted cuttings. Assuming, after 3 years, the program of the plantation is to plant 100,000 cuttings per year, 10,000 to 15,000 of the harvested sponges would have to be cut to be used for replanting during this fourth year to bring the total number of cuttings to the desired 100,000 level. This would leave between 25,000 and 30,000 sponges for marketing, yielding about $15,000 at present average market prices. It is quite conceivable that the cultivated sponges would be a quality product and bring in a somewhat higher price.

3. The same schedule of partial harvesting and replanting would have to be maintained during the fourth, fifth, and sixth years.

4. During the seventh year it would be possible to harvest 80,000 of the original 100,000 planted sponges of which 5,000 would have to be sacrificed for cuttings. A number of sponges might be deformed by the proximity of plants or alcyonarians growing on the sponge or the stone base. These deformed sponges could be cut up for seed; the loss of the 5,000 would not necessarily represent an unexpected heavy loss of revenue.

The 75,000 sponges harvested yearly would represent about one-quarter of the 1955 or 1956 yield from the entire Florida area, where at least 140 men working full time are required merely to gather the sponges. On the basis of manpower alone, therefore, it would only require 8 to 10 men to produce as many sponges by cultivation as 35 or more men harvesting naturally growing sponges at the present rate of production once the plantation was in full production.

Establishing sponge plantations along the coast of Florida presents several additional problems that would be less serious in an area such as the Bahamas.

1. Turbidity of the water along the Florida coast is much greater than in the Bahamian water because of greater land drainage and differences in the type of soil. Poorer underwater visibility would increase the difficulty of planting and gathering the sponges. There is also the danger of periodic mortality due to freshwater runoff.
2. Heavier water traffic over potential plantation areas would require closer supervision of the grounds.
3. On the west coast of Florida the diving boat crews find that the water is sufficiently calm and clear enough for work only about 100 days each year. On the shallow larger banks of the Bahamas, where the water is crystal clear, the number of work days would be expected to be considerably higher.

From the standpoint of quality the logical choice for a sponge plantation off Florida would be in the Rock Island area, probably in the region of the Econfina flats off the Econfina River. From the standpoints of faster growth and availability of quantities of natural sponges the area off Cape Sable would be the most profitable. In the northern part of the area, the winter weather is rather severe for water work and in addition, there is the constant danger of freshening of the sea water. In the southern area off Cape Sable there are relatively few days when the water is sufficiently clear for work of any kind underwater.

Some parts of the Florida Bay area in the vicinity of the lower keys would appear to be a practical area for a plantation. Much would depend on the quality of sponges that could be produced there.

DISTRIBUTION

Determination of Distribution

Distribution of the commercial sponges in the Gulf was determined on three survey trips. On the first two trips, I did the diving; on the third trip, two regular sponge divers did the surveying. The first trip was made with a small pleasure craft in September 1955. This cruise surveyed the area from Tarpon Springs to St. Marks in water depths from 6 to 60 feet. The second trip was made aboard a regular diving boat in November 1955 when the area from Tarpon Springs southward to the Ten Thousand Islands was explored. The third field trip, again aboard a regular diving boat *(Elini)*, was made in July 1956 and covered the area from Tampa Bay to Carrabelle. This trip was made to survey the bottom at depths from 50 to 100 feet to establish the outer limits of commercial sponge distribution.

In the three field trips, 88 diving stations were established in the area between Tampa Bay and Carrabelle, with well over 100 dives being made (fig. 10). Nine stations were south of Tampa Bay, but these did little more than verify the scarcity of sponges between Tampa Bay and the area seaward of Everglades City. A careful survey of sponging areas from Plantation Key to Key Largo was made on the Florida east coast from chartered small open boats; my assistant, Robert Work, and I made about 40 dives on 11 stations in this survey.

From the information obtained on the field trips plus additional information from the spongers themselves it has been possible to construct a diagram of the present distribution of the commercial sponges (fig. 11). This distribution diagram represents only the areas where commercial sponges are found at the present time (1958) in the upper Gulf and does not indicate the density of the population.

Concentration of Sponges and Extent of Sponging Area

Density of the sponge population on the bars is important economically as well as

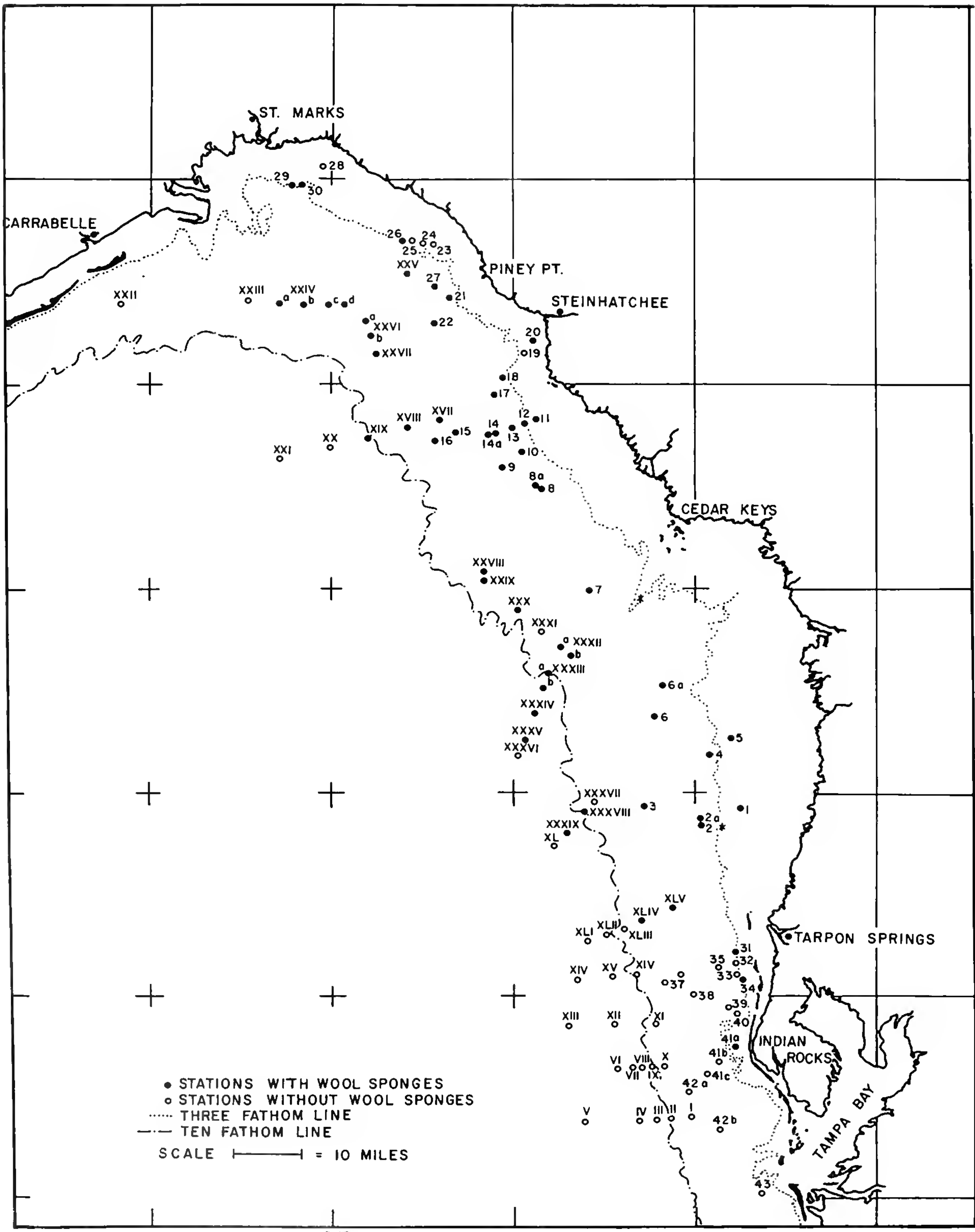

Figure 10.--Diving stations, Tampa Bay to Carrabelle. Each station numbered with Arabic numerals represents two to four 2-hour periods by the author. Stations numbered with Roman numerals represent exploratory dives made by sponge divers on the June 1957 expedition.

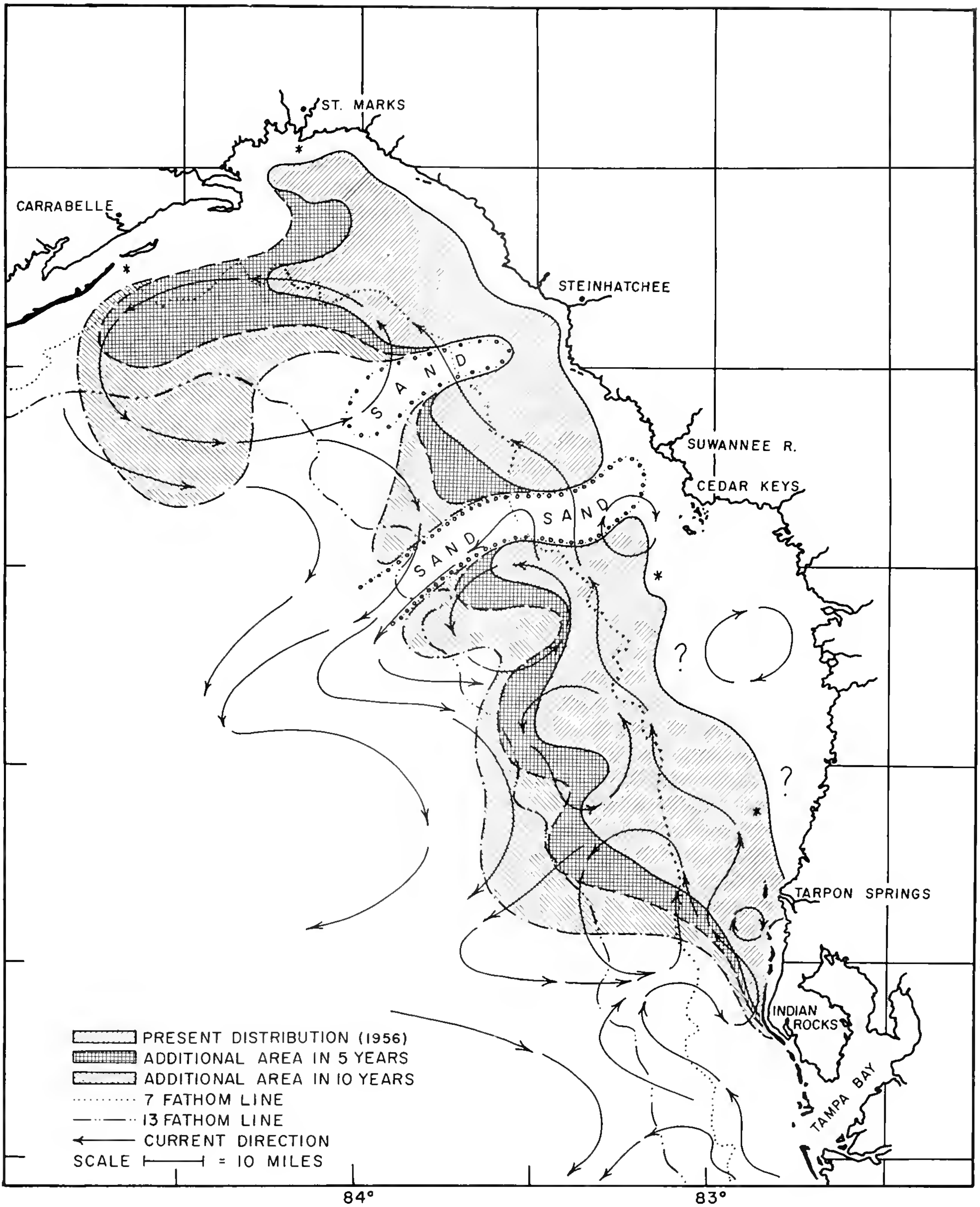

Figure 11.--Probable distribution of sponges in 5 and 10 years (from 1958). This figure also shows present distribution and the water current pattern.

biologically, as shown in the section on reproduction of sponges. It is necessary for each sponge diving crew to gather from 125 to 150 sponges per day of effort, or 12,500 to 15,000 per year. This number gives only the minimum return required for operation of the boat, with the shares to the members of the crew providing only the minimum for existence.

Several methods have been tested to estimate the average density of the sponges on the rock bars. The best and most practical method found is a calculation based on the area covered daily by the diver, the total number of days of work annually, and the average number of sponges taken by each diving boat. It has been estimated that the diver walks at an average rate of one-half mile per hour and can see about 15 feet on either side. The rate of walking varies greatly according to the concentration of the sponges, slowing down when the sponges are numerous and increasing where the sponges are scarce. Underwater visibility also varies from day to day.

The two divers aboard each boat work underwater for a total of 10 hours per day out of the 12-hour working day. Poor weather conditions, travel time, and time lost in port reduce the number of working days to 100 per year. Multiplying the distance in feet traveled by the divers in 1 day by the width of the area searched and dividing this total area by 43,560 (the number of square feet in 1 acre) provides a calculation of the area covered by the divers in 1 day. The area is about 18 acres. At this rate, the area covered in 1 year by the divers of one boat would be 1,800 acres or 2.8 square miles. The 1957 fleet of seven diving boats would therefore cover some 19.6 square miles per year.

The total sponging area being used by the divers may be estimated as follows:

1. At the present time the mean diameter of the wool sponges being taken by the divers is 7 inches. Since the smallest legal size is 5 inches, the sponges taken have to range between 5 and 9 or more inches to obtain this 7-inch average.

2. The growth rate above a 5-inch size is approximately 1 inch per year, and therefore it will be necessary to exploit at least part of the total sponging area only once every 5 to 6 years to obtain sufficient numbers of the larger sponges to maintain the 7-inch average size. As a basis for making a calculation of the total area being worked by the divers, the assumption is made that all the sponge-producing bars are worked at least once in every 5-year period.

3. To search all the sponge-producing area once in a 5-year period requires that the total area covered would be three times that covered in any 1 year, and this would represent the total sponging area available and being worked by the diving boats at the present time. This total area would therefore be 59 square miles in extent. All factors considered, this appears to represent a minimum estimate.

Lack of adequate data makes it impossible to estimate the area covered by the sponge hookers. Since the average size of wool sponge being taken by the hookers is about 6 inches in diameter, it appears that the available shallow-water hooking area is being covered far more thoroughly than the bottom below the 20-foot depth. Using a total of eight diving-boat equivalents[3] for the number of hooking boats working and the same process of calculation, the area being worked by the hookers is less than 40 square miles in extent.

Average daily take has been estimated by the spongers for each area (see fig. 15 for areas) and is given in table 4 along with the calculated concentration of the legal-sized sponges per acre, based on the above calculations. This concentration agrees very closely with that observed during the present investigation of the sponge beds.

Based on several counts of the number of sponges on a bar and the measurements of the sponges, there are on the average three sponges less than 5 inches in diameter to each one more

[3] Diving-boat equivalents are calculated in section on "present status of the sponge industry."

Table 4.--Daily take and density of sponges by areas, 1957

Area[1]	Low take	High take	Average take (estimated)	Average density per acre of legal-size sponges
A	80	250	125	6.9
B	70	[2]225	130	7.2
C	200	415	300	16.6
D	125	365	230	12.7
E	100	300	200	8.3
F	250	1,115	660	36.6

[1] See appendix A and figure 15 for details of areas.
[2] High concentrations of sponges found only in shallow water.

than 5 inches (legal-sized sponges). The population density of wool sponges of all sizes in any area will, therefore, be about four times that given in table 4.

In areas A and B[4] the low number of sponges taken per day is in part offset economically by the better quality of sponges taken in these areas and the correspondingly higher price. On the other hand, large number of sponges taken in area F is not as profitable to the sponger, because these sponges are inferior to those from other areas and bring a much lower price.

In all areas except F the concentration of the wool sponges is not dense enough to expect any sudden increase in the number of sponges through natural propagation. In area F, however, the spongers reported substantial increases in the concentration of sponges between 1954 and 1957, and this recorded concentration of about 36 legal-sized sponges per acre would appear to be above the level necessary to not only maintain but increase the population of any given area. Because of the increased turbidity, which limits underwater vision, and the higher concentration of sponges, which slows the diver's progress, the density of sponges per acre indicated in table 4 for area F is low. Density per acre may be as much as 50 percent greater than shown.

Distribution of Diving and Hooking Depths

The data on the landings of sponge from the Tarpon Springs Sponge Exchange enabled us to obtain the distribution of the various commercial species of sponges by depth. The diving boats are limited by law to work in water of more than 21 feet (3-1/2 fathoms). The hooking boats on the other hand usually work in water from a fathom or more to less than 21 feet. By separating the landings of divers and hookers the relative distribution of the sponges in depth can be estimated. The market returns for the years 1955 and 1956 have been analysed on this basis (table 5).

Table 5 does not give a completely accurate picture of the comparative harvest by divers and hookers. As we shall see later, the average size of sponges landed by the two methods differs quite considerably. Wool sponges taken by diving boat crews are about 50 percent greater in volume than the average size taken by the hooking method. Thus the deeper water area is producing about 50 percent more sponges by weight than indicated when the method of comparison is only by the number of sponges.

Causes of Short-Term Variations in Landings

Unfortunately the records of landings for 1950-56 are not complete; only 1955 and 1956 records are sufficiently accurate for tabulation. Although any analysis of the situation based on these 2 years alone is not indicative of trends in productivity of the sponge beds, several observations can be noted from the table above and from available information obtained from the sponge fishermen.

[4] See appendix and figure 15 for details of areas.

Table 5.--Number and percentage of sponges taken by species and depth

Species and year	Depth	
	Less than 21 feet	More than 21 feet
Wool:		
1955:		
Number......	192,215	128,552
Percent.....	59.9	40.1
1956:		
Number......	164,711	173,931
Percent.....	48.6	51.4
Yellow:		
1955:		
Number......	11,881	945
Percent.....	92.7	7.2
1956:		
Number......	26,166	4,505
Percent.....	85.3	14.7
Grass:		
1955:		
Number......	7,660	698
Percent.....	91.6	8.4
1956:		
Number......	18,317	1,647
Percent.....	91.7	8.3
Glove:		
1955:		
Number......	90	0
Percent.....	100	0
1956:		
Number......	976	54
Percent.....	97.6	2.4

In the shallow-water area the wool sponges have had a setback during the 2-year period (1955-56). This was the result of local losses of sponges by a disease in the shallow area just north of Tarpon Springs and the dying of large numbers of wool sponges in the shallow water north of Steinhatchee after the hurricane in October 1956. This latter loss was probably caused by a freshening of the water (see section on sponge disease). These losses are only temporary, and the situation is expected to return to normal within a few years in these very limited areas. In the deeper water the concentration of wool sponges is increasing and additional areas are coming into production. Part of the increase in landings can be attributed to the increased number of diving boats. The increase in the numbers of wool sponges is very slow, and, in my opinion, there is not likely to be any sudden expansion of the sponge population.

There are too few yellow and grass sponges on the bars as yet to make any prediction of the trend. In 1957, however, it appeared that the population of these sponges in some areas was sufficient for large numbers of larvae to be produced and their numbers to increase rapidly during the following few years. Landings in 1958 and 1959 carried out this prediction.

Factors Affecting Dispersion

One of the more important aspects of the present study was to determine what factors were affecting the dispersion of the wool sponges and how fast this dispersion was taking place. With this information it should be possible to predict with some degree of accuracy the new areas that will be producing sponges within a given number of years, the extent of those areas, and the potential landings of sponges. These facts are of considerable importance to both the sponge producer (the sponge fisherman) and the sponge distributor, who must have some idea of future production in order to know what long-range advertising and sales campaigns should be carried on.

Given a breeding population of sponges, three major factors affect dispersion:

1. The direction, rate of flow, and characteristics of the ocean currents in the sponge-producing area.

2. The duration of the larval stage.

3. The growth rate of sponges to maturity.

There are two types of ocean currents--tidal and semipermanent--affecting the dispersion of the free larval stage of the sponge.

Measurements of the tidal flow and its calculated excursion show that in the upper Gulf the total distance traveled by the water during a tidal period is about 2 miles where the depth of the water is 24 feet. Excursion varies according to the depth of water; in water of roughly three times the above depth, excursion is about one half.

The normal direction of the tidal flow is approximately at right angles to the coast and has a more or less elliptical excursion. Compared to the strong inshore current that flows parallel to the shore, the back and forth movement of the tide is relatively ineffective in dispersing the larvae in any set direction.

Tidal excursion is important, however, to the fertilization process since it carries released sperm back and forth over the sponge-producing area, greatly increasing the chances of fertilization. Wave action plays a similar role on a much smaller but still important scale.

Semipermanent currents in the Gulf, however, are most important for the wider dispersion of the commercial sponges from their present limited distribution. These are the northward inshore current and four offshore eddies, the latter dispersing the sponges seaward. The current pattern in figure 11 has been modified from the determination of the Gulf currents along the west coast of Florida made by members of the Red Tide Project at the Marine Laboratory of the University of Miami. The distribution pattern of the sponges along the coast north of Tampa Bay coincided almost exactly with what one would have expected to find as a result of these current directions.

The most important single current for sponge distribution at present is the inshore current that lies between the shore and the 50 to 60 foot depths. This current flows more or less parallel to the shore. Current flow was measured by dropping a series of drift cards in the area off Piney Point in the upper Gulf at various distances from shore. In June 1957, drift cards released about 4-1/2 miles offshore in 20 feet of water were picked up south of Alligator Harbor. The rate of flow estimated from these cards was 5 miles per day. Those drift cards dropped 10 miles from land in 35 feet of water were picked up near Panama City; the estimated rate of flow was 8.2 miles per day. Between the time of dropping and the time of recovery the wind was very light, and shore recoveries were made a day or so after the beginning of a strong southerly wind. Depending on the strength and direction of the wind, variations in direction and rate of flow would be expected in water of this depth. The summer current, as measured by the drift cards, is probably fairly consistent since the summer winds are usually light and from the southeast. Majority of the sponge larvae are released between May and August.

The three eddies between Tampa Bay and the Cedar Keys area are between 20 and 25 miles in their greatest diameter where water depths are 50 to 100 feet (fig. 11). Estimated current velocities in these eddies is 1 mile per day.

The most northerly eddy, located south of St. Marks, is 50 miles in its greatest diameter; and since the shoreward side of the eddy is part of the inshore current, the velocity of the northern part of the eddy is similar to that of the inshore current. With the shoreward side of the eddy flowing in much the same direction as the prevailing winds in the area there are times when the velocity of the current in the eddy should increase substantially. The seaward movement of the eddy, off Carrabelle, would retain much the same velocity as the shore current, because much of the water moves Gulfward with the eddy. In the deeper water the offshore current flowing counter to the shore current flows at about 11 miles per day. The northern eddy is by far the most important to both the present and future distribution of the sponges to the deeper water areas of the Gulf.

Several other features of the current pattern over the sponging grounds are important for sponge distribution. In the area just west and north of Indian Rocks, 15 miles north of Tampa Bay, the set of the current is generally shorewards. Lack of commercial sponges in any area upcurrent from Indian Rocks and the constant shoreward set of the current appear to be the primary causes in limiting the occurrence of commercial sponges to the Indian Rocks area and downcurrent from this area. In this case the movement of the permanent current is possibly preventing the spread of commercial sponges to a large area just north of Tampa Bay which is now supporting a very healthy population of noncommercial species and which appears to have all the essential ecological characteristics necessary for the growth of commercial types of sponges.

Lack of active circulation of the water by the semipermanent currents in the area just north of St. Martins Reef Light and Anclote Key may be responsible for the present scarcity of sponges in the shallow water of this area. The few sponges found here on the field trip were all more or less the same size, indicating that larvae had been brought into the area during one or two short periods when the current had swung towards shore. No sponges of less than legal size were seen in the 10- to 25-foot depths north of St. Martins Reef Light.

Calculated Rate of Dispersion

The only way an area can become repopulated naturally by commercially valuable sponges is by the drifting of their planktonic larvae into the area. These larval stages last several days at most (Duboscq and Tuzet, 1937), which limits the distance sponges are dispersed. No work has been done to date with life span of commercial sponge larvae. To calculate the rate of dispersion of the sponges, I have made an arbitrary estimate that the larval stage lasts a maximum of 4 days.

If it requires 4 years for a sponge to mature in the upper Gulf, the annual dispersion rate is approximately equal to the current flow per day during the reproductive season.

STRUCTURE OF THE OCEAN BOTTOM IN SPONGING AREAS

Bottom Slope and Sediment Zones

The composition of the bottom sediments within the sponging area of the Gulf south of Cedar Keys and the slope of the bottom give considerable information with regard to the general type of sponge habitat. Fortunately a detailed report of the area has been made (Society of Economic Paleontologists and Mineralogists, 1955), and most of the following description is based on this report, with specific details added from personal observation.

The bottom west of Tarpon Springs is fairly representative of the entire northern sponging area from Tampa Bay to Carrabelle. The average slope is 2.6 feet per mile. This slope is maintained to the 180-foot depth and comprises the inner shelf.

From the shore to the deeper water, the unconsolidated sediments can be divided into a series of zones roughly parallel to the coast. In the inshore zone, about 20 miles in width, the sediments are relatively uniform in structure, composed chiefly of quartz sand, with phosphorite grains abundant locally. The sediment also contains shell, coral fragments, calcareous algae, and sponge spicules. The quartz particles contribute more than 50 percent to the makeup of these unconsolidated sediments and are for the most part fine to medium in texture, similar to the material brought down by the rivers or found along the shore.

Many local concentrations of medium and coarse quartz and phosphorite sands occur within the shore zone, often mixed with coarse sandy limestone fragments and foraminiferal tests, primarily those of *Archaias angulatus*. The sandy limestone and the fossil foraminiferal tests probably originated from the outcroppings of Pleistocene limestone exposed on the inner shelf. The local concentrations of the above materials are, therefore, those which one would expect to find in the vicinity of the rocky sponging bars.

The zone seaward of the inshore or quartz zone is a quartz-shell zone in which the shell material replaces the quartz in making up more than 50 percent of the sediment. This zone also averages about 20 miles in width but may be only a mile or so wide in parts of the sponging ground further northward. Local concentrations of sediments around the rocky outcroppings are similar to those found in the same areas shoreward. The other constituents of the sediments are similar to those found inshore, with the shell and other sediments of marine origin becoming more predominant seaward. No quartz sand is found seaward of this zone.

Further seaward from the quartz-shell zone the other zones in order are: broken shell, algal sand, oolite sand, and foraminiferal sand and silt. Within the limits of the previously worked sponging grounds (less than 130 or 140 feet in depth) parts of the broken shell and algal sand zones may be found (fig. 12).

The rocky portion of the sea bottom is composed of lithified sediments of cemented lime. These consolidated sediments have been identified as soft marly limestone, sandy limestone, and dense, fine-grained limestone. Much of this material is similar to that found on land. Apparently all the limestones were deposited during the times of the changing sea level in the Pleistocene. Much of the rock outcropping on the sea bottom has been eroded and worn down by physical and biological means. The edges of the outcroppings are usually rounded, rarely rough or jagged, except where there is a distinct edge exposure of a bed of rock. The divers report that along much of the northern coast between the 60- and 70-foot marks, the outcroppings of rock are very rough and "high" (up to 12 feet), supporting little sponge growth.

The unconsolidated sediments form a relatively thin layer over the surface of the rock. The slope of the bottom is so gradual that the waves have little if any effect in moving the sand in any one direction. There is sufficient evidence to show that occasionally during storms wave movements are sufficiently strong to clean off the rocky areas and wash away the sediments from the edges of sponging bars.

The Sponging Bars

Clean exposed rock is essential for the attachment of wool and other species of commercial sponges. The limestone rock bars supporting sponge growth may have areas of a few square feet to many thousands of square yards. Much of the bar rock is at the same level as the surrounding bottom or only a few inches higher. In many cases also the rock has been fractured in two directions roughly at right angles to each other, so that the bars are frequently composed of rectangular-shaped or diamond-shaped pieces 4 feet by 6 feet in size. The appearance depends upon the layer or bed of rock exposed.

The spongers refer to several different kinds of rock bar. Flat bar refers to flat rock usually covered by a thin layer of sand, high rock to a bar made up of smooth rectangularly shaped pieces as described above, which are 2 or more feet above the lowest level of the bar, and rough bar to rock that is jagged. Any bar may be a combination of these types.

Along most of the west coast of Florida, rock bars usually do not rise more than 1 or 2 feet above the lowest level of the bar. This lowest level does not necessarily correspond with the level of the surrounding unconsolidated bottom. The highest rocky reef found along the west Florida coast lies between the 40- and 65-foot depths and extends in a northwest direction from Anclote Key to a point southwest of Cedar Keys, an area approximately 8 miles wide and 50 miles long. On parts of this reef the rock is as much as 12 feet in height, rough, and provides excellent fishing and sponging.

In the shallower water area down to depths of 60 feet the sponging bars are normally surrounded by a growth of eelgrass or marine flora. Bars are usually bordered by a strip of open sand, 20 or more feet in width, which is free from almost all plant growth. The rocky edges of the bars do not support a heavy growth of marine animals or plants, and there is considerable evidence to show that these edges

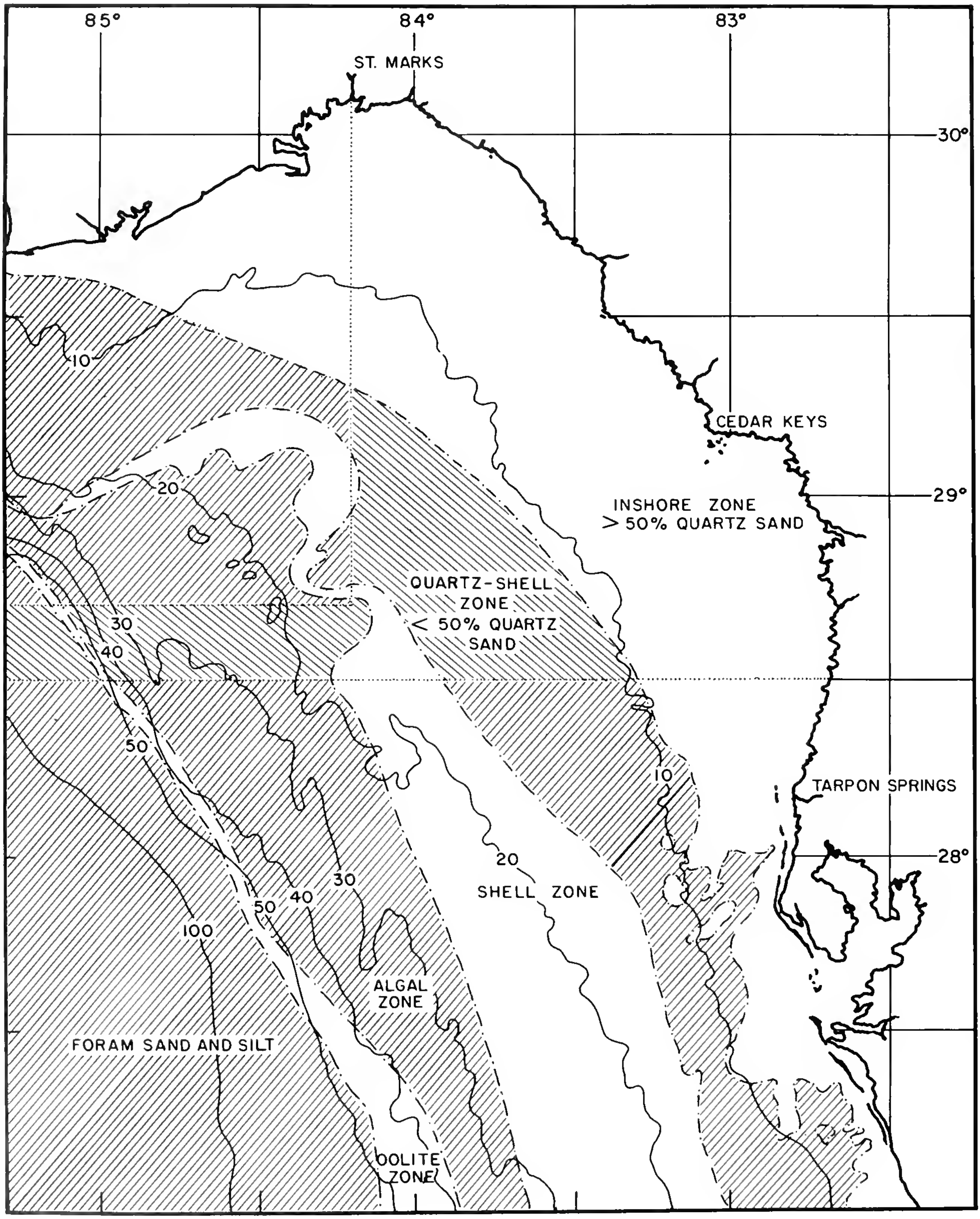

Figure 12.--Sediment zones of the upper Gulf of Mexico off the Florida coast, based on the Society of Economic Paleontologists and Mineralogists (1955). Enclosed area starting at Cedar Keys area extrapolated.

are periodically covered with sand. This sand tends to kill off many of the attached animals and plants. The edge of the bar is a particularly favorable zone for the setting of wool sponges and is the area the spongers work most intensively. Toward the central portion of the bars or where individual sharp-sided rocks are to be found, the surface of the rock is covered with a heavy population of sponges and other types of attached animal and plant life.

Sponging Bars in Relation to Surrounding Bottom

Contrary to the ordinary concept of submarine rocky outcroppings, many sponging bars are not above the general level of the surrounding bottom but actually anywhere from a few inches to as much as 6 feet lower. This phenomenon is of considerable assistance to the sponge fishermen. In deeper or slightly murky water where it is impossible to locate a bar visually, sounding leads are used. In most cases the sand sample brought up by the soaped-end of the lead gives the necessary information about the closeness of a rock outcropping. In many cases, however, a sudden deepening of the water is indicative of the presence of a bar in the immediate area; and if two sounding leads are being used, a deeper sounding on one side is sufficient indication to tell on which side of the boat the bar is to be found.

A series of echo sounding recordings was obtained in the upper Gulf. These recordings show graphically and in condensed form the bottom contours near the sponge or fish bars.

Figure 13 shows five selected sonic recordings of the bottom contour. Figure 13a is the tracing of echoes off a fairly flat bottom, taken while we moved from the shore towards deeper water. The grassy bottom with the soft underlying fine sediment material gave an echo that caused a wide recording on the tracing. In the center portion of the recording, the echo trace is narrow, thus indicating hard bottom. This rocky bar was unusually flat, and very little plant or animal life of any kind was to be found on this bar area.

In the second tracing three bar areas are shown (fig. 13b). On the extreme left is a tracing of high rock.

The next three tracings of bars in deeper water show the effect of the softer sediments found at these depths in the area southeast of Piney Point. A much thicker line is made by the echoes off these softer sediments covered with marine vegetation. In the central portion of the third tracing, a very rough rocky bar is indicated by the jagged thinner tracing fig. 13c. On the fourth tracing a rough rocky bar is recorded (fig. 13d). The last recording shows most clearly the edges of the bar in the central portion of the tracing. These bars were 4 to 5 feet below the general level of the bottom.

I consulted a number of oceanographers, who agreed with me that the bars lying below the general level of the bottom remain free of silt only because of wave action. Over open bottom the heavy growth of eelgrass and other marine plants and the flatness of the bottom offer very little resistance to the movement of the water so that little turbulence is developed. During diving I observed that the water among the bases of the plants moved little if at all with the motion of the waves. Over the rocky bars, however, the many larger growths of coral, sponges, and other bottom animals, as well as the irregularities of the bar itself, create considerable turbulence during the passage of the waves.

Examination of many bars leads to the conclusion that during long periods of calm weather the bars are gradually encroached upon by the finer sediments normally held in place by the mat roots and rhizomes of marine vegetation. Eelgrass is known for its role as a sediment trap. During heavy wave activity from storms or the passage of hurricanes through the Gulf as observed in October 1956, turbulence over the bar areas results in the uprooting of quantities of marine plants and the shifting of large amounts of sediment, as a result, some parts of the bar areas are uncovered while others are laden with sediment.

Sediment Distribution Across the Bar

The bar areas support not only sponges, but also populations of animals and plants that form calcareous shells or skeletons. Most

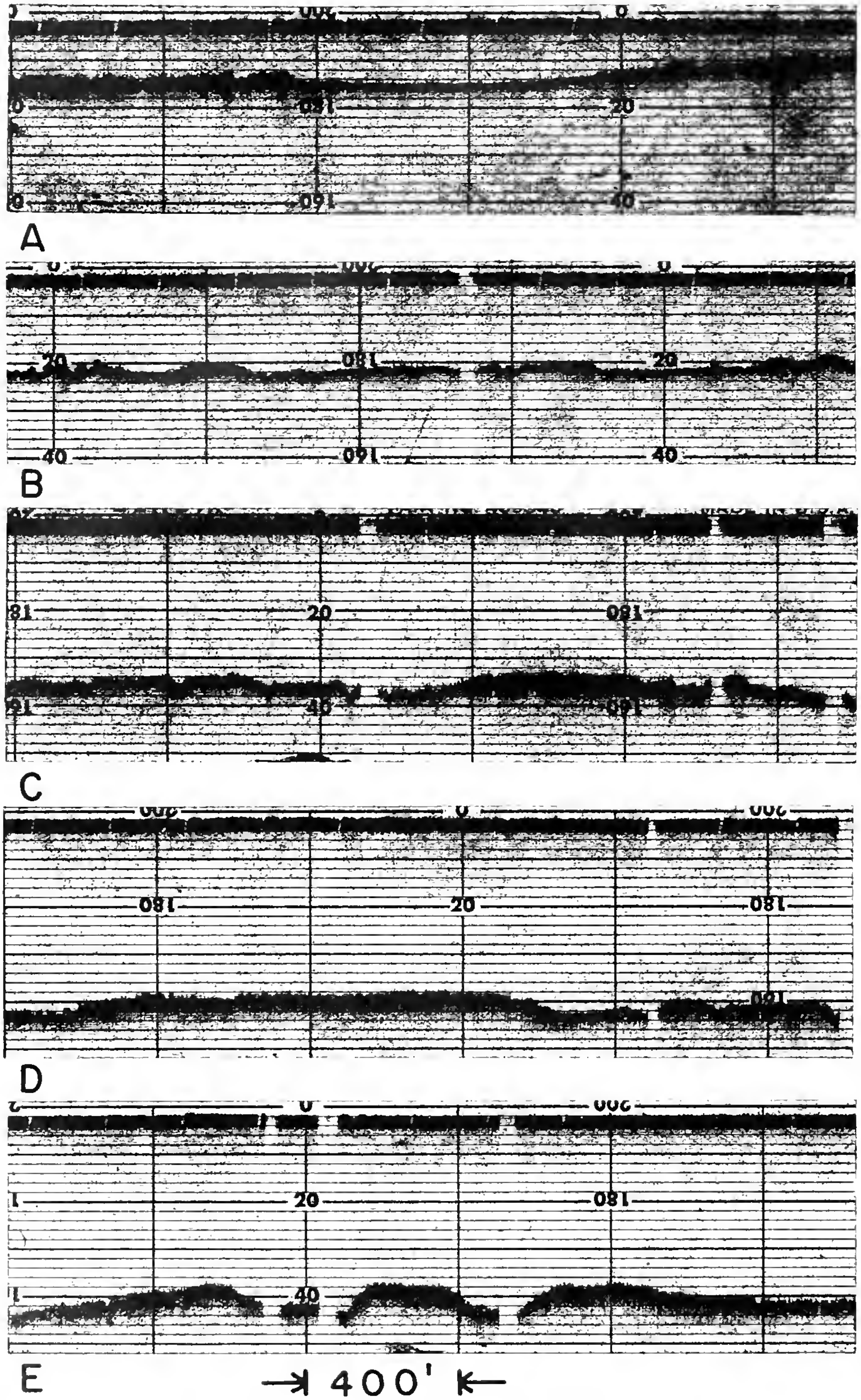

Figure 13.--Echo sounder tracings made during investigation to show typical sponge bars. Each section between the vertical lines represents a distance of about 400 feet. Individual tracings explained in text.

important of these are the corals, *Solenaster hyades*, two species of *Oculina* coral, and various species of the alga *Halimeda*. The clam, *Arca zebra*, is also important for it is found attached in great quantity on the bar rock, and on some bars is of importance for the attachment of wool sponges.

Calcareous sediments form from the breakdown of these corals and the various animals that live on the central parts of the sponge bars. Sorting of these sediments is brought about by wave activity, and there is a gradation of the sediments from coarse to fine from the central areas of the bars to the edges.

To assess the effect of the large production of calcareous material in the loose sediments, series of sediment samples were taken at evenly spaced intervals from the central part of the bar area to the edge. The results of two such series, one selected from an isolated bar in 25 feet of water off Piney Point and the other from a bar in 16 feet of water off the mouth of the Aucilla River, represent the extremes of the samples taken (table 6).

Samples from the central portion of the bar had large percentages of the sediments over 0.5 mm. in size. This coarse material was made up primarily of fragments of coral, mollusk shells, sea urchin tests, and other skeletal remains. Toward the edge of the bar and in the grassy area around the bar, the sediment size was finer. The sample series from the isolated bar shows the effect of the shifting of the finer sediments, principally quartz particles, onto the bar area. This particular series was taken after very rough weather which upset the normal sorting action described above.

The series of samples taken from a bar in a very rocky area off the Aucilla River reflects the effect of the addition of large amounts of calcium to the sediments in the area. In this case the sediment sample taken from the grassy region off the bar area contains more calcareous material than did the central part of the bar in the series from Piney Point.

Although much variation in sediment distribution across a bar is to be expected, the sample series from the Aucilla River area indicates the importance of a bar area in the production and addition of calcareous material by animals and plants to the unconsolidated sediments. This was apparent from visual observation of the sediments.

ECOLOGICAL RELATIONSHIPS

Salinity Tolerances of Sponges

Little is known about the salinity tolerances of commercial sponges other than wool sponges. A number of wool sponges shown to me by divers had lost most of the living material, leaving the remainder of the sponge with clean skeletal fibers. The divers attributed the dying of the sponges to "fresh" water. Such sponges were not more than normally odoriferous, but there were no signs of decay or disease even when examined microscopically. Such sponges are commonly found west of the mouth of the Suwannee River in the area where fresh-water discharge would be expected. Salinity data from the Red Tide Cruise of June 1956, carried out by the Marine Laboratory of the University of Miami, show salinities as low as 27.7 ‰ , in this area extending as much as 5 miles from land.

In October 1956, during a sponge investigation field trip to the area just north of the Steinhatchee River, a large number of sponges appeared to be affected in much the same way as those off the mouth of the Suwannee River. Later the hookers and divers reported that large numbers of wool sponges in the shallow water zones from Piney Point to St. Marks had been killed. There was every indication that the destruction of the wool sponges was related in some way with a tropical storm which had passed northward through the New Orleans area a few days before. Tagged sponges at one of the buoyed stations were examined and found healthy before the storm. Seven days later they were dying off. Within this period the Steinhatchee River (fig. 10) had begun to flow for the first time in 4 years; the initial flow was particularly strong, following exceptionally heavy rainfall.

Water samples from St. Marks to Steinhatchee taken 6 days after the beginning of the outflow showed lowered salinities throughout

Table 6.--Percentage occurrence of sediments according to particle size and percent calcium content in sediment samples from sponge bars

Particle Size	Samples from bar at Piney Point[1]				Samples from bar off Aucilla River[1]			
	1	2	3	4	1	2	3	4
0.5 mm..................	32.7	9.7	5.2	4.4	59.2	43.9	22.6	19.4
0.25 mm.-0.5 mm.........	39.6	23.9	24.8	68.0	20.7	24.5	25.7	27.9
0.125 mm.-0.25 mm.......	27.3	64.4	67.4	26.3	17.4	24.9	47.9	45.5
0.125 mm................	.3	1.9	2.4	.3	2.6	6.5	4.8	6.6
Percent calcium.........	15.2	7.8	6.6	6.6	66.8	57.9	33.8	23.8

[1] Numbers refer to samples taken at evenly spaced intervals from the central part of the bar to the edge.

the area. With normal salinities above 36 ‰, the samples showed that salinities just above 33 ‰ were common. One salinity was 31.04 ‰ .

In addition to the mortalities of the wool sponges, almost all of the *Styela plicata* tunicates had died as well. Since these are notably intolerant to lowered salinities (Van Name, 1954), I believe that water conditions were the cause of the wool sponge deaths. With the exception of two or three noncommercial sponges, very few other sponges and sessile animals showed any adverse effects.

There is a possibility that the first heavy outflow of the river may have moved shorewise as a parcel of low salinity water which would have been dispersed or mixed only after a number of days. The time lapse between the first outflow and the sampling would have allowed sufficient time for the lowest salinity water to have moved out of the sampling area.

Moore (1910b) in his experiments with cultivating sponges at Anclote Key determined that salinities of 27.5 ‰ were detrimental to wool sponges while salinities of less than 26 ‰ were lethal. In the Bahamas, W. Smith reported that salinities of less than 32 ‰ are very harmful to sponges; however, his cultivated sponges were in water less than 6 feet deep in a very different ecological situation.

Elevated temperatures also have detrimental effects on wool sponges, and it is probable that the combined effect of elevated temperatures and salinities not quite as low as 26 ‰ would be lethal.

The commercial sponges appear to be able to withstand very high salinities. The salinity of the water over the Andros banks, a sponging area in the Bahamas, is often as much as 46 ‰ .

Temperature

Temperature effects on wool sponges observed during the present investigation are:

1. There is an optimum temperature range in which wool sponges produce eggs in quantity.

2. There is a clinal effect on the size of the wool sponges producing eggs.

3. Sudden changes in temperature cause withdrawal of the living tissue with regression in size.

The first two of these temperature relations were discussed previously in the section on reproduction.

From the evidence at hand, commercial sponges appear to have a tolerance range from as low as 50° F., as observed during the study, to at least 95° F. (W. Smith, personal communication).

During the laboratory experiment carried on from September 1955 to June 1956, a number of yellow sponges and wool sponge cuttings were maintained in salt-water aquaria and the effect of changes in temperature on these specimens was observed. Photographs of these sponges were made at 2-week periods and later at monthly intervals until the experiment was terminated by the sponges' dying during an accidental stoppage of the water flow.

The effect of temperature on growth is shown by a series of photographs of a whole yellow sponge (fig. 14). The first of these photographs was taken within 4 days after the sponge had been taken from the sea and placed in the aquarium. At that time the temperature range over a period of a week was between 80° F. and 85° F. The appearance of the sponge at this time was normal.

The second photograph was taken in December, almost 3 months from the time the sponges were placed in the aquaria. During this 3-month period the temperature had gradually decreased to 70° F. Observations made on the sponge at this time showed that there had been an increase in size of almost one-quarter of an inch in diameter. This increase in size was made despite the necessary healing of the sponge base, the change to a much different environment in the aquarium, and probably a lowered food supply.

The third photograph of the series shown was taken a month later in January 1956, 6 days after the temperature had dropped from 70° F. to 62° F. within a 6-day period. This sudden drop in temperature was the apparent cause for the very considerable withdrawal of living material from the periphery of the sponge. This withdrawal amounted to more than one-quarter of an inch in places. Close examination of the sponge at this time showed that the "skin" was as healthy at this lower level as before, and the only apparent change was the exposure of the ends of the spongin fibers. The photograph shows clearly that the bared fibers are light in color while in places the healthy "skin" of the animal shows through as black. Within a few months the exposed fibers rotted away and the sponge again appeared normal but reduced in size.

Similar, but not as severe, withdrawal of tissue inward has been observed during the field studies (fig. 17, p. 50) and in preserved material collected in the winter. A number of sponges have been taken which had the fibers of the conules exposed for one-eighth of an inch or more.

When the temperature is 80° F. to 90° F., sudden increases in temperature have been reported by F. G. Walton Smith to be detrimental to commercial sponges.

Effect of Water Currents on Sponges

Mean tidal flow along most of the coast in water depths of 24 feet is about one-half of a knot. The rate of flow is affected by bottom contour and modified considerably by the rate of flow of the inshore current which travels at a rate of at least one-third of a knot in water of a 40-foot depth.

Commercial sponges grow well in water currents with this rate of flow. In areas, such as at Indian Rocks, a current of 2 knots or more may be responsible for the rapid growth of some sponges and other bottom inhabitants. Wool sponges in this area were not affected greatly except that the conules were longer and the oscules higher, up to 2 inches in height. These sponges had heavy overgrowths of tunicates and algae which distorted their shape, and at times were deformed by the crowding of other sponges on the bar.

The grass sponges in this strong tide area were growing in conical rather than vase shape, with the central portion completely filled in. This was true also of the same species of sponges in the Cape Romano area where strong tides were found. These grass sponges were soft in texture and commanded a higher price than other grass sponges on the market, having a texture and use comparable to the finest Mediterranean sponges.

There is a noticeable change in the appearance of wool sponges from water of less than 12 feet to those sponges from 40 and more feet in depth. Sponges from shallow water have up to twice as many conule tufts per square inch. The oscules of wool sponges from shallow water are as much as 1-1/4 inches wide while those from the deeper water are rarely more than three-quarters of an inch wide and usually less. Only slight differences were found in the actual weight to volume ratio from the different depths, the shallow-water sponges being lighter. There was a noticeable difference in compressibility and strength of fiber;

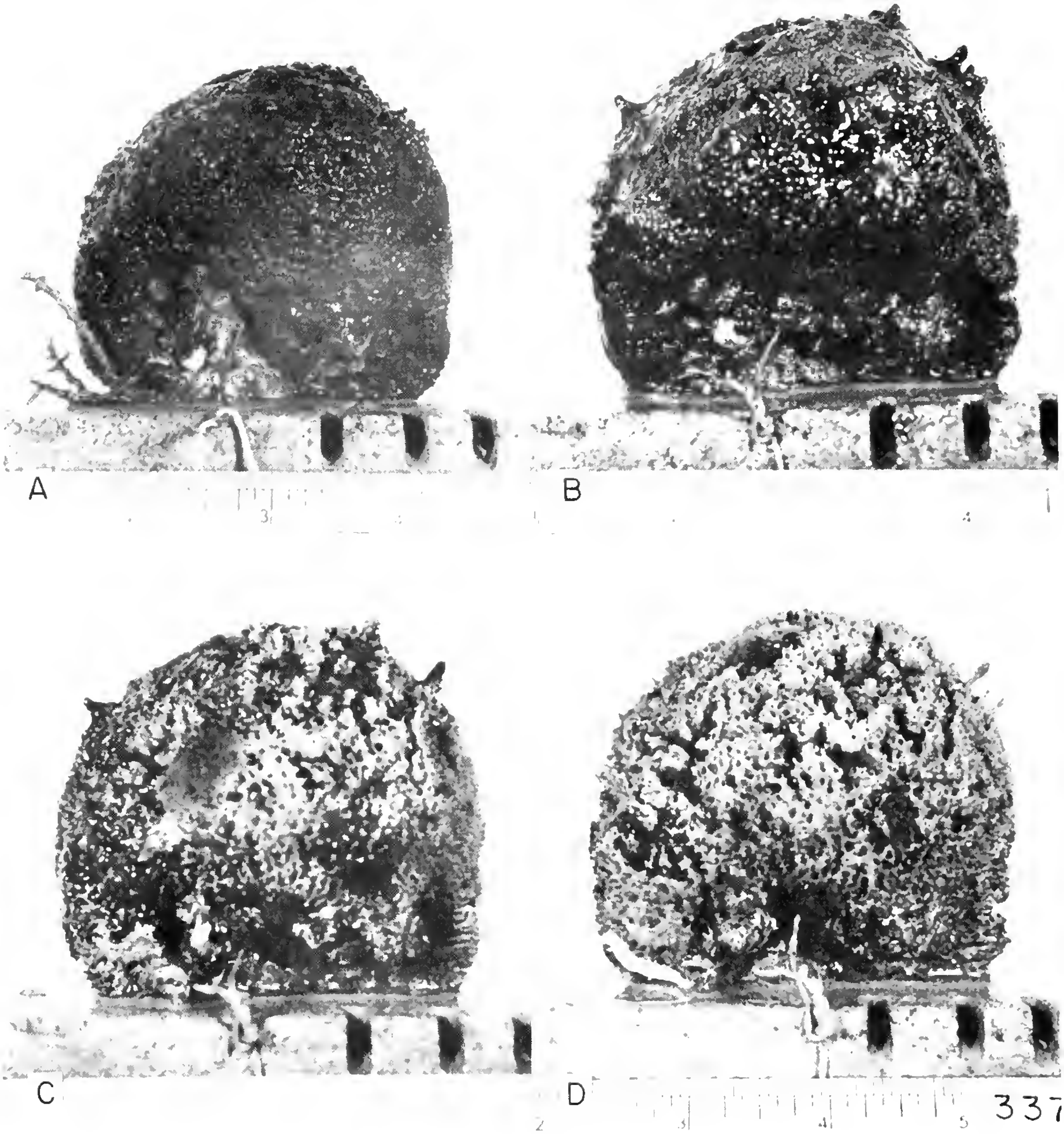

Figure 14.--Effect of temperature variation on a yellow sponge maintained in an aquarium with running salt water. a. A few days after being put into aquarium. b. Three months later with 1/4-inch increase in diameter. c. Withdrawal of living material and baring of spongin material, 6 days after a rapid fall in temperature. d. Two months later, with spongin beginning to slough off.

compared to the deeper water sponges the shallow-water wool sponges are very soft and weak. A study of the microscopic structure of the fibers shows that fibers from shallow-water sponges are finer and more loosely connected than those taken from sponges that grew in deeper water.

Competition for Space

Two methods of evaluating bottom populations were attempted: (1) measuring the concentration in small quadrants using general groupings of attached animals and plants and (2) a more extensive study identifying plants and animals in defined bar areas.

In the first study the bottom flora and fauna in a number of 10-foot squares were evaluated quickly using an arbitrary method of division of the bottom growth into groups (table 7). Since loggerhead sponges are generally over 1-1/2 feet and up to 3 feet in diameter, these sponges are listed separately as one group. The average size of the other sponges is between 4 and 6 inches. The concentrations for each area are also divided into two regions--shallow-water, less than 21 feet, and deeper water, more than 21 feet.

There seems to be no direct connection between a heavy bottom population and the concentration of wool sponges. Rather it is the indirect effect of concentrations of bottom animals, which provide a sediment trap that excludes the wool sponge from most areas of higher concentrations of animals. This sediment is reduced or almost entirely removed only during stormy weather, the heavy wave action cleaning off the edges of the bar at the same time and making these areas available for wool sponges.

Animals and Plants Associated with Wool Sponges

In addition to those animals and plants intimately associated with the wool sponge as cohabitants, there is a considerably larger group of sessile forms found on the adjacent bottom forming an ecological group to which the wool sponge belongs. To determine this group, collections of the sessile plants and animals were made at each of the shallow-water stations of the first two major field trips. We intended that these collections would establish a record of bottom forms by area rather than by stations. Sponges were the only group for which complete occurrence records

Table 7.--Typical concentrations of animals and plants in 10-foot squares on rock bars

Area[1]	Sponges		Alcyonarians	Sessile mollusks	Sea squirts	Algal plants	Corals	Millepora
	All[2]	Loggerhead						
A: <21'	1	4	4	16	12	25	6	0
>21'	12	1	5	28	34	30	2	0
B: <21'	13	4	10	24	20	43	0	0
>21'	8	1	3	40	35	6	2	0
C: <21'	27	6	5	3	2	8	0	0
D: <21'	23	3	8	8	9	17	0	0
>21'	21	2	24	20	16	28	3	0
E: <21'	4	1	8	3	2	3	3	0
>21'	58	2	21	35	41	18	3	0
F: <21'	15	2	7	4	0	8	2	0
G: <21'	2	0	25	0	0	9	4	3

[1] Areas are given in appendix.
[2] All sponges except loggerheads since these are three to six times average size of other sponge species.

were attempted. In other groups of animals and plants only those most commonly occurring were regularly collected and/or recorded.

Twenty-three sessile animals and plants were recorded 25 percent or more of the time as being found growing on the same bar as the wool sponge (table 8). Of these, 10 were found at 50 percent or more of these same stations. These 23 animals and plants represent the basic ecological group associated with the wool sponges. Where wool sponges are absent, the presence of this group will possibly indicate an area where ecological conditions are favorable and into which wool sponge might be transplanted successfully.

If suitable substrate is limiting the attachment, it might be practical to use "cultch." The cultch would have to be of a fairly large size to hold the sponges firmly on the bottom.

Several sponges were found only once or not at all on the same bar with wool sponges. This appears to be of no significance and seems to indicate either their scarcity or the fact that they were overlooked at other stations. These sponges were: *Callyspongia arcesiosa, Neopetrosia longleyi, Aulena columbia, Fibulia massa, Higginsia strigilata.*

Total Sponge Species and Their Distribution

Counting both those sponges collected in the Keys area and the west Florida coast, we collected and identified 83 species in 58 genera (table 9). This is only a part of the collection record of a large number of plants and animals. These data will be published elsewhere. The major portion of the identification of the sponges was made by Robert Work, who assisted during the first year of the

Table 8.--Record of association with wool sponges, by percentage of stations

	25 percent to 50 percent of stations	50 percent or more of stations
Sponges:		
Darwinella mülleri	X	
Ircinia campana		X
Ircinia fasciculata		X
Ircinia strobilina		X
Spongia graminea	X	
Verongia longissima	X	
Callyspongia vaginalis		X
Microciona juniperina	X	
Axinella polycapella		X
Spheciospongia vesparia		X
Geodia gibberosa	X	
Sea whips and feathers:		
Antillogorgia acerosa		X
Eunicea sp.	X	
Leptogorgia virgulata		X
Pterogorgia guadelupensis	X	
Corals:		
Oculina robusta	X	
Oculina varicosa	X	
Solenaster hyades	X	
Mollusks:		
Arca zebra		X
Sea squirts (tunicates):		
Clavelina gigantea	X	
Styela plicata		X
Algae:		
Avrainvillea levis	X	
Sargassum filipendula	X	

Table 9.--Distribution of sponges by area from collections made in 1955-57 off the Florida coast

[*indicates probable new species.]

UMML No.	Sponge species	Area[1]					
		A	B	C&D	E	F	G
	Porifera - sponges:						
	Order - Keratosa:						
	Aplysilla sulfurea		1	1	1	T1	
	Aulena columbia	T[2]				1	1
	Darwinella mülleri	T	5[3]	1	1	2	1
	Dysidea crawshayi			2	2	T1	
	Dysidea etheria						1
4.247[4]	*Dysidea* sp.*				1	1	
	Hippiospongia lachne	T4	4	6	3	2	1
	Ianthella ardis	1	2	3	2	2	T
	Ircinia campana	T5	11	7	10	T7	T8
	Ircinia fasciculata	T3	9	3	2	T1	T7
	Ircinia strobilina		1	5	2	T3	T9
	Spongia cheiris			2			3
	Spongia anclotea			2			
	Spongia graminea						3
	Spongia graminea tampa	T2	4	1	1	1	
	Spongia sterea			1	1		T
	Spongia barbara	T2	1	1			1
	Verongia fistularis	1	1	1	1		
	Verongia longissima	T1	3	3	5	1	T1
4.257[5]					1		
	Order - Haplosclerina:						
	Callyspongia arcesiosa				1		
	Callyspongia sp.*						1
	Callyspongia vaginalis	T2	5	5	2	5	T6
	Dasychalina cyathina						T1
	Fibulia massa				1	T1	
	Fibulia nolitangere						T1
	Haliclona rubens			2	1	2	T5
	Haliclona subtriangularis		1	1		2	
4.280[7]	*Haliclona* sp.*						1
	Haliclona variabilis	1	1	2	1	2	5
	Haliclona viridis	T1		2	4	2	T3
	Iotrochota birotulata						T1
	Neopetrosia longleyi			1	2	T3	3
4.282	*Patuloscula procumbens*						1
4.251	*Xytopsene sigmatum*			1	1		
	Xestospongia muta						T2
	Order - Poecilosclerina:						
4.275	*Agelas* (?) *conifera*						1
4.246	*Allantophora* sp.*				1	1	

See footnotes at end of table.

Table 9.--Distribution of sponges by area from collections made in 1955-57 off the Florida coast--Continued

[*indicates probable new species.]

UMML No.	Sponge species	Area[1] A	B	C&D	E	F	G
4.252	*Axociella spinosa*			1		1	
	Desmacella pumilio					1	
	Lissodendoryx isodictyalis		1	2	2		
4.274	*Lissodendoryx* sp.*			1			
	Merriamium tortugasensis	1	5	1			
4.284[8]	*Microciona juniperina*	1	3	2	2	2	1
	Mycale angulosa			1			T3
	Tedania ignis			2	3	1	2
	Thalyseurypon vasiformis	T1	1	3	4	2	
4.265	*Toxadocia* sp.*				1		
4.256	*Toxemma tubulata* (?)					1	
	Xytopsues griseus			3	3		T
4.259[5]						1	
	Order - Halichondrina:						
	Axinella polycapella	T1	7	3	6	T2	T1
4.249	*Axinella* sp.*				1		
4.271	*Axinella* sp.*				1		
	Halichondria melanadocia						1
	Higginsia strigilata		1		1		1
	Homaxinella rudis	2	1	2	1	T1	1
	Homaxinella waltonsmithi	T1	4	1	2	1	
4.253	*Hymeniacidon heliophila*				1		
4.261[9]	*Thrinacophora funiformis*					1	
4.255	*Trachyopsilla* sp.*			1		1	
	Order - Hadromerina:						
4.279	*Aaptos aaptos*						1
	Aaptos bergmani			1		1	
	Anthosigmella varians	T	3	3	4	T4	8
	Cliona caribboea	T1	1	1	4	3	
4.269	*Cliona lampa*	T	3		1		T
4.262	*Cliona* sp.*				1		
	Placospongia melobesioides				2	1	T
	Spheciospongia vesparia	T3	7	3	7	T4	T10
	Spirastrella coccinea	T1	1	1	1		
4.260	*Terpios fugax*				1		
	Order - Epipolasida:						
	Cryptotethya crypta		3	2	5		
4.270	*Epipolasis angulospiculata*				1		
4.268[10]	*Stellettinopsis detostea*		1				
	Tethya actinia						1
	Tethya diploderma	1	1	3	1	1	T
	Trachygellius cinachyra	1		1			

See footnotes at end of table.

Table 9.--Distribution of sponges by area from collections made in 1955-57 off the Florida coast--Continued

[*indicates probable new species.]

UMML No.	Sponge species	Area[1] A	B	C&D	E	F	G
	Order - Choristida:						
	Cinachyra cavernosa	1	1	3	3	1	T
4.263	*Cinachyra* sp.*				1	1	
	Geodia gibberosa	T1	4	3	4	2	T1
	Myriastra debilis				1	1	
4.272	*Myriastra kallitetilla*					1	1
	Stelletta grubii	T1	1	1	1		
	Unimia trisphaera	T					1
	Order - Carnosa:						
	Chondrilla nucula	1	1	1	1		

1 Total number of stations per area: Area A, 10; area B, 13; area C & D, 9; area E, 14; area F, 8; area G, 11.

2 T indicates that this species was only taken by Tierney during the Marine Laboratory Gulf of Mexico Expeditions in 1947 and 1948 (de Laubenfels, 1953).

3 The numbers in the area columns indicate the number of stations in the area at which the sponge was taken and recorded.

4 UMML (University of Miami Marine Laboratory) numbers are catalog numbers of specimens and indicate those specimens identified by Willard Hartman. These sponges are preserved in the museum collection. The identification of a number of other species was confirmed by Hartman.

5 Specimens indicated by UMML numbers 4.257 and 4.259 could only be identified to family and order.

6 UMML number 4.278 was identified as *Callyspongia* near *ramosa*, a sponge found in the waters of Australia and New Zealand but not as yet described from Florida or the West Indies.

7 UMML number 4.280 in *Haliclona* near *simulans* a sponge most like the European *simulans* and likewise not as yet described from Florida and the West Indies.

8 UMML number 4.284, *Microciona juniperina* is a very common small bright red sponge which is found in a number of forms, either uniformly ramose or leaflike. At least eight form variations were collected and are represented by separate specimens in the museum collection. When it is possible to collect a large enough series of these forms, several species may be identified.

9 UMML number 4.261 is *Thinacophora funiformis*. This record may be the first since it was originally taken by the Challenger Expedition off Bahia, Brazil.

10 UMML number 4.272, *Stellettinopsis detostea* has heretofore only been recorded from Bermuda waters.

investigation. Any sponges that could not be identified readily or about which the identification was at all doubtful were sent to Willard Hartman, of the Peabody Museum of Natural History. The preliminary but detailed examination of the specimens submitted to him indicates that at least 13 probable new species of sponges were collected (table 9).

A comparison was made between the species of sponges collected during the present investigation and those recorded by the 1948 survey of the sponge beds and identified by de Laubenfels (1953). In the northernmost range, area A, only four of the stations reported in the 1948 survey lay within the same general area as that of the present investigation. Twenty-four species of sponges were collected in area A in 1948. Of these, 18 were retaken in the same area during the present survey, with all but 4 of the 24 being recorded from other areas. The velvet sponge was one of these four, while the other three were similar to those described by de Laubenfels as being new species taken for the first time.

In the Florida Keys and Ten Thousand Islands areas, 35 species of sponges were recorded by the 1948 survey. Seven of these, were not taken during the present survey, and three others were taken but not in these areas. Of the 59 identified species collected by us, 34 were different from those recorded in 1948 in the same areas. In all, 11 species taken by the 1948 survey in the same general areas explored by the present investigation were not recorded as being taken a second time.

The temperatures are based on the nearest permanent tide station data. Check of the cruise data of the Red Tide project at the Marine Laboratory indicates that temperature data are accurate for the areas indicated.

In table 10 the lesser number of species recorded from area A may be partly due to the fact that although very intensive work was done, only a few bars were surveyed. The population make-up of individual bars will vary greatly even within a limited area, and it would therefore be necessary to examine a large number of bars to obtain a true population sample.

In area F the several stations southwest of the Cape Romano buoy yielded a number of sponges which could not be identified with certainty. These stations were in an area where the flow of the tidal current was strongest. Generally speaking, the sponges found at these stations were growing more profusely, the shape and texture varying greatly from that of the same species in zones where the tidal flow was less. These differences in shape, texture, and internal structure (purely ecological variations) made identification of many of the species difficult.

Sponges recorded from area G represent those species collected in the upper Keys from Miami to Plantation Key. The combination of the collections made in areas F and G were used to make the comparison with the 1948 collection from the Key West and Ten Thousand Islands areas.

Area G is the only ecological zone that differs physically from all the others. This area is the coral reef zone of the upper Keys, and the slope of the bottom, nearness to land, and proximity to the Gulf Stream and deep open ocean set this zone apart ecologically from the others. The lesser number of species found indicate that this is an unfavorable habitat for many sponges.

A comparison of the number of species in each area with the yearly mean temperature (table 10) suggests that the optimum water temperature for the growth and existence of most species of sponges is about 75° to 76° F. Of greater importance ecologically than the mean temperature of an area is the temperature range. There is a difference of 52° F. between the lowest and highest recorded monthly temperature in area A while the difference is 35° F. in area F. In addition, as indicated by a study of yearly weather conditions, there is far more likelihood of sudden changes in area A than in area F. In the case of Florida sponges, (1) some species are incapable of reproducing effectively in colder water, (2) the mature sponges are killed by sudden water temperature changes, and (3) the prolonged low water temperatures of the winter found in the northern Gulf kill the sponges or drastically deter growth.

Sponging Grounds and Zones

A full description of individual productive sponge beds has been made by Moore (1910a). Little can be added to that description as the names or areas have not changed appreciably.

Table 10.--Distribution of species by number in each area

Area	A	B	C&D	E	F	G
Number of species	29	34	45	53	44	37
Lowest monthly mean water temperature - °F[1]	56.5	59.7	[2] 62.5	65.3	71.8	71
Yearly mean water temperature - °F	71.4	72.4	73.5	75.6	79.6	78.5

[1] Based on U.S. Department of Commerce Special Publication No. 278.
[2] Average between Cedar Keys and St. Petersburg recordings.

The present most important sponging area extends from Anclote Key to St. Marks, a distance of about 200 miles. From Piney Point north to St. Marks the present Florida law states that the diving boats cannot work within 10 miles of land and are limited to working in water depths of more than 3-1/2 fathoms between Tampa Bay and Piney Point.

The entire sponging area along the Florida coast has been divided by the spongers into smaller regions, the sponging grounds (fig. 15). The primary reason for this division is the practical necessity of being able to designate the particular area in which a boat is to work or has worked. In part also this division serves to delineate individual sponging grounds that differ ecologically. Different grounds possess varying types of bottom and produce distinct ecological types of sponges. Sponge fishermen claim that the appearance and feel of a sponge indicates to them what part of the sponging area it was taken, within a 10-mile section of the coast. Differences in appearance of sponges from various localities are certainly apparent, even to the inexpert eye. At times the division of the area into grounds also carries with it a connotation of texture and quality; for example, the term "Rock Island" (wool) sponge is equivalent to a grade of sponge and is used as a marketing term.

For ease in analysis of various factors on the sponge beds as a whole the grounds have been grouped here as areas (fig. 15, detailed description in appendix).

Only limited portions of all the total sponging area, except area F, have concentrations of sponges comparable to those found before the first disease period, 1938 (table 4). The importance of each of the areas to the industry cannot, however, be judged alone by the concentration of the sponges. Quality of the sponges is also important, for it is often better to take fewer sponges of higher quality than more sponges of lower quality. Generally speaking the quality of the sponges is better in areas A, B, and C. South of these areas, the sponges are progressively more open-textured and weaker. This is true of both the wool and the grass sponges. In area F off Shark River, for example, the sponges have a much lighter texture and less desirable shape than those from area A (Rock Island). A load of sponges from area F may have only two-thirds the value of the same quantity from area A. Grass sponges from the Florida Keys generally are of poor quality and may only command a third of the price of those taken at Anclote Key.

On the other hand, the Florida Keys glove sponge is of much better quality than those found off Anclote Key. The range of this sponge is from the Florida Keys area to just south of Cedar Keys. At the present time the concentration of the glove sponge is much higher in the Keys area than at its more northerly limits.

Depth Zones

The sponging areas may be divided into three distinct depth zones:

Shallow	40 feet and less
Middle	41 feet to 80 feet
Deep	81 feet to 120 feet

The shallow zone (fig. 15) is the only area now worked extensively by the sponge fishermen. During 1956 some good-sized sponges were taken in water as deep as 55 feet, and as indicated by the deep-water survey of the present investigation, some quantities of wool sponges occur in limited areas in water as deep as 80 feet.

The Florida State law limiting the sponging depths of the diving boats was drawn up by the Florida State Conservation Department as the result of an agreement between the hook boat spongers and the diving boat crews.

The hook boats usually work in water of 20 feet or less, and the diving boats, because of the age and physical condition of the divers, rarely work in more than 40 feet. Most of the diving is done in the 20- to 30-foot zone.

Most of the yellow, grass, and glove sponges are found in the shallow water. The shape of the wool sponges in this zone is somewhat more flattened than those from deeper water, the ratio of the diameter to height varying from 2 : 1 to 4 : 3. Those wool sponges growing

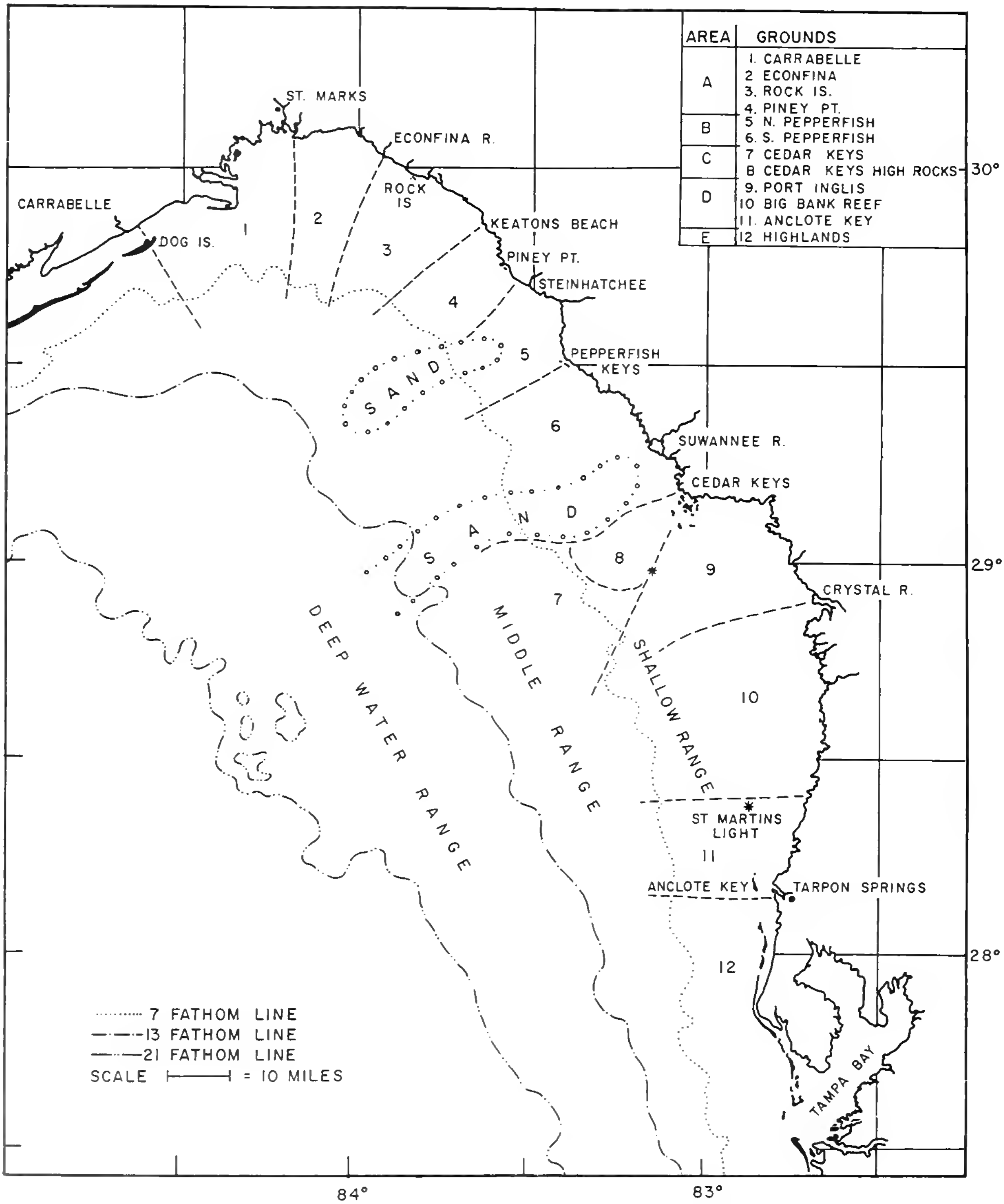

Figure 15.--Sponging areas of the upper Gulf of Mexico (see appendix for details).

in less than 10 feet are often deformed by their close proximity to other bottom-growing forms or have algal plants, bryozoans, or other animals growing on the surface. In addition the texture of the sponge fibers is more open and the oscules larger.

In the middle zone no glove or grass sponges are to be found. Considerable quantities of yellow sponges were formerly found in the middle zone along with wool and wire sponges. Now majority of the yellow sponges appear in shallow water. In the middle zone the best areas for wool sponges was formerly in the 60- to 80-foot depths. The wire sponge is normally not found in the shallow water but occurs in water of 40 feet or more. Wool sponges in the middle zone are usually slightly taller with a ratio of diameter to height of 1 : 1 or greater. The texture is also fine, and the shape well rounded, so that sponges from this depth or greater have always brought a good price.

In the deep water the best production was found at the 85-foot and 100- to 110-foot depths. The importance of this zone, as a sponge producer before the disease of 1938, can be estimated from reports of the daily take of sponges. It is said that up to one thousand pieces of wool sponges were taken per day of effort. Five divers were used in rotation in this depth, each diver remaining only about 15 minutes on the bottom. The quantity and size of the sponges made such methods profitable. Deep water produced the best grade of sponges, with an estimated 12 to 18 inches average diameter, some considerably larger. The sponges were wider near the top than at the bottom, and the estimated ratio of diameter to height would have been 3 : 4 or 3 : 5 or greater. In deep water large 3-foot wire sponges were also seen in quantity but never taken because of their very low value.

DISEASE, PARASITES, AND EPIZOICS

The 1938-39 Sponge Disease

Some of the earliest reports of sponge losses are recorded by Rathbun (1887), who lists heavy losses during the years 1844, 1854, 1878, and 1890. At that time the most heavily worked beds were those in the Florida Keys and Florida Bay areas. It is interesting that these years of sponge mortality coincide with heavy outbreaks of red tide, caused by *Gymnodinium brevis* (Feinstein, 1956). Rathbun (1887) refers to poisonous colored waters about the reefs and in Florida Bay with sponge losses occurring at the same time.

Brice (1898) describes heavy losses of sponges in the Knight Key to Cape Sable area when the sponges "rotted internally" and died in large numbers. F. G. Walton Smith (1941) described similar mortalities caused by a fungus in British Honduras, the Bahamas, and throughout the Gulf in 1938-39. The fungus was tentatively identified by Galtsoff (1942) as *Spongiophaga communis*. Carter (1878) first observed a fungus parasite on sponges. If the disease described by Brice is the same as that found in 1938-39, occurrences of this fungal disease are very rare indeed. Occurrences of "poisoned waters" and fungal disease were undoubtedly made possible by special combination of oceanic conditions that led to sudden blooms of the causative planktonic and fungal organisms. It has been difficult to obtain any knowledge of this fungal sponge disease since it was impossible to culture the fungus in the laboratory at the time of the occurrence. *Spongiophaga communis* is the only true sponge disease organism which has been adequately described and illustrated. This was done by F. G. Walton Smith in 1941. The disease first attacked the interior portion of the sponge; here the organisms are found in greatest abundance in the narrow zone between the healthy living tissue and the dead area. The hyphae appeared in groups as a number of short colorless unbranched filaments between 0.001 and 0.002 mm. in diameter. Only one end of each filament was attached to the sponge tissue (fig. 16). As the disease progressed, a greater and greater portion of the central mass of the sponge was affected. The outer skin was finally pierced, and in a short time the entire sponge rotted away. The sponge fishermen described the hooking of a heavily diseased sponge by saying that the "sponge disappeared in a cloud of dust."

In the 1938-39 occurrence of the disease in British Honduras, the sponge species were

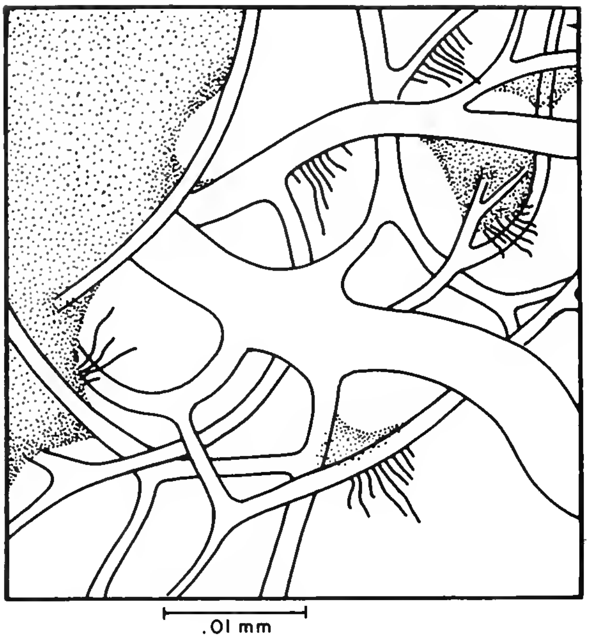

Figure 16.--Wool sponge fibers showing fungal disease growth. Fungal fibers attached by one end only. Living material of the sponge is indicated by the stippled areas (after Smith, 1941).

attacked in the following order: velvet, grass, wool, and reef. In the Bahamas, the order of attack was different, for the wool sponges were attacked before the grass.

In British Honduras *Spongiophaga* was observed growing on the surface of eelgrass, *Thalassia*, with no apparent effect on the health of the plant.

Between 90 and 95 percent of the commercial sponges were destroyed in most areas of the Caribbean and Gulf. All the velvet sponges were destroyed in the Bahamas, and none has been observed since. Two or three velvet sponges were taken along the west coast of Florida in 1947. In 1938 the sponging grounds in the Gulf along the west coast of Florida north of Tampa were least affected by disease with production falling off by 1940 to about one-third of 1936.

The 1947-48 Sponge Disease

In 1947 commercial sponges along the west coast of Florida were again attacked by disease. Immediate investigation by members of the scientific staff of the Marine Laboratory of the University of Miami did not reveal the cause of this destruction of the sponges. No evidence of fungal disease was found, and the oceanographic conditions were generally within the range common to inshore Gulf of Mexico waters.

Other Detrimental Effects

Sponge fishermen claim that a killing off of sponges in shallow water is sometimes associated with the occurrence of the "mallee" (from the Greek "hair"). This mallee is a heavy growth of fine alga which apparently covers the rocky bars during the late spring, the time of occurrence depending on temperature. After a short period of attached growth, the mallee breaks loose and rolls or washes about the bottom, thus making sponging in the area next to impossible. By inference mallee has come to mean any heavy bottom plant growth that finally breaks loose and rolls about the bottom in large mats 2 to 3 feet deep. At times this mat is made up of a "sea grass," *Halophila baillonis* Large amounts of other sea plants may add to the mass. Certainly a collection of this material covering the sponges would be detrimental. The actual cause of the sponge destruction accompanying this condition is unknown. Examination of sponges apparently affected by a malleelike condition in the summer of 1956 did not reveal any fungal disease or other disease organism. The condition was local in extent, affecting a series of rather limited areas in the shallower water just north of Tarpon Springs with serious effects to the sponges.

Growth experiments by Moore (1910b) and Crawshay (1939) showed a 2-percent mortality of sponges during the winter and a 10-percent mortality in the summer. Total mortality of sponges during the period required to reach a 6-inch diameter was estimated at 20-30 percent. These percentages represent the expected mortalities in water depth of 6 feet and in protected areas where adverse ecological factors would be expected to be encountered most often. Mortalities in deeper and more open water could be expected to be lower.

A sudden freshening of the water in local areas has also caused considerable loss of sponges. Rathbun (1887), Moore (1910b), Crawshay (1939), and others mention both local and widespread kills due to heavy rains and sudden runoff from rivers. Most of this type of destruction occur in relatively shallow water within a few miles of shore. The salinity tolerances of sponges and the detrimental effects of temperature were discussed in the section on ecology.

Parasites and Epizoics

With so many animals and plants living in the mass of the sponge, in the internal canals, or on the surface, it is difficult to establish which are harmful and which are merely living in or on the sponge as epizoics. No detrimental animal or plant, with the exception of the disease fungus, can be said to be parasitic exclusively on commercial sponges. Many animals such as the small snapping shrimps are found in far greater numbers in the canals of the sponges than in any other habitat, but no true case of commensalism can be stated.

Commonly associated with the commercial sponges and growing on the surface are such algae as the fairy cup, *Acetabularia crenulata* and *Batophora oerstedi*, as well as various species of *Halimeda* and other calcareous algae. So great is the mass of plant material on the surface of some sponges, especially those growing in the warmer and shallower water, that the shape becomes considerably distorted. These plants may not greatly affect the total growth of the sponge; however, the distortion reduces the commercial value. Plants that cover any of the inhalant pores or restrict the flow of the oscules adversely affect sponge growth.

Any animal living within any of the inhalant pores, the internal canals, or the oscules would be similarly detrimental to the sponge. A number of 1/2-inch long hydroids live within the small inhalant pores of the wool sponge and stretch out from the sponge. Such hydroids are commonly associated with other types of sponges as well, for example, the tubular sponge, *Callyspongia vaginalis*. The anemone, *Aiptasia*, may form depressions in the surface of the sponge into which it can retract.

Various kinds of polychaete worms, some of considerable length, have been found in the canals. One common worm was *Leodice spongicola*, but there were also a number of small free-swimming syllid worms and a few tube-forming terebellids. In some of the non-commercial sponges, polychaete worms may be as long as 2 or more feet, although none of this length were found in the commercial sponges examined.

Common inhabitants of the larger canals, the oscules, and shallow depressions on the surface of the sponge were many small brittle stars such as *Ophiactis savigny*. The starfish, *Echinaster*, has been found on sponges which bear small cuts or lesions in the surface, but there has never been any evidence that the damage to the sponge was initially caused by the starfish.

By far the commonest inhabitants of the canals of the commercial wool sponge are various species of the snapping shrimp. *Synalpheus brooksi*, *S. meclendoni*, and *S. brevicarpus* were the three identified. Other shrimps, such as the portunid *Coralliocaris pearsei* and the stomatopod, *Gonodactylus oerstedi*, similar to the ghost shrimp, have also been found. A number of species of small crabs of the genus *Mithrax* are also common.

Major damage to the commercial value of the wool sponges is caused by the sponge crab, *Pilumnus sayi*, a small hairy animal that may attain a width of 2 inches. This crab often occupies a hole at the base of the sponge (fig. 17). The original hole may be the result of local damage to the sponge, but constant occupation by the crab prohibits regrowth and filling in of the hole. There is no evidence that the crab eats any of the sponge. The hole may not affect the sponge as a living animal but certainly destroys the commercial value of the sponge almost completely. Damage by this crab most frequently occurs to wool sponges in the Pepperfish Key sponging grounds, just north of Cedar Keys.

Other crustacea commonly found in the canals are ostracods, such as *Cylindoleberis floridana*; the amphipod, *Leucothoe spinicarpa*; and various isopods. The barnacle, *Balanus declivis*,

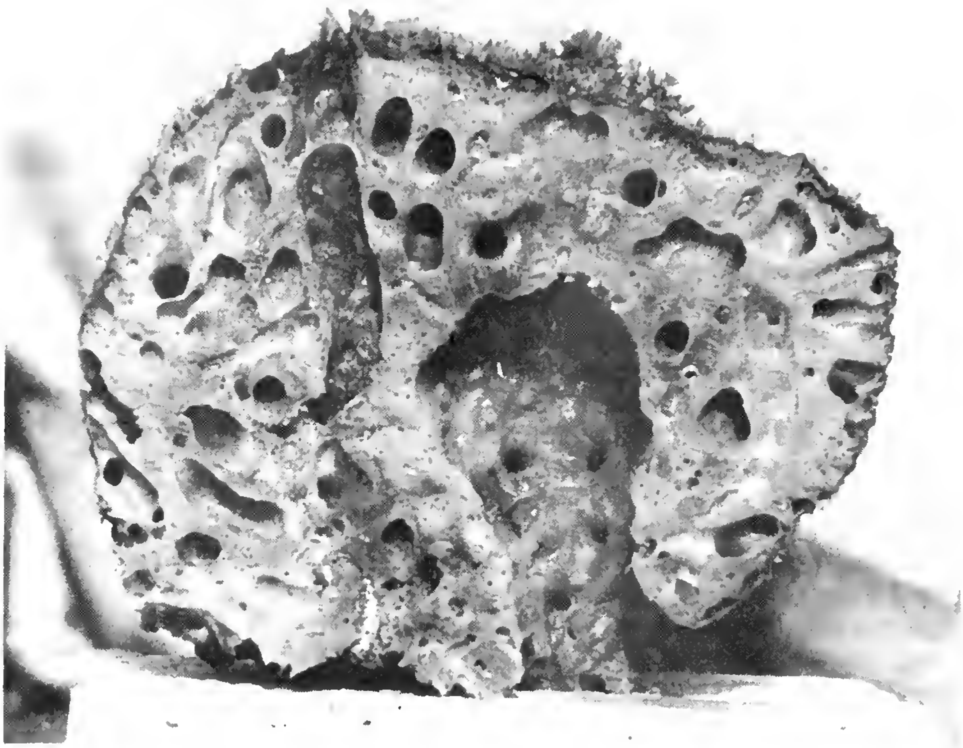

Figure 17.--Cross section of a wool sponge with hole occupied by a sponge crab, *Pilumnus sayi*. The surface of the interior of the cavity is smooth and shows no sign that the crab eats any of the sponge material. Around the edge of the sponge, bare fibers of spongin material have been exposed by the withdrawal of living material of the sponge, probably as a result of sudden lowering of the water temperature. See section on temperature relationship for details.

is sometimes found imbedded in the surface of commercial sponges but is more commonly found on the noncommercial species.

Large numbers of developing larval forms of a tunicate were found attached to the walls of the canals in almost all of some 200 wool sponges examined microscopically. These were microscopic in size and were not identified. Larger colonial tunicates often attach and grow on the top or sides of the sponge, usually affecting the shape.

Many small snails, key hole limpets, and small bivalves are found in the mass of the sponge apparently surrounded by the sponge as it grows. These animals are also found in the canals of the sponge into which they have crawled in their search for food. The spongers believe that some species of the key hole limpet eat and damage the sponge. Nudibranchs have also been found on the surface of the sponge, especially in the surface depressions. These may also occasionally feed on the sponge tissue. The basal portion of the sponge often contains the open-coiled shells of the snail *Vermetus*. Fish fry may occupy the canals of the sponges.

I have noted that many of the finger sponges bore the teeth marks of fish. The stomach contents of the spadefish, *Chaetodipterus faber*, show that this fish may be responsible for damage to finger sponges. Several other unknown species of fish must also eat this sponge. There is no evidence that any of the other commercial species of sponges are damaged by any fish.

The association of many plant or animal forms with the commercial sponges is apparently fortuitous. Almost any small plant will attach to the surface, and almost any small animal that either normally attaches to an object on the bottom or else seeks shelter in a protected cavity will live on or in the sponge.

Generally those sponges that are growing in warmer and shallower water have a far greater number of species of animals and numbers of individual animals in the canals and on the surface than those found in the more northerly or deeper ranges of the commercial sponges. Because of this difference a far greater proportion of the wool sponges from the northern Gulf are more perfectly formed than those from areas such as Cape Sable. The same is true of sponges from deeper water of 25 to 30 feet, as is shown by comparing sponges taken by hookers with those taken by divers.

COMMERCIAL SPONGE PRODUCTION

Production Before and After the 1938-39 Sponge Disease

Table 11 presents the production and value of sponges from 1913-62. For the sake of discussion, table 11 and figure 18 may be divided into two periods, a predisease period from 1917-38 and a postdisease period from 1938-56. Without adequate information on the number of boats operating yearly from 1917-35, it is impossible to say with certainty what portion of the variation in productivity is due to the intensity of fishing effort during the predisease period. From the data available it would appear that the small changes in the number of fishing boats would not bring about any appreciable change in landings of sponges by individual boats.

It was important, however, to find some explanation for the wide variation in yearly landings that took place during the period 1917-35. Yearly take was from 267,000 pounds to 468,000 pounds, with an average of about 350,000 pounds. According to sponge fishermen, there were few additional areas that were harvested during that period with the exception of the Cape Sable and Everglades areas in 1936 (often referred to by the divers as the Key West area). A considerable portion of the yearly variation undoubtedly was caused by the effects of weather on fishing. Observations made during the past 2 years suggest that some portion of the variation was probably due to mortality of sponges in localized areas, especially in the shallower sponging areas. This has already been discussed in the section on disease.

In the postdisease period (after 1938) productivity fell within 3 years to two-fifths that of 1938 or about one-half the yearly average. There was a levelling off of the yearly take during the next 5 years despite a 50 percent increase in the number of boats in the sponging fleet (fig. 18). According to published reports of the Sponge and Chamois Institute, undersized sponges were being taken indiscriminately in large numbers during this 5-year period. The rapid increase in the wool sponge price per pound (table 12), from about $2 to almost $30, and the reported failure during the war period to prohibit the taking and/or selling of undersized sponges encouraged this illegal practice to continue without serious restraint. The effect of taking undersized sponges before they had an opportunity to mature and produce eggs was possibly a factor in preventing (1) the repopulation of the deep-water sponge beds and (2) an increase in the concentration of sponges in the more limited inshore areas. Had there been a more extensive distribution of small sponges and greater numbers of small sponges during the 1947-48 disease period the effect of this disease would probably not have been nearly as great as it was. The fact that the total landings of sponges did not increase appreciably during the 5-year period despite greatly increased effort suggests that the sponge beds were being depleted. The decline in return per unit of effort also indicates the steady decrease in the concentration of the sponges that took place.

Production After the 1947-48 Sponge Disease

After the disease of 1947-48, which affected the Big Bank grounds (appendix, #10) more than any other, the yearly total of landings once again fell off rapidly. A large part of this recorded drop resulted from the withdrawal of boats from the sponge industry. Return per unit of effort changed little. Within 3 years after the disease began only 57 boats were sponging, and by 1951 only 32 boats remained in the sponging fleet. Of these, only two were diving boats. On the basis of the 1955 and 1956 returns, it has been estimated that the return

Table 11.--Weight and value of wool, yellow, and grass sponges sold on the Tarpon Springs Sponge Exchange, 1913-62[1]

Year	Wool weight	Value	Yellow weight	Value	Grass weight	Value	Total value
	Pounds	*Dollars*	*Pounds*	*Dollars*	*Pounds*	*Dollars*	*Dollars*
1913	362,000	586,000	65,000	47,000	56,000	40,000	673,000
1914	332,000	515,000	65,000	26,000	42,000	17,000	558,000
1917	332,000	785,000	76,000	46,000	50,000	27,000	858,000
1918	273,000	554,000	57,000	28,000	17,000	9,000	591,000
1919	364,000	640,000	61,000	39,000	20,005	25,000	704,000
1920	308,000	602,000	61,000	43,000	37,000	30,000	675,000
1921	307,000	492,000	59,000	30,000	26,000	13,000	564,000
1922	418,000	638,000	96,000	38,000	34,000	20,000	696,000
1923	395,000	664,000	73,000	47,000	36,000	16,000	727,000
1924	430,000	672,000	68,000	38,000	6,000	3,000	731,000
1925	396,000	654,000	101,000	48,000	11,000	8,000	710,000
1926	355,000	629,000	46,000	23,000	20,000	13,000	665,000
1927	389,000	814,000	55,000	33,000	20,000	14,000	861,000
1928	359,000	674,000	51,000	29,000	30,000	21,000	724,000
1929	321,000	656,000	57,000	32,000	24,000	14,000	702,000
1930	403,000	750,000	47,000	33,000	22,000	17,000	800,000
1931	267,000	547,000	81,000	39,000	25,000	19,000	611,000
1932	274,000	431,000	75,000	44,000	52,000	29,000	504,000
1933	259,000	352,000	80,000	51,000	20,000	9,000	412,000
1934	351,000	572,000	105,000	71,000	29,000	19,000	662,000
1935	270,000	528,000	80,000	67,000	22,000	16,000	611,000
1936	468,000	938,000	122,000	74,000	26,000	17,000	1,029,000
1937	399,000	977,000	130,000	96,000	17,000	12,000	1,085,000
1938	421,000	893,000	92,000	46,000	8,000	6,000	745,000
1939	325,000	916,000	60,000	79,000	24,000	24,000	1,019,000
1940	212,000	826,000	6,000	8,000	13,000	12,000	846,000
1941	167,000	1,244,000	6,000	23,000	28,000	97,000	1,364,000
1942	157,000	1,533,000	5,000	44,000	22,000	123,000	1,700,000
1943	156,000	2,033,000	10,000	97,000	20,000	175,000	2,305,000
1944	161,000	2,257,000	9,000	99,000	22,000	191,000	2,547,000
1945	158,000	2,377,000	8,000	91,000	28,000	248,000	2,716,000
1946	162,000	2,590,000	---	---	---	---	---
1947	107,000	1,142,000	4,000	45,000	9,000	58,000	1,245,000
1948	60,240	433,989	5,023	12,865	9,311	10,983	465,937
1949	57,700	455,176	4,550	9,097	6,500	6,530	412,280
1950	15,628	132,843	3,115	9,346	1,106	3,319	145,737
1951	10,984	79,635	381	1,231	318	1,176	82,128
1952	14,298	125,824	1,546	4,639	1,373	4,121	134,871
1953	14,407	117,279	1,115	3,624	795	2,292	123,349
1954	15,523	126,364	942	3,062	859	2,475	131,901
1955	27,020	229,672	1,128	3,951	990	3,456	237,084
1956	25,958	229,688	2,178	10,326	1,375	6,889	247,021
1957	36,396	224,618	5,151	10,689	2,580	9,660	245,339
1958	19,263	197,627	8,200	2,125	1,891	7,270	215,947
1959	23,430	268,861	1,864	8,029	1,544	7,751	284,644
1960	32,540	286,568	1,684	5,905	433	1,562	294,187
1961	34,352	355,239	752	3,629	139	801	359,669
1962	41,510	385,828	1,480	6,333	1,552	9,621	401,815

[1] All weights of sponges are estimated by use of a conversion factor using probable value of sponges by the pound, calculated yearly by the Tarpon Springs Sponge Exchange. No records available for 1915 and 1916.

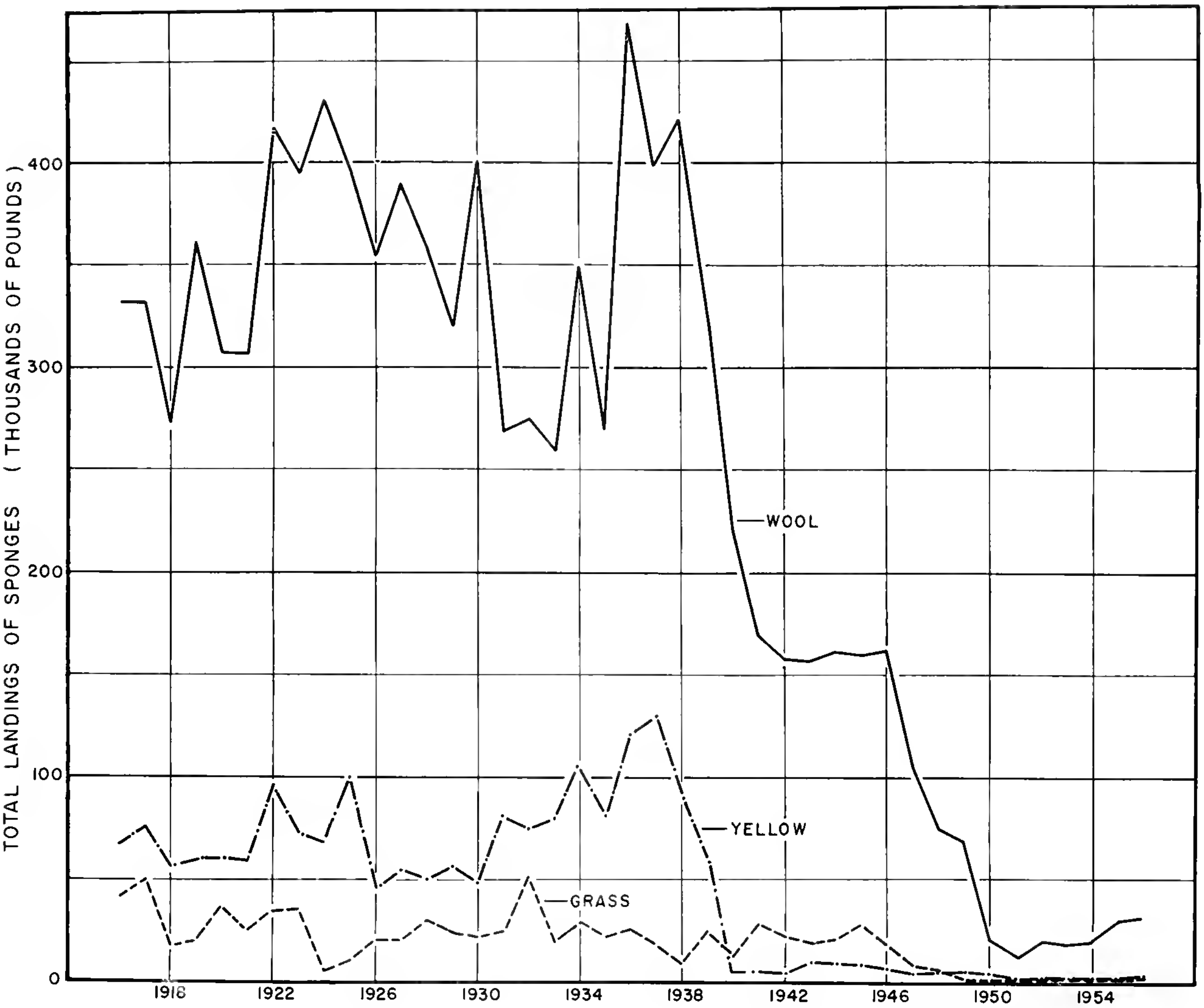

Figure 18.--Total landings of wool, grass, and yellow sponges, 1917-58.

obtained by one diving boat is equivalent to the return obtained by 4.5 hooking boats. On this basis (table 12) only 11.2 percent of the number of boats operating in 1946 were still working in 1951.

By 1948 the value per pound of wool sponges had dropped from a 1946 high of $30 to an average of just over $6. The total return for the year 1948 was $466,000 or more than $2 million less than was received for wool sponges alone in 1946. Although the return per unit of effort remained at about the same level and even increased as more boats left the fleet, it was not possible to operate economically with the lowered price per pound. As a result, continued withdrawal of boats took place with a corresponding decrease in sponge landings so that by 1951 the total take of sponges was less than 3 percent of the peak production year of 1936, with a dollar return of less than 3 percent of the peak value year of 1946.

If the sponging fleet had been as large in 1951 as in 1946, the yield per unit effort would have declined because of the limited sponging area. In this second postdisease period, a reduction in the sponging fleet was accompanied by a sizeable increase in the take per unit of effort (as in 1948)--something that had never happened in the history of the industry.

By 1957 there were 7 diving boats and about 35 hooking boats actively sponging. These boats landed sponges as an annual rate of about 29,000

Table 12.--Average catch per boat, based upon the sale of wool sponges on the Tarpon Springs Sponge Exchange from 1935-61

Year	Quantity sold	Diving boats employed	Hooking boats employed	Catch per boat 100's of pounds per diving boat equivalent[1]	Value of annual sales	Price per pound average[2]	Average income per diving boat equivalent
	Pounds	*Number*	*Number*	*Hundred Pounds*	*Dollars*	*Dollars*	*Dollars*
1935	270,000	54	63	40	528,000	2.00	7,800
1936	468,000	53	68	69	938,000	2.00	13,800
1937	399,000	63	60	53	977,000	2.50	12,900
1938	421,000	70	55	51	893,000	2.10	10,900
1939	325,000	73	52	39	916,000	2.80	10,900
1940	212,000	76	50	24	826,000	3.90	9,500
1941	167,000	67	70	20	1,244,000	7.40	15,000
1942	157,000	60	75	20	1,533,000	9.80	20,000
1943	156,000	69	92	18	2,033,000	13.00	22,800
1944	161,000	69	92	18	2,259,000	16.00	25,400
1945	158,000	76	115	15	2,377,000	15.10	22,600
1946	162,000	75	114	16	2,590,000	16.00	25,600
1947	107,000	75	75	12	1,142,000	10.70	12,400
1948	74,000	35	32	20	466,000	6.20	11,200
1949	69,000	28	29	20	412,000	6.00	11,800
1950	20,000	7	27	15	146,000	7.30	11,200
1951	12,000	2	30	13	82,000	7.00	9,100
1952	17,000	4	30	16	136,000	7.80	12,300
1953	16,000	6	34	12	123,000	7.50	9,400
1954	17,000	7	25	13	132,000	7.60	10,100
1955	29,000	8	34	18	237,000	7.80	14,800
1956	29,561	10	36	19	247,000	8.35	14,970
1957	38,514	13	66	14	245,339	6.37	8,759
1958	29,354	10	42	15	215,949	7.36	11,363
1959	26,874	7	[3] 37	17	284,644	10.59	17,713
1960	34,691	10	[4] 40	18	294,187	8.48	15,484
1961	35,243	10	[4] 84	12	359,669	10.21	12,405

[1] Ratio of catch of diving boat to hooker boat estimated as 4.5:1 (based on 1955 and 1956 returns).
[2] Price per pound average based on total value divided by total quantity in pounds sold.
[3] Includes one boat equipped for diving.
[4] Includes two boats equipped for diving.

pounds and a value of $250,000, the diving boats accounting for slightly more than half of this take. In 1956 as many as 10 diving boats were operating, but landings decreased because of insufficient crews.

Needs of the Sponging Industry

From the standpoint of the sponging industry the greatest need in 1957 was for younger experienced divers. The average age of the men on the diving boats was estimated to be well over 50 years. The labor problem can be solved in two ways:

First, to attract younger divers from the Greek sponge industry in the Mediterranean. This has complications and objections. At the moment, the Mediterranean spongers are earning a better wage than formerly because of the higher price obtainable for sponges in Europe and America. The immigration problem has to be overcome, and any request by the sponge industry to allow these divers to come into the country meets with objections. Sponge fishermen not of Greek descent state that there are many divers in Florida who would dive for sponges if the earnings were greater. This may be so, but no divers are as yet forthcoming.

It could be that the possible high income of a physically capable and well-trained sponge diver is not sufficiently appreciated.

A comparison of the returns of one 5-month trip in 1956-57 by the boat with the two youngest divers (about 40 years of age) compared with returns for the same trip by other diving boats is rather revealing:

Boat with youngest divers . . .	$17,808.00
Boat A	11,434.00
Boat B	9,202.00
Boat C	8,061.00
Boat D	7,136.00

The boat with the youngest divers had a return that was over 50 percent greater than any other boat. (These returns are based on sales in the Tarpon Springs Sponge Exchange; it is possible but unlikely that some sponges were sold by these boats outside the Sponge Exchange.)

Even with the boat trip expenses (for 5 months) of $1,800, the diver's earnings would be $5,500 per year; and if he were captain as well, his yearly income could be over $7,000.

Second, to recruit divers from the local area. As pointed out above, an increase in the actual cash return to the diver would be an inducement. Better physical facilities for the crews of the sponging boats would also attract men.

Analysis of the Yearly Take and Value of Sponges, 1950-56

As sponges have been sold by the piece rather than the pound since 1951, it is possible to gain considerable insight into the value of the sponges and the market since 1950 by analysing the data available. Because sponges are dried and cured aboard the boat, there is no need to sell them as soon as they are landed. If the price at any time is not thought to be satisfactory, sale of the sponges may be held over for several months and at times for longer periods. It is the general rule of the diving boats that the sponges from the 5-month trip, the "long trip," be sold at the end of the trip so that the men can receive their shares. The boat owner or sponsor of the trip is also anxious to sell the sponges at that time, as he has been paying out a weekly allowance to each of the families of the crew throughout the 5-month period. With trips ending as they do in January and July, these 2 months usually have the highest sales. It is quite possible, however, that in December the price may be so favorable that the sale takes place during this time and the totals for the current year are affected considerably. Heavy sales may take place in any month if there is a sudden attractive advance in price.

In table 14, the number of pieces of wool sponge given per year is fairly accurate for all years except 1950 when sales were not recorded on a per piece basis. The figures have been arrived at by use of the conversion factor now being used to convert number of pieces to pounds by the Branch of Statistics of the Bureau of Commercial Fisheries (table 13). This factor is based on an analysis of data supplied by the Tarpon Springs Sponge Exchange.

In table 14, the numbers of yellow, grass, and glove sponges are not always accurate since sales slips records indicated that sponges were sold either on a combined per piece basis or as bunches. In the latter case the number of pieces in each bunch could be roughly calculated only from individual sales records during some part of the year. Only in 1951, 1955, and 1956 were the sales recorded by individual pieces, with each species of sponge being sold separately. Thus, the figures for these years are the only truly accurate ones

Table 13.--Number of wool, yellow, grass, and glove sponges to the pound[1]

Gear	Wool	Yellow	Grass	Glove
Diving boat	11	14	18	20
Hook boat	16	14	14	22

[1] From statistical records of Tarpon Springs Sponge Exchange.

Table 14.--Harvest of Florida sponges, 1950-62

Year	Wool		Yellow		Grass		Glove	
	Number	*Dollars*	*Number*	*Dollars*	*Number*	*Dollars*	*Number*	*Dollars*
1950..	207,565	132,843	56,056	9,346	19,601	3,319	3,271	229
1951..	107,456	79,635	3,936	1,231	4,129	1,176	1,444	86
1952..	140,277	125,824	13,105	4,639	11,579	4,121	4,963	307
1953..	149,893	117,279	10,476	3,624	6,593	2,292	2,497	154
1954..	164,546	126,364	7,471	3,062	3,785	2,475	1,022	?
1955..	320,767	229,672	12,826	3,951	8,358	3,456	90	5
1956..	338,742	229,688	30,671	10,326	19,964	6,889	1,033	?
1957..	477,048	224,618	72,629	10,689	40,764	9,660	1,134	372
1958..	250,169	197,627	115,492	9,128	30,015	7,270	5,166	1,922
1959..	274,610	268,861	26,096	8,029	22,584	7,751	840	316
1960..	373,940	286,568	23,576	5,905	6,906	1,562	704	152
1961..	396,232	355,239	11,928	3,629	2,194	801	0	0
1962..	479,150	385,828	20,776	6,333	22,512	9,621	198	33

for all sponges both as to numbers and average price.

In July 1956, on my recommendation, the Branch of Statistics of the Bureau of Commercial Fisheries changed the method of gathering data on the price and quantity of the sponges landed. These changes will improve the reliability of the statistics on sponge landings and values and will aid any biological and market analyses in the future.

There has been a steady increase in the landings of sponges from 1951 onward (table 14). This increase is caused largely by the increased sponge fleet, except in 1955, when the number of sponges taken almost doubled the take of the previous year. It would appear that a large number of sponges reached egg-producing size in 1955, and assuming that conditions for spawning were favorable in 1955, there should have been a large number of sponges of legal size from this spawning reaching egg-bearing size in 1957 and throughout 1958. Records of landings for 1957 and 1958 indicate that this probably had come about. During the first half of 1957 the total landings were almost equal to the total take of 1956. Unfortunately, during the late spring and summer there was a heavy mortality of wool sponges due probably to freshening of the water. Samples examined indicated that this was the reason. Consequently, landings fell off during the next two sponging periods, but reports from the fall trips of 1958 show that there has been a rapid return of the sponges, to the level of 1956 at least.

As long as the sponge fishery is entirely dependent upon sponges growing in the shallow area, the fishery will be plagued by intermittent adverse conditions. The industry cannot be stabilized until the sponges are growing in quantity in the deeper water.

Probable Reasons for Annual Fluctuations in Landings

Any probable increase in the number of sponges growing in shallow water will be predicated on the following:

1. Concentrations of mature sponges in all parts of the areas are greater than the minimum required for adequate fertilization.

2. Fishing for sponges will not deplete the present beds or seriously reduce the concentrations below the level required for adequate fertilization.

3. No serious disease or adverse ecological condition such as a freshening of the water will take place.

Records of take per unit effort in various areas, the wide daily fluctuation of take, and the several local severe losses of sponges because of adverse conditions point up the fact that the concentration of the wool sponges is erratic on the northern sponging grounds. It is unlikely that the increase in concentration by natural reproduction throughout the present fishing grounds will increase by as much as 60 percent in this area during the coming 4 years. There is, however, the probability that new areas coming into production may relieve the pressure on the present sponging areas and allow them to recover at the above predicted rate. This phase of the problem is discussed more fully in the final section of the paper.

Sponge fishermen believe that a major portion of the yearly fluctuation in landings is due to variation in weather conditions that determine the number of days of fishing. Some of the fluctuation in sponge production is undoubtedly related to the finding of new sponge beds, to long periods of inclement or favorable weather, and to other factors. In 1956 for example, the returns by the hooking boats fell off by 14 percent from the previous year, principally because of a local sponge disease north of Tarpon Springs and the destruction of the sponges by fresh water in the area north of the Steinhatchee River. Diving boats increased their landings by 26 percent in the same period because of the excellent production in the Cape Sable area.

When reporting various losses of sponges on the bars, sponge fishermen often state that only the young sponges were left and the larger sponges were killed off. Presumably, therefore, the younger sponges are more resistant to disease and adverse conditions than the mature sponges.

The price per piece for wool sponges has been dropping steadily since 1952 (table 15). This decline, however, may be checked, for the situation in the Mediterranean has changed recently. The Egyptian Government has introduced restrictions on sponging, making it practically impossible for the Greek sponging fleet to work along the Egyptian coast. With the demand for sponges in Europe said to be increasing, shipments to American buyers have decreased (table 16). If the demand in Europe continues and synthetic sponges do not make further inroads to displace the use of domestic natural sponges, the present price and demand may continue.

PRESENT STATUS OF THE SPONGE INDUSTRY

Methods of Harvesting

At the present time there are three distinct groups of spongers employing two basic methods of harvesting--hooking and diving. Two of these are sponge hookers--one group in the Tarpon Springs area and the other in the Florida Keys area. The divers make up the third group.

The Tarpon Springs hookers traditionally use a heavy round-bottomed dinghy with the rower sitting on a raised seat in the middle part of the boat. The hooker kneels in the bow of the boat with a water glass in one hand and in the other a long pole with four-pronged rake or hook fastened to the lower end. The water glass or glass-bottomed bucket is used

ERRATA -- page 57

Table 15.-- Average prices per sponge for sponges sold on the Tarpon Springs Sponge Exchange

Year	Wool	Yellow	Grass	Glove
	Cents	Cents	Cents	Cents
1950	64.	32.	34.	7.
1951	74.1	31.3	28.5	6.2
1952	89.7	35.4	35.4	6.2
1953	73.2	34.6	34.6	6.2
1954	76.	40.9	65.	6.2
1955	71.6	30.3	41.3	5.1
1956	67.8	33.7	34.5	[1] 12.
1957	51.3	14.7	23.6	[1] 32.8
1958	30.7	7.9	24.2	[1] 37.2
1959	97.9	30.8	34.3	[1] 37.6
1960	76.6	25.	22.6	[1] 21.5
1961	89.6	30.4	36.5	?
1962	80.5	30.4	42.7	[1] 16.6

[1] Includes miscellaneous types of sponges.

Table 16.--Imports of sponges to the United States[1]

Year	Volume	Value	Value per pound
	Pounds	*Dollars*	*Dollars*
1945	95,596	791,979	8.22
1946	328,307	3,087,963	9.40
1947	214,198	1,768,130	8.25
1948	355,026	2,587,336	7.27
1949	268,055	1,936,974	7.22
1950	369,775	2,329,108	6.30
1951	281,645	2,116,123	7.69
1952	191,776	1,295,935	6.75
1953	284,362	1,628,192	5.72
1954	191,107	1,123,692	5.88
1955	216,348	1,341,692	6.20
1956	217,506	1,291,567	5.93

[1] Published in various sponge and chamois trade reports.

to search the bottom for commercial sponges. When a sponge is sighted, the hooker directs the rower to turn the boat in that direction. When the sponge is within reach, the pole is lowered quickly to the bottom, and the size of the sponge is judged by the width of the hook. If the sponge is large enough, the hook is set into the base of the sponge, which is then torn from the bottom with an upward pull. This method of harvesting often tears off part of the sponge or leaves a considerable amount of the sponge base from which a new sponge will grow. It is quite probable that the number of torn sponge bases left make it possible for this hooking method to continue to be used extensively and constantly in the shallow-water areas without excessively depeleting the sponge beds.

The hooking method does not produce the best quality of sponges for three reasons:

1. Normally, shallow-water sponges have lighter texture and poorer quality than those found in deep water, except for the wool sponges growing in the Rock Island area.

2. Sponges harvested by the hooking method are often torn.

3. The hookers work the limited hooking area so constantly that the sponges never have a chance to grow very large and the average size taken is about 6 inches in diameter. The wool sponges taken by the hookers average 16 to the pound, and those taken by the divers, 11 to the pound. Thus the sponges taken by the divers are almost 50 percent heavier.

About 35 hooking boats of various sizes are operating from Tarpon Springs along the coast northward of this sponging center. In former times the standard hooking unit was a 30- to 40-foot schooner with three or four dinghies in which men worked in pairs. Now, only a few schooners are used. Small converted pleasure craft with a crew of two, small schooners, and a number of small boats that work from a land base do a considerable amount of the harvesting.

At least two methods of hooking in the Florida Keys are different than those found in the Tarpon Springs area. In one method only one man works from a dinghy. Using his hooking pole, he keeps the boat in the center of a shark-oil slick as the slick is moved along with the tide. The oil smooths the water surface and enables the hooker to identify and hook the commercial sponge on the bottom. The second method of hooking uses a powerboat with a long boom lashed across the stern. Three or four lines with end loops are attached to the boom. The loop in the rope on the boom is put around the upper end of the hooking pole, which is then fitted into a hole in the stem post of the dinghy. The dinghy man lies down in the boat with his head and shoulders over the stern and holds the water glass in the eddy behind the dinghy with little effort. This allows the powerboat to move along while the men in their dinghies search the bottom. When a sponge is seen, the man jerks the pole free of the stem hole and the rope lopp, and, if the man is quick, the sponge is hooked while the dinghy is still moving forward. The powerboat swings around, and the dinghy is again attached to the powerboat by the same method. Thirty or thirty-five miles of ground may be covered in one day and a large number of good-quality sponges can be taken. This method is good from the conservation point of view because smaller and poorly shaped sponges cannot be taken economically.

Diving boats working out of Tarpon Springs are designed after the original diving boats used by the Greek spongers in the Mediterranean. They are now diesel-powered, and the air pump is powered directly from the main engine. The boats are heavy and seaworthy.

The crew is made up of a captain (who usually also serves as either the engineer or one of the divers), two divers, an engineer, a lifeline tender, cook, and deckhand. In good weather the two divers put in a 12-hour day between them, the actual time underwater being about 10 hours. The diving dress is similar to the standard deep-water equipment. The diver jumps off the starboard side of the bow and can support himself by hanging onto the weighted dropline that hangs from the bow.

The diver's sponge hook is attached to a short pole about 2 feet in length and is similar to that used by the hooker. As the sponges are gathered, they are kept in a fish-net bag with a jointed-ring top, the stephani. The diver can easily control the short pole, so the sponge can usually be torn cleanly and carefully from the bottom with a sidewise pull.

Cleaning of Sponges

Once aboard the boat, the sponges are first squeezed to initiate the degeneration of the living material, then piled base down to allow the "gurry" or decaying matter to drain from the sponge. The pile is covered with wet burlap sacking so that the sponges will not dry out.

In warm weather the sponge decays fairly rapidly and by the next morning the sponges that were collected the day before are well on their way toward final cleaning. During the day the sponges are turned and wet down several times and by midday or midafternoon, they are ready for final cleaning. In cleaning, the sponges are rinsed in clean sea water and thrown hard against the deck to knock out sand and particularly the small snapping shrimp that lived in the larger canals of the sponge. The outside of the sponge is scraped with a knife to remove the last traces of the "skin." As a final step, the sponges are wrung out and strung on coarse cord as a "line," each line holding 150 sponges. At this point well-cleaned sponges are light tan in color but the bottom of the base and inside may be almost black. As the sponges dry in the sun, the black color disappears. After drying they are stored in the forward hold of the boat.

If the rotting is allowed to continue too long, the spongin fibers are greatly weakened; the sponge is limp and of poor quality. Wool sponges cannot be cleaned in fresh water as this causes them to be dark in color and hard in texture.

Selling and Sharing System

Ashore the sponges are stored in the Sponge Exchange, and the day before the sale they are graded and strung on 5-foot lengths of line, known as bunches. Each bunch is made up of 20 to 30 or more sponges depending on size. The sponges are sold to the packers at auction. The seller has the right to refuse a bid that he believes to be too low, and this may be done if there is any hope that the market price will rise.

One and one-half to two percent of the selling price is withheld by the Exchange, as a charge for the use of the storage sheds and other facilities. If the sponger is a member of the local Greek Orthodox Church, 3 percent of the price may be withheld and half of this is given to the church.

The share system for dividing the cash returns is used generally throughout the industry wherever two or more men work in one boat. A typical sharing system is that of the diving boats. At the beginning of a 5-month trip, the boat is, in a sense, turned over to the crew who are then responsible for any repairs and loss of gear during the trip. Returns are usually divided into 12 shares, but before these are distributed among the crew, costs are deducted, such as food, diving dress if needed, boat fuel, replacement of broken gear, minor engine repair, diving ropes, etc. The remainder is then proportioned as follows:

1st diver (who may also act as captain)	2 shares.
2nd diver	2 shares.
Engineer	1-1/2 shares.
Lifeline tender	1-1/2 shares.
Cook	1 share.
Deckhand	1 share.
Boat	3 shares (with 1/2 share going to the captain).

Division of the shares may vary slightly, but the above is the general pattern.

Amount and Value of Sponges Sold

Until 1951 sponges were sold by the pound. This practice had certain disadvantages because of the large number of grades that were set up and the obvious drawback in making possible (and almost encouraging) the loading of sponges with foreign material. The weight of the sponges was also affected by the amount of water contained.

In 1951, the method of selling sponges was changed to price per piece, and cleanliness, shape, and texture of the sponges were used as the criteria for value. Unfortunately, any comparison between yearly take before and after 1951 is confused by the change, but for the sake of continuity, the take from 1951 to the present has been converted into pounds and presented in figures 18 and 19 on this basis along with the data from the years 1917-51. The take of the three principal species--wool, yellow, and grass--are represented in figure 19, which is the graphical representation of table 11.

Take Per Unit of Effort and Historical Analysis

The diving boat is used here as the fishing unit. It usually employs six men and spends about 100 days at sea each year. From sales slips in the Tarpon Springs Sponge Exchange for the 1955 and 1956 landings, it can be calculated that 4.5 hooking boat units land as many sponges in 1 year as one diving boat. Since individual sales by hookers on the Exchange may represent the efforts of just one man, or, as in some cases, the take by two or three small schooners with crews of up to five, the hooking boat unit represents the efforts of more than two men in a dinghy. The consistent use of a ratio of 4.5 hooking boat units to 1 diving boat unit, however, gives as accurate a comparison as is possible to obtain with the available information. When all small boats along the Florida coast are licensed, it will be possible to obtain a ratio of effort of two-man hooking boats to one diving boat.

By dividing the total number of diving boat equivalents into the total catch by pieces or by weight, the average catch per unit of effort can be determined. The results give a good indication of the density of the sponges on the bottom, because the yearly effort, unless severely hampered by weather, will be about the same. In the long run, this information is the most reliable that can be obtained for any analysis of the biological situation.

The data on take per unit of effort are given in table 12 and figure 20. Previous to 1938 there was considerable fluctuation in the return per unit of effort, the average take per diving boat equivalent being about 5,100 pounds. In 1936, the year the beds off the Ten Thousand Islands were first harvested, the return per unit of effort went up. The effect of the 1938 disease was an abrupt drop in the return per unit of effort, which continued to drop as the number of boats increased. Since sponges in deep water had been killed off by the disease, the intensity of the fishing effort on the shallower grounds was greatly increased and was probably about four times that previous to the disease.

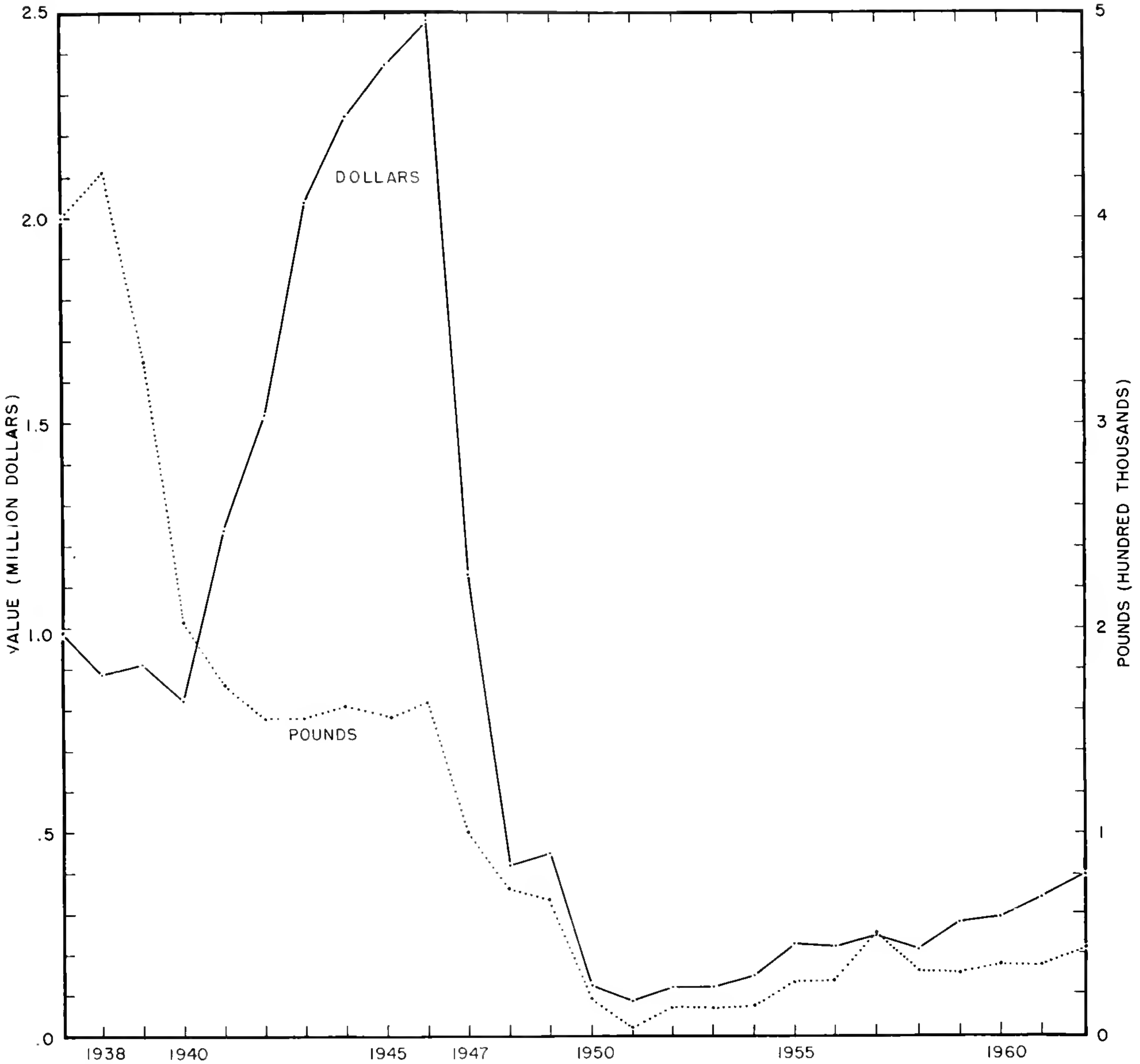

Figure 19.--Total take of wool sponges and value, 1937-62. Line A gives the value of wool sponges alone. Line B gives the total take of wool sponges.

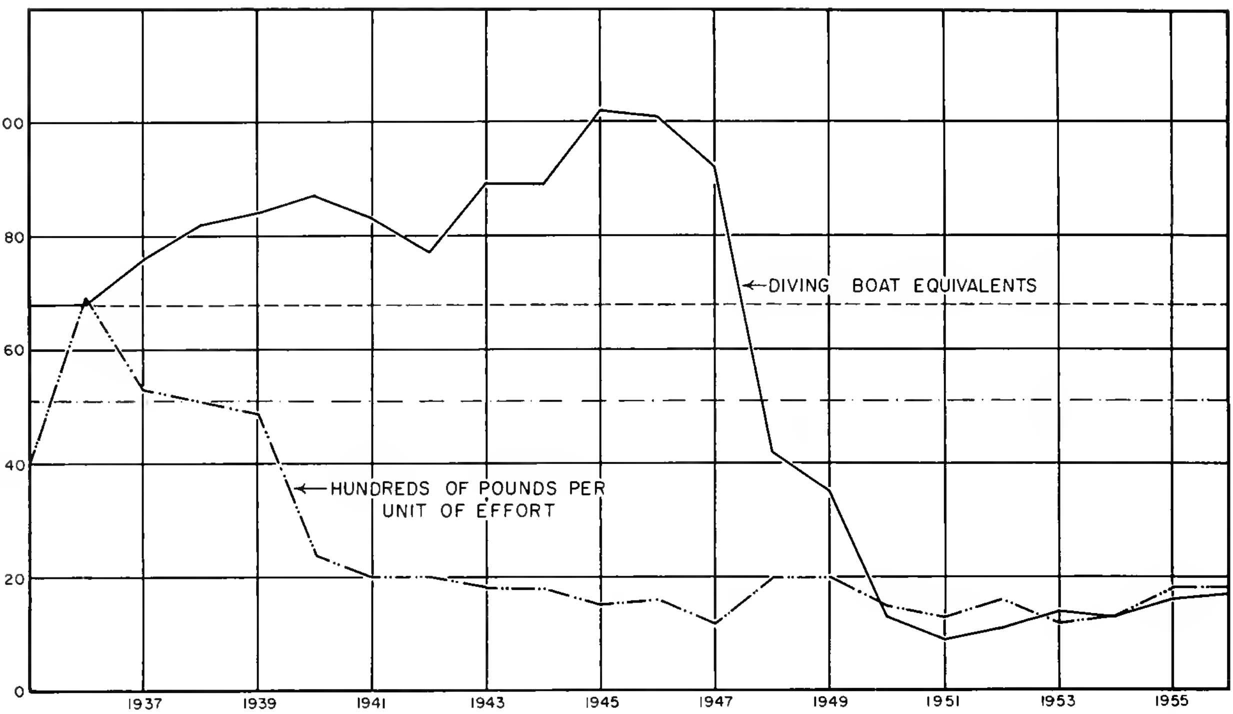

Figure 20.--Take of wool sponges per unit of effort, 1935-56.

This fishing effort was more than the sponging area could bear. In the period 1941-46 we find that the size of the sponging fleet increased 22 percent. If it is assumed that the number of sponges on the bars remained the same, it can be calculated that the return per unit of effort would drop by 18 percent. In actual fact the return per unit of effort dropped by 20 percent (by weight). When it is considered that during this time more and more smaller sponges were being harvested before they could produce eggs, the fishing intensity would probably have severely damaged the sponging grounds. The sudden drop in price immediately after the war in 1946 and the disease of 1947 brought disaster to the industry instead.

It may be assumed from the above discussion that from 1941 to 1946 the number of sponges on the bottom was the same or nearly so at all times. It is possible, therefore, to construct a graph to represent the return per unit of effort for varying sizes of a sponge fleet when this level of concentration of sponges is found. This has been done in figure 21, line A, and the line interpolated to give the return per unit of effort if the sponge fleet in terms of diving boat equivalents were 68. Sixty-eight boats probably represent the average size of the fleet before 1938. Line A thus represents the approximate level of return per unit of effort that is taking place when the concentration of sponges on the sea bottom is below replacement level.

Lines C, D, and E in figure 21 represent the low, average, and high returns per unit of effort found before 1938. Only the solid part of the line is supported by data, the dashed portions being extrapolated. The low return per unit of effort before 1938, line C, may be interpreted as being the lowest possible level of return per unit of effort, and by extension, of the concentration of sponges on the bottom which will allow rapid recovery of the sponging beds. Any return per unit of effort, and concentration of sponges on the bottom, below that represented by line D would be less than the desired level. At this level of concentration and a 68-boat fleet, each boat would be taking about 5,100 pounds of sponges per year, this representing a concentration of 2.8 pounds per acre (5,100

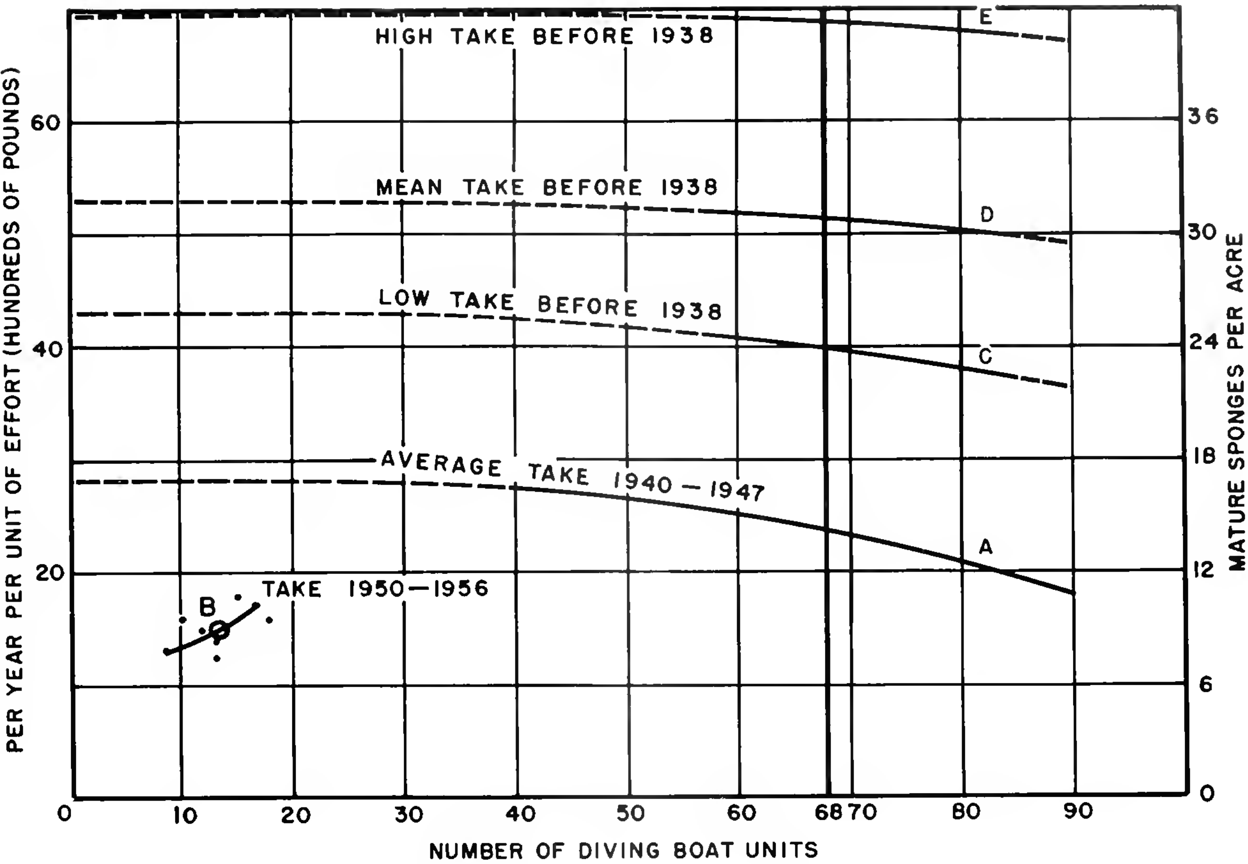

Figure 21.--Levels of take per unit of effort.

divided by 1,800 - the number of acres covered by one diving boat in 1 year) or 31 mature sponges per acre (at a rate of 11 sponges per pound).

The difficulty in attempting to project the return per unit of effort, as represented by line A in figure 21, to a level of 20 boats or less is in trying to determine the point below which changes in the size of the sponging fleet will not affect return per unit of effort. Theoretically any decrease in the number of boats in the sponging fleet should result in a slight increase in the average return per unit of effort if they all work the same areas. Since the boats move in a random pattern while working the sponge bars in any given area, some bars will be worked more than once per year, others only once, and some not at all.

Before 1938 about 68 diving boat equivalents were working the entire productive sponging grounds. At the present time only one-third of the former area is producing sponges. In order to have the same intensity of fishing on the present area only 23 boat equivalents would be required. With the present sponging fleet of just under 17 boat equivalents the intensity of fishing effort is below that of 1938 and about equal to that of a 51-boat fleet working the entire former sponging area.

In region B, figure 21, the individual dots indicate yearly returns per diving boat equivalent; the circle, the average value; and the line, the mean value over the 6-year period, 1951-56. This average take is much below the very lowest return (line C) for the period before 1938 and even below that of the average take during 1940-47 when overfishing was taking place. The best return per unit of effort, however, was considerably higher than indicated by the circle at B. The diving boat making the best return in 1956 landed almost 2,200 pounds of sponges.

On the basis of a concentration of effort equivalent to a fleet of 68 diving boats certain conclusions may be reached. When the take per unit of effort is below 2,400 pounds per year (the 1940-47 average), it should be a clear indication that overfishing is taking place and harvesting is retarding the natural replacement of sponges. The very slow increase in return per unit of effort during the past 6 years supports this contention.

Average return per unit per year of effort during the years 1951-57 was about 1,500 pounds. This indicates a concentration of sponges on the bottom of about 10 per acre in the area worked. This concentration is far too low to bring about any substantial increase in the number of sponges within a short period of time. Line C in figure 21 suggests that a minimum of 24 sponges per acre on the sponging area is close to the lowest concentration necessary for rapid natural repopulation of the beds.

As concentrations of sponges in the present growing area increase, bringing more of the area into economic production, and additional sponging area is added, the fishing effort will be spread more thinly over the sponging grounds. This is based on the assumption and expectation that the sponging fleet will not increase in size because of the limited number of available sponging boats and experienced sponge fishermen. Less concentrated sponging will allow the sponges to increase in size, and the larval producing potential will rise considerably. As a result, concentrations of sponges on the bottom may be expected to increase more and more rapidly.

Probable Sponge Distribution in 5 and 10 Years from 1957

By using what we now know about the reproductive cycle of the sponge, the growth rate, the rate of dispersion, and the current pattern, it is possible to make an estimate of the probable direction and rate of expansion of the wool sponging grounds during the next 5 and 10 years. Several features of the expected future distribution are of considerable interest.

Because of the slowness of the eddy circulation, seaward extension of the sponging grounds all along the western coast from Tarpon Springs to Steinhatchee will be slow indeed. Most, if not all, of the spread into deeper water will have to be by way of an extension of the sponge producing area into the deeper water from the northern eddy, south of Carrabelle.

The most interesting evidence of extension of the sponging area by this northern eddy was gathered on the July 1957 exploratory trip. Five half-hour dives were made at approximately 3-1/2 mile intervals in 50 feet of water directly south of the mouth of the St. Marks River, Stations XXIII and XXIV a, b, c, and d (see fig. 10). The wool sponges collected or seen were as follows:

Station XXIII -	None
Station XXIV a -	Only 2 wool sponges less than 2" in diameter.
Station XXIV b -	11 wool sponges under 5", 3 over 5".
Station XXIV c -	8 wool sponges under 5", 7 over 5".
Station XXIV d -	4 wool sponges under 5", 5 over 5".

No wool sponges were found west of these stations; and although the evidence is limited, the steady change in the ratio of small sponges to large sponges is indicative of wool sponge dispersion to the west of this area.

Once the wool sponges are dispersed as far west as Carrabelle, the meandering southward current running counter to the shore current will be primarily responsible for extension into the deep-water zones.

The only possible exception to the above pattern may be the seaward circulation of water in the area of the sandy zone off the Suwannee River. A boatload of 12- to 14-inch wool sponges was taken in the fall of 1956 on the southern side of this sand area in 55 feet of water. This would indicate that a small area in this region was unaffected by the disease in 1947 and may have been effective in spreading the wool sponges seaward since that time. It was impossible to explore this area completely as the area beyond the 60-foot depth was restricted by the U.S. Air Force as a target range.

Because of the age and physical condition of the divers at the present time, most of the sponging work is done in water less than 40 feet deep. If this situation continues the only useful extension of the sponging area will be that from Rock Island to Carrabelle in the northern part of the sponging grounds. Since the concentration of sponges in commercial quantities in the deeper water to 120 feet cannot be expected for another 15 to 20 years, this does not entail serious consideration by the industry at the present time. Concentration of sponges in quantity in 60 to 70 feet can be expected in the next 5 or 10 years.

Within 5 years (after 1957), the total sponge producing area should increase by 50 percent, of which only 7 percent will lie within the 40-foot depth, the present range of most of the diving boats. Assuming sponge concentration equal to that in the present grounds, the added area will increase production by only 7 percent. A further extension of 40 percent of the then existing area in the next 5-year period will add very little if any available sponging ground, provided divers are still limited to less than 40 feet of water. As the sponges extend into deeper and deeper water, dispersion may progress more quickly as currents of up to 11.5 miles per day are recorded for the area.

A much more important factor to the sponging industry than extension of the beds would be a sizeable increase in the concentration of sponges on the bottom. After careful examination of all the biological data gathered, I believe that an increase from 40 percent to 60 percent in biological production within a 4- to 5-year period may be expected through increased sponge concentration, if more diving boats are not put into operation and no disease or adverse ecological condition occurs.

In the region of the circular eddy just southeast of Cedar Keys, an accurate picture of sponge concentration has been difficult to obtain. Exploration of this area on the field trips did not disclose any large concentration of sponges, but, according to reports by some spongers, there are parts of this area where sponges are to be found in some quantity. One take of 3,000 sponges in 40 to 55 feet from this area had 32 percent larger than 10 inches in diameter.

Within the limits of the present sponge producing area (fig. 11) large sections are not now producing sponges in quantities great enough for economical harvesting. Certainly much of the expected increase in the immediate future must come from increased concentration and filling in of those spots where the sponges are thinly distributed.

The above predictions are based on the assumption that there are uniform currents and uniform survival rates of the sponge larvae from year to year. Temperature patterns, which control egg production, will vary from year to year, as will wind pressure and the resulting changes both in the rate and direction of the currents. It is quite conceivable that conditions one year would result in very unexpected distribution of the sponge larvae in large quantities, while during another year the production of larvae would be small or large numbers would be killed by adverse weather conditions. In the area north of Cedar Keys, the large numbers of sponges less than 2 inches in diameter and the heavy production of larvae by the mature sponges indicate that in 1955 large numbers of sponge larvae settled on the bottom. Also, larval production in 1956 and 1957 was high and should have resulted in the starting of large numbers of sponges. Few small sponges were observed during the field trips on the bars immediately north of St. Martin's Reef Light and in water of less than 40 feet. Few mature sponges in this same area were seen to be producing larvae.

DISCUSSION AND RECOMMENDATIONS

History of Decline in Sales from 1938

During the past 15 to 20 years, synthetic sponges have appeared on the market as a serious competitor for natural sponges. Present retail sales of synthetic sponges are 10 to 15 times that of the trade in natural sponges, and more than $20 million of synthetic sponges are sold each year. The decline in the use of natural sponges can be attributed to several factors.

Before 1938 the sponge industry market for natural sponges in the United States was divided, according to Sponge and Chamois Industry trade reports, as follows:

25 percent went to amateur cleaners and housewives;

25 percent was used by the pottery, tile, shoe, and miscellaneous manufacturers; and

50 percent was sold to professional painters, decorators, and wall washers.

Cheaper grades of sponges, grass and yellow, were used by the amateur cleaners and housewives while the better grades went to various industries. With the start of World War II, imports of sponges from the Mediterranean declined. During the war total landings of sponges in Florida declined about 50 percent as a result of the 1938 disease. With sponges in short supply, the price rose steadily. Immediately after the war, imports of sponges from the Mediterranean were again resumed--over $3 million worth in 1946--with the result that domestic sponge prices were depressed.

During the war increased prices, short supply of natural sponges, and the introduction of an inexpensive synthetic substitute resulted in the natural sponges being unavailable to the amateur cleaners and housewives. High prices also forced industrial users to try synthetic sponges as substitutes so that part of the market was lost in this way as well. In the decorating industry, where the greater percentage of the natural sponges were used, changes in methods and materials, such as the use of paint for ceilings instead of calcimine, and higher wages, which discouraged the preparation of walls by washing, reduced the uses of sponges by about half in this phase of industry.

The two principal objections to the synthetic sponge at the present time are that (1) the plastic material is not as strong as the natural spongin fibers of the wool sponge and (2) the foamlike structure of the synthetic tends to pick up and hold the dirt while the meshwork of the natural sponge allows the dirt to be washed out thoroughly. It is not improbable that a synthetic sponge with the strength and quality of the natural sponge and with the added advantage of controlled shape will in time be developed with fibers so arranged that the synthetic can be as readily and as thoroughly cleaned as the natural sponge. Even if this is accomplished, it would not necessarily mean that a good grade of natural sponge at a competitive price could not find a place in the market for special purposes.

Principal aims of the sponge producer, therefore, should be to solve the problem of keeping the price of the natural product down so that less expensive natural sponges can be reintroduced into the market for the housewife, a market that has remained untouched for the past 15 years. Secondly, there should be an effort made to reduce the price of the better grade wool sponges so that they will be more in line with the competitive price of the synthetic. This can only be done if the sponge producers are willing to adopt more efficient methods of harvesting and better management of the sponge grounds, which in turn will assure a large and continuous supply of sponges at a lower price.

Purposes of Recommendations

My recommendations are made with the following purposes in mind:

1. To increase the number of sponges available for harvesting so that the return to the individual sponge fisherman will increase within a reasonably short length of time.

2. To assure a continued and stable supply of sponges for harvesting so that:

   a. The sponge fishermen will be guaranteed a reasonably steady income in the years to come.

   b. The ultimate dealer can depend on a constant and reliable source of sponges, for without this assurance it would be impossible to build a sound and steady trade.

Just as the individual farmer must follow sound rules and practices for the biological management of his farm if he hopes to be successful, so sponge fishermen should follow a set of rules and practices if they hope to see an increase in the number of sponges on the sea bottom and maintain the maximum harvest of sponges per year that can be grown.

It has been shown both by experimental cultivation of sponges and the observed concentration that is to be found off Cape Sable in south Florida that even when wool sponges are concentrated one or more per square yard there is sufficient food in the water for them to grow at the maximum rate for that area. It follows, therefore, that the basic problem is to find ways and means of increasing the concentrations of sponges on the available, suitable rock bar areas. Other recommendations made below suggest that the efficiency of harvesting methods might be increased and that future biological investigations should be carried out.

Recommendations

Establish a 6-inch size limit.--This recommendation has been made many times in the past but has never been acted upon, presumably because of lack of information on larval production. There has never been any direct evidence presented why a larger size limit is not only desirable but necessary.

The minimum diameter for egg producing sponges, with few exceptions, is 5-1/2 inches in the area north of Cedar Keys and 5 inches in the area between Tampa Bay and Cedar Keys. It is obvious that the present 5-inch size limit allows the taking of a number of sponges which have not yet reproduced or are not reproducing in quantity.

Before a 6-inch size limit is adopted, the immediate disadvantages and future benefits need to be reviewed.

1. Immediate disadvantages.--At my request, the agents of the Conservation Department of the State of Florida made spot checks of the percentages of sponges of less than 6 inches that were being taken by both divers and hookers. Of the sponges examined only 15 percent were wool sponges less than 6 inches in size. This probably represents a minimum percentage, and some of the hooking boats would probably have some catches with as high as 25 percent wool sponges.

   a. Thus, if a 6-inch size limit were adopted, loss in catch would be at least 15 percent but probably not as high as 25 percent. The loss in revenue would be considerably less than this. As priced by the sponge buyers all the sponges of less than 6 inches in size have an average value per piece of less than half that of the average price for wool sponges. Calculations show that the smaller sizes of sponges of 5 to 6 inches do not account for more than 5 percent or 10 percent of the actual cash value of the total take.

   b. In those areas visited by the spongers every year, especially the hooking areas, this loss in revenue would be felt most strongly during the first year after adoption of a 6-inch limit. In the second year those 5- to 6-inch sponges not taken in the area would have grown to harvesting size and the greater return from these larger sponges would offset any loss in actual number of sponges taken during the next year or two.

   c. The diving boats might have to bear a small loss in revenue from the take of sponges of less than 6 inches for a 3-year period since they fish a much larger area for their catch.

   d. The adoption of a 6-inch size limit while sponge populations are increasing would not affect actual income of the sponge fishermen because of normally increasing landings. With expected increases in landing, the 5-year period from 1959 onward seems to be favorable for adopting this recommendation.

2. Future benefits.--a. It has been shown in previous sections of this report that a 6-inch sponge will produce at least enough larvae to make possible the establishing of one and probably more new sponges. Consequently, with a 6-inch size limit, every sponge harvested will have produced enough larvae to replace itself. Unless an area were badly affected by disease or adverse ecological conditions, a 6-inch size limit would enable every sponging area not only to maintain the present concentration but, because there will always be a few larger sponges in each area producing large numbers of larvae, the total number of sponges in each area would steadily increase. No area would be depleted by overfishing alone if a 6-inch size limit were adopted.

b. By the end of the fourth year after the adoption of a 6-inch size limit, a 15- to 25-percent increase in catch could be expected as a result of the spawning of those sponges of less than 6 inches that were not taken during the first year after the size limit was established. This increase would be a permanent one with a likely further increase of over 15 percent every 4 years until an ecological balance is reached.

c. Food supply is not a factor limiting the density of sponges on the bottom. The two possible factors limiting high concentration on the sponging grounds north of Tampa Bay would be available area for attachment and quantity of reproduction. There is much available clean rock with very low competition for space on the plentiful rocky bars in the northern areas formerly densely populated with sponges prior to the disease. Availability of space for attachment and growth of wool sponges is, therefore, not an immediate limiting factor. Late maturing of the sponges as compared with those further south, combined with the harvesting of large numbers of sponges which have never produced eggs, is the only apparent deterrent to increased and heavy concentration. Regrowth from old torn bases and excess of larval production by larger sponges would, it is believed, assure a steady increase in total sponge population up to the carrying capacity of the bars.

Improve fishing techniques.--1. A number of sponge fishermen and scientific workers have suggested that cutting the sponges from the rock would leave a clean base from which a new sponge could grow. It can be calculated that such a method of harvesting could increase production by 30 to 50 percent within a 3-year period.

A number of experiments were carried out to test this possibility. Unfortunately, it was found that more than 50 percent of the sponges were growing on irregular rocky areas and could not be readily cut from the bottom. Instead, after cutting was attempted, the sponges finally had to be torn away, making this type of harvesting wasteful of time and effort. In about 10 percent of the other cases, the sponge came free of its attachment so easily that it would have been torn loose before it was cut. Harvesting sponges by cutting could be most beneficial but, unfortunately, is impractical.

2. Some change should be made in the harvesting methods used by the hookers. The most practical suggestion for increasing the take by the hookers is the adoption of the tested method used by the Florida Key fishermen. This is the use of a larger power craft and three or four hookers working individually from dinghies. In the present hooking method in the northern Gulf, only one man out of two on the smaller boats and only two out of five on the hooking schooners are actually harvesting sponges. In the Florida Key method as many as four men out of five are taking sponges. Individual income could almost be doubled if this latter method was adopted.

3. Although diving equipment is the most efficient gear being presently used, its efficiency could be increased by the use of lightweight diving equipment. Present diving equipment and methods requiring the use of heavy diving gear have one man at a time harvesting sponges to support the entire crew of six. Since most of the diving in the upper Gulf is carried on in 20 to 35 feet of water, lightweight diving equipment, such as was used on the present investigation, could be safely employed. If 16- or 18-foot boats were designed with an inboard engine which could both power the boat and run a compressor for the diver, one or two such boats could be employed as auxiliary craft to the present diving boats. By use of lightweight equipment aboard both the regular diving boat and the auxiliary craft, it would be possible to double or treble the present effort, with very little added running expense. It would mean that two or four more members of the crew would of necessity be divers, in the latter case the size of the crew would be increased.

   In the Cape Sable area such equipment would be particularly useful where the diving is done in less than 25 feet.

   With synthetic foam suits, which could be made for less than $20 each, diving could be carried on with comfort throughout the upper Gulf from March through November.

   Lightweight equipment, such as the air-supplied mask, has already been used with success by individual sponge fishermen working from Tarpon Springs.

Transplant Sponges.--Previously it was shown that sponges transplanted to establish a sponge plantation resulted in large numbers of sponges being established naturally in the area. Transplanting sponges to the area just north of Tampa Bay might be particularly useful. This area from Tampa Bay to Anclote Key is not producing wool sponges except in the shallow water off Indian Rocks and Honeymoon Island. Two thousand or more mature sponges transplanted to the area beginning 3 or 4 miles northwest of the outermost Egmont Channel Buoy and on the bars in a line west from this point from 35 to 70 feet could in time populate the area. Most of the bars in the area have the appearance of excellent sponging bars and the noncommercial sponges growing on them are healthy in appearance. There are no wool sponges upcurrent from this area, however, to bring about repopulation of the bars.

Transplanting of mature sponges should be done at the peak of reproduction, in June and July, for the transplanted sponges would continue to release all the larvae they contained. If the sponges were transplanted at a concentration of 25 or more for each bar, both successful fertilization of the sponges and a high production of larvae each year would be assured. Once established, the sponges even in deeper water of 70 to 90 feet would increase the wool sponge growth in the area of Anclote Key because of the shoreward movement of the current in this area (fig. 11).

Any other area which is at present producing very few sponges could be brought into production much more quickly by using this same method of transplanting large mature sponges from areas of good concentrations. One such area that is in need of repopulating by this means is that to the north and northwest of St. Martin's Reef Light. Before 1947, this area was quite productive.

Institute further biological research on the commercial sponges.--Answers to the following problems would assist in showing additional ways and means of obtaining the greatest possible harvest of commercial sponges from the sponging grounds:

1. The embryology of the commercial sponges is not known in detail. Observation of the larval production suggests that either the spermatozoa enter the sponge in clumps rather than singly or that only certain flagellate chambers in the egg-producing sponges are capable of producing eggs.

2. Much more information is needed on wool sponge larvae. It is not known with

certainty how long the larva lives after being released. It may be presumed that during part of the life span the larva floats at or near the surface as other larvae do, then towards the end of its life span it sinks to the bottom for attachment. Underwater observation of noncommercial sponges closely related to the commercial sponges suggests that larvae are released at various stages after maturation, depending on how deeply they are buried in the matrix of the sponge. A number of these larvae may be released so late in their short life span that they immediately sink to the bottom and attach. What percentage, if any, follow this pattern of behavior would be important to a better understanding of how sponge concentrations are increased.

3. The effect of various concentrations of sponges on rate of reproduction per sponge needs to be studied in more detail.

4. All five stations established for the study of growth have been left intact. I recommend that the necessary arrangements be made to have the spongers not disturb these areas and that they be marked so that the sponges could be remeasured for information on their growth rate.

5. Much more needs to be known about suitable habitats for sponges. Reports from the Key West spongers state that some wool sponges grow beneath the limey mud or are at least covered with mud. Certainly a number of wool sponges will continue to grow even though half buried in limey mud or even fine sand.

The industry is at a critical turning point. There is considerable pressure to expand the sponging fleet, yet the present catch of the best and most efficient diving crew is less than two-thirds the lowest level of take per unit of effort in the 1917-36 period. Increased fishing without a 6-inch size limit will only impede recovery, which at the present time is progressing as fast as one could hope to expect of any biological process.

The adoption of a 6-inch size limit will not solve all the problems besetting the industry by any means but it is the first step in assuring that no area will be overfished and that concentrations of sponges will become greater even with increased fishing effort.

It can be only through the close cooperation between the sponge fishermen, the Tarpon Springs Sponge Exchange, the sponge packers of Tarpon Springs, the large sponge dealers in the north, and the Conservation Department of the State of Florida that a 6-inch size limit could be set and maintained. Unfortunately, everyone concerned must be convinced of the necessity and value of a 6-inch limit before adoption of this law is possible.

ACKNOWLEDGMENTS

A considerable amount of help and encouragement has been received throughout this investigation of the commercial sponges. In particular, mention should be made of Robert Work, who was the assistant during the first year of the investigation. M. Gianaris assisted on two of the field trips. John Maillis of the sponging boat *Elini* did an excellent job during the deep-water field trip in the summer of 1956 and was responsible for collecting sponges for larval examination during the 1956-57 period. A number of other diving boats also collected sponge material during the first year of the investigation. L. Smitzes, President of the Tarpon Springs Sponge Exchange, and M. Dritsos, Secretary of the Sponge Improvement Committee, were both most helpful throughout. R. M. Ingle and other personnel of the Florida State Board of Conservation were generous with both advice and assistance whenever the need arose.

Bud Taylor of Steinhatchee, whose boat, *Rose Bros. II*, was used for all the ecological studies in the field in the northern Gulf, supplied a keen interest, unstinting help, and encouragement in carrying out this phase of the work. Many members of the University of Miami Marine Laboratory (and my wife) assisted in discussing the various aspects of the problem, critical reading of the report, and identification of collected material.

LITERATURE CITED

BLOCK, RICHARD, J., and DIANA BOLLING.
1939. The amino acid composition of keratins. The composition of gorgonin, spongin, turtle scutes, and other keratins. Journal of Biological Chemistry, vol. 127, no. 3, p. 685-693.

BRICE, JOHN J.
1898. The fish and fisheries of the coastal waters of Florida. U.S. Commission of Fish and Fisheries, Part 22, Report of the Commissioner for the year ending June 30, 1896 (1898), p. 263-342.

CARTER, H. J.
1878. XVIII. Parasites of the Spongida. Annals and Magazine of Natural History, ser. 5, vol. 2, no. 8, p. 157-171.

CRAWSHAY, L. R.
1939. Studies in the market sponges. I. Growth from the planted cutting. Journal of the Marine Biological Association of the United Kingdom, vol. 23, no. 2, p. 553-574.

DAWSON, CHARLES E., and F. G. WALTON SMITH.
1953. The Gulf of Mexico sponge investigation. State of Florida Board of Conservation, Technical Series No. 1, 28 p. Marine Laboratory, University of Miami, Miami, Fla.

DE LAUBENFELS, M. W.
1936. A discussion of the sponge fauna of the Dry Tortugas in particular and the West Indies in general, with material for a revision of the families and orders of the Porifera. Papers from Tortugas Laboratory, vol. 30, 225 p. [Carnegie Institution of Washington, Washington, D.C., Publication No. 467].

1953. Sponges from the Gulf of Mexico. Bulletin of Marine Science of the Gulf and Caribbean, vol. 2, no. 3, p. 511-557.

DUBOSCQ, O., and O. TUZET.
1937. L'ovogénèse, la fécondation et les premiers stades du développement des éponges calcaires. Archives de Zoologie Experiméntale et Génerale, vol. 79, no. 2, p. 157-316.

FEINSTEIN, ANITA.
1956. Correlations of various ambient phenomena with red tide outbreaks on the Florida west coast. Bulletin of Marine Science of the Gulf and Caribbean, vol. 6, no. 3, p. 209-232.

GALTSOFF, PAUL S.
1942. Wasting disease causing mortality of sponges in the West Indies and Gulf of Mexico. Proceedings of the Eighth American Scientific Congress, vol. 3, p. 411-421.

MOORE, H. F.
1910a. The commercial sponges and the sponge fisheries. Bulletin of the [U.S.] Bureau of Fisheries, vol. 28, 1908, Part I, p. 399-511.

1910b. A practical method of sponge culture. Bulletin of the [U.S.] Bureau of Fisheries, vol. 28, 1908, Part I, p. 545-585.

RATHBUN, RICHARD.
1887. The sponge fishery and trade. *In* George Brown Goode, The fisheries and fishery industries of the United States, sec. 5, vol. 2, p. 817-841.

SMITH, C. L.
1940. The Great Bahama Bank. I. General hydrographical and chemical features. Journal of Marine Research, vol. 3, no. 2, p. 147-170.

SMITH, F. G. WALTON.
1941. Sponge disease in British Honduras, and its transmission by water currents. Ecology, vol. 22, no. 4, p. 415-421.

1949. Report on a survey of the sponge grounds north of Anclote Light. State of Florida Board of Conservation, 29 p. [Mimeographed.]

SOCIETY OF ECONOMIC PALEONOTOLOGISTS AND MINERALOGISTS.
1955. Finding ancient shorelines. Society of Economic Paleontologists and Mineralogists, Tulsa, Okla., Special Publication No. 3, p. 1-129.

STORR, JOHN F.
1956. The sponge industry of Florida. State of Florida Board of Conservation, Educational Series No. 9, 29 p. Marine Laboratory, University of Miami, Miami, Fla.

U.S. DEPARTMENT OF COMMERCE, COAST AND GEODETIC SURVEY.
1955. Surface water temperatures at tide stations, Atlantic coast, North and South America. *Its* Special Publication No. 278, 69 p., 5th ed.

VAN NAME, WILLARD G.
1954. The Tunicata of the Gulf of Mexico. *In* Paul S. Galtsoff, Gulf of Mexico: its origin, waters, and marine life. U.S. Fish and Wildlife Service, Fishery Bulletin 89, vol. 55, p. 495-497.

VON LENDENFELD, ROBERT.
1889. A monograph of the horny sponges. Trübner and Co., London, 936 p.

APPENDIX

Sponging Grounds (See fig. 15)

AREA A:

1. Carrabelle grounds - from Dog Island to St. Marks. Not visited by the spongers since the 1947-48 season.
2. Econfina grounds - from St. Marks to the mouth of the Econfina River. Part of this ground is known as the Econfina flats.
3. Rock Island grounds - from Econfina River to Keaton Beach. This ground and the Econfina grounds are used primarily by the hook boats at the present time.
4. Piney Point grounds - from Keaton Beach to Grass Island. Used by both the hookers and divers in their assigned depths.

AREA B:

5. North Pepperfish grounds - from Grass Island to Pepperfish Key. This includes the area off the Steinhatchee River. Offshore from the mouth of the river a large quartz sand patch stretches seaward and is about 8 miles wide. There are only a few small rocky bars on which the sponges can grow.
6. South Pepperfish grounds - from Pepperfish Key to the mouth of the Suwannee River. There are few shallow-water rock bars, and the water is often turbid.

AREA C:

7. Cedar Keys grounds - a wide quartz sand strip about 8 miles wide separates these grounds on the north side from the ones above. The strip of sand lies off the mouth of the Suwannee River. The southern limits of the grounds is along a line southwest of Cedar Keys.
8. Cedar Keys High Rocks grounds - this is the portion of the Cedar Keys grounds in less than 40 feet of water.

AREA D:

9. Port Inglis grounds - from a line southwest of Cedar Keys to the mouth of the Crystal River.
10. Big Bank Reef grounds (or St. Martins Reef) from the mouth of the Crystal River to St. Martins Reef Light.
11. Anclote Key - from St. Martins Reef Light to just south of Anclote Key.

AREA E:

12. Highlands grounds - from Anclote Key south to Tampa Bay.

AREA F:

(Very little sponging was ever carried on in the area between Tampa Bay and Sanibel Island. The primary reason for the lack of sponges is the relatively steep slope of the bottom.)

In area F the two most common sponging grounds in the Ten Thousand Islands area are:

13. Pavilion Key grounds - the flat rocky bar and gravel area southwest of Pavilion Key.
14. Shark River grounds - off the mouth of Shark River and Cape Sable. This area was first worked in 1936.

AREA G:

The Keys grounds are confined to very limited areas at the present time. The entire area produced more than half the sponges in the early 1900's when not all of the west Florida coast sponging areas were being exploited. Only those grounds in the Keys area presently producing sponges are listed below. Production is low.

15. Biscayne Bay grounds - between Elliott Key and the mainland.
16. Hawk Channel grounds - primarily along the shallow inshore areas of Key Largo and Plantation Keys.
17. Key West grounds - the most productive areas at present are close to Big Coppett Key on the Florida Bay side of the Keys.

MS #1007

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

As the Nation's principal conservation agency, the Department works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States—now and in the future.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES
WASHINGTON, D.C. 20240

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF THE INTERIOR

Librarian,

Marine Biological Lab.,

128 T Woods Hole, Mass.