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National Marine Fisheries Service

The Calico Scallop, *Argopecten gibbus*

DONALD M. ALLEN and T. J. COSTELLO

SEATTLE, WA
May 1972

National Marine Fisheries Service, Special Scientific Report--Fisheries Series

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The Calico Scallop, *Argopecten gibbus*

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CONTENTS

Figures

Table

The Calico Scallop, *Argopecten gibbus*[1]

By

DONALD M. ALLEN and T. J. COSTELLO, *Fishery Biologists*

National Marine Fisheries Service
Southeast Fisheries Center
Miami Laboratory
Miami, Florida 33149

ABSTRACT

The calico scallop, *Argopecten gibbus*, supports a developing fishery off the southeastern coast of the United States and in the Gulf of Mexico. Information is given on classification, description, distribution, environment, relative abundance, reproduction, age and growth, mortality, associated organisms, behavior, and the fishery.

INTRODUCTION

The calico scallop, *Argopecten gibbus*, a commercially valuable shellfish, is fished in the Atlantic Ocean off North Carolina and Florida and in the northeastern Gulf of Mexico. Development of the fishery has been slow and erratic, due to problems related to stock availability and processing. The apparent large concentrations of scallops off the Florida east coast and the introduction of scallop shucking and eviscerating machines suggest, however, that the harvest of calico scallops will increase in the next few years.

Biologists at the National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, Miami, Fla., are studying the biology of the calico scallop to determine which ecological factors control distribution and abundance and to predict seasonal and annual availability of the harvestable stock. As a first step, this report summarizes available information concerning the biology and the fishery of the calico scallop.

[1] Contribution No. 207, National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, Miami, Fla.

BIOLOGY

Classification

The calico scallop, *Argopecten gibbus* (Linné), is a benthic marine pelecypod mollusk of the family Pectinidae. Formerly known as *Pecten gibbus* or *Aquipecten gibbus*, the species was placed in the genus *Argopecten* by Waller (1969). In the same genus he also placed two closely related species that occur within the range of the calico scallop. These are the nucleus scallop, *Argopecten nucleus* (Born), and the bay scallop, *Argopecten irradians* (Lamarck), which, unlike the calico scallop, are generally restricted to very shallow water in the region of overlapping distribution. Methods of separating these scallops by shell characteristics were given by Waller. A calico scallop is shown in Figure 1.

The shell morphology of the calico scallop varies with locality (Bullis and Ingle, 1959) and perhaps environment (Waller, 1969). The subspecific status of a less convex form, *A. gibbus portusregii*, from buoys off South Carolina was questioned by Waller.

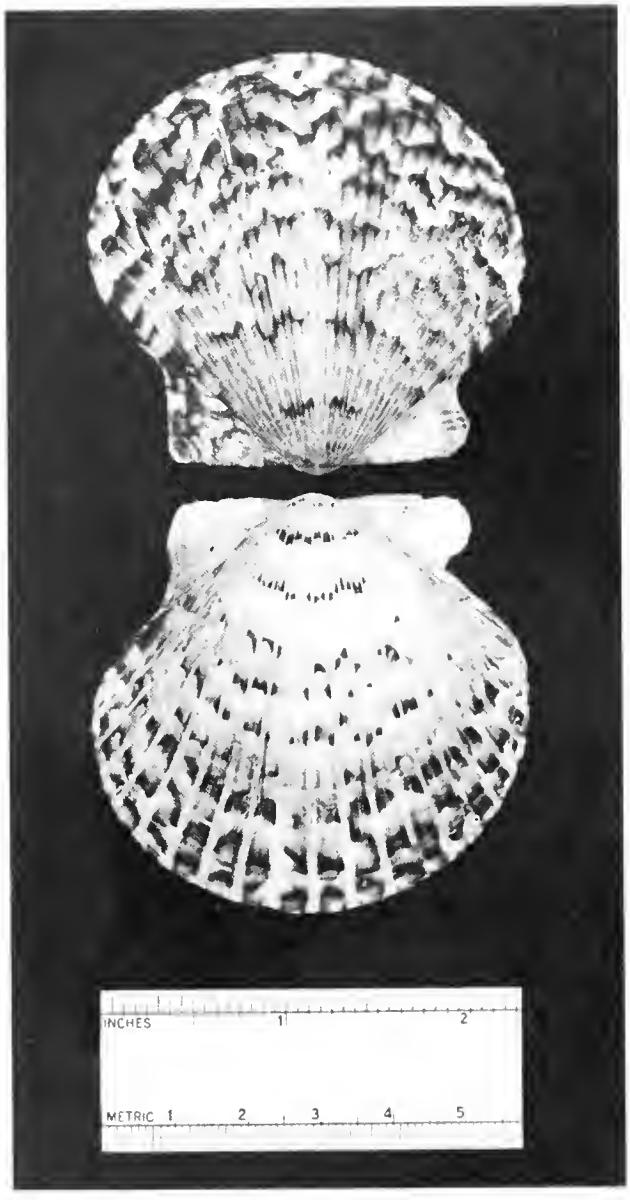

Figure 1.—Calico scallop, showing left valve (top) and right valve (bottom).

Description

A thorough description of the calico scallop shell was given by Waller (1969). He noted that this species generally reaches 40 to 60 mm in shell height (a straight line measurement of the greatest distance between the umbo and the ventral margin). Maximum size reported is about 80 mm in shell diameter (a straight line measurement of the greatest distance between the anterior margin and the posterior margin) (Roe, Cummins, and Bullis, 1971). Shell diameter is about the same as shell height in individual small scallops. As height increases, however, diameter increases more rapidly.[2] The height-diameter relationship for calico scallops ranging from 43 to 61 mm in height was shown by Wells, Wells, and Gray (1964).

Both valves are well inflated and according to Waller (1969) "generally equiconvex to slightly left-convex." The disk outline is "roughly equilateral to slightly produced posteriorly." There are 17 to 23 ribs on the right valve. Waller noted that the color of the left (upper) valve is variable, usually with red or maroon mottling or banding on a white or yellow background. The right (lower) valve is more lightly pigmented with the same colors as the left valve.

Distribution

The calico scallop apparently is restricted to the western North Atlantic Ocean. Distribution of this species is shown in Figure 2. Its known range extends from the northern side of the Greater Antilles and throughout the Gulf of Mexico to Bermuda and slightly north of Cape Hatteras (Waller, 1969; Kirby-Smith[3]; Merrill[4]). According to Waller, however, the "precise southern limit" of the calico scallop is obscured by confusion with other species. Calico scallop shells, but no living animals, were found off Delaware Bay (Merrill, see footnote 4). Although this species might be expected from the Bahama Islands, its occurrence there has not been verified.

This scallop, generally found on continental or insular shelves, was reported from depths less than 2 m (Kirby-Smith, see footnote 3) to 370 m (Waller, 1969). The depths of occurrence vary with locality. Near the southern end of its range, on the northern side of the Greater Antilles, this species was caught in depths of 22 to 26 m

[2] Unpublished data on file at the National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, Miami, Fla. 33149.

[3] William W. Kirby-Smith, Duke University Marine Laboratory, Beaufort, N.C. Personal communication, 1971.

[4] Arthur S. Merrill, Laboratory Director, National Marine Fisheries Service, Northeast Fisheries Center, Oxford Laboratory, Oxford, Md. Personal communication, 1971.

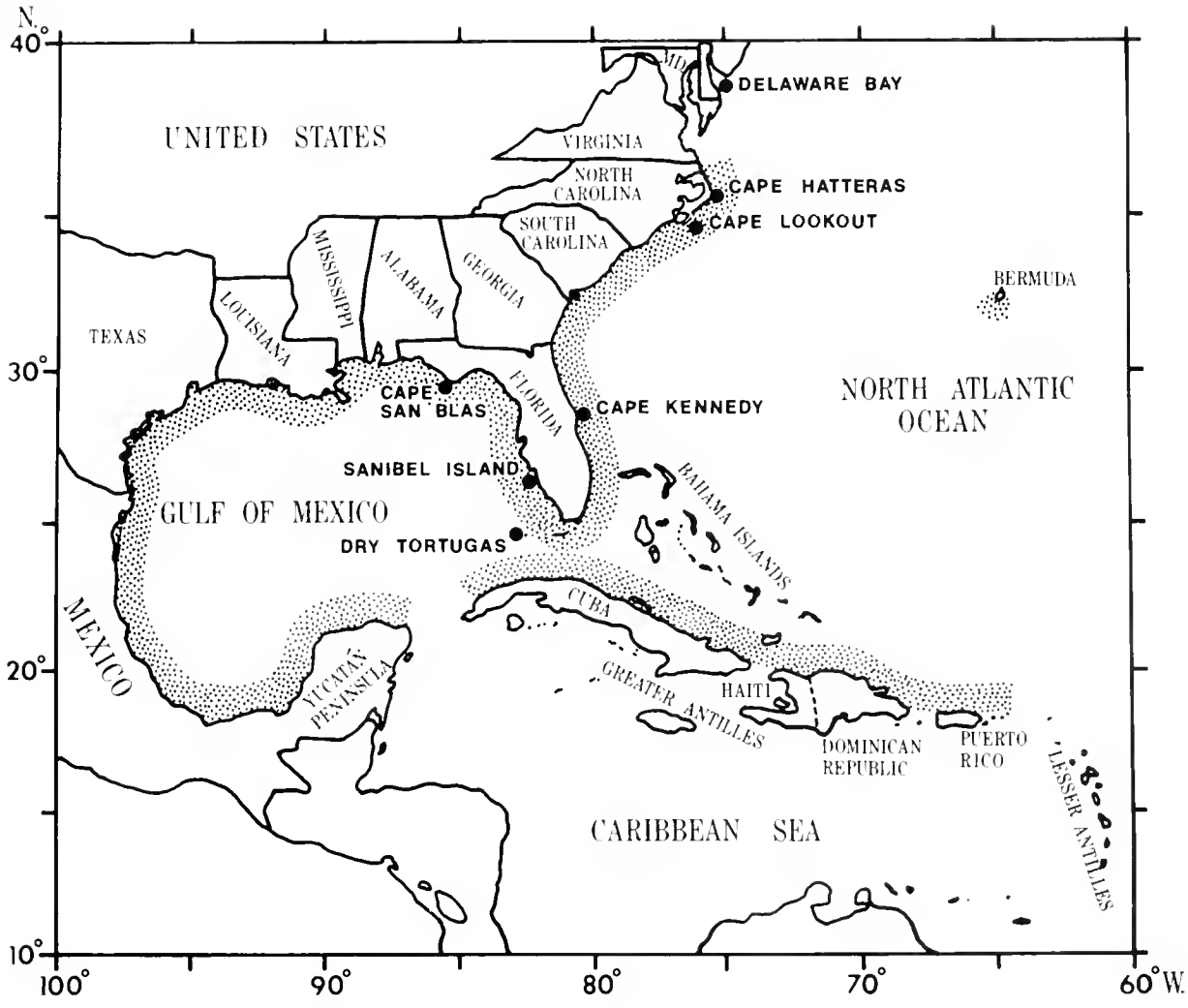

Figure 2.—General distribution of the calico scallop is shown by the stippled area.

(Waller)[5] and 277 m (Waller, 1969). In the southeastern Gulf of Mexico, off the Yucatán Peninsula, it was reported from 37 m (Springer and Bullis, 1956) to 78 m (Rice and Kornicker, 1965). In the northern Gulf, this species is common in depths of 32 to 65 m (Parker, 1960); and in the northeastern Gulf, it was reported from 11 to 93 m (Carpenter, 1967). In the eastern Gulf, calico scallops were found in depths from 6 m (Bullis and Thompson, 1965) to 46 m (Bullis and Ingle, 1959). Off the Florida east coast, the calico scallop was reported from 9 to 74 m by Drummond (1969), although maximum depth of occurrence in this area may be greater (Cummins).[6] Off North Carolina, south of Cape Hatteras, calico scallops were found from about 13 m (Bullis and Thompson, 1965) to at least 94 m (Cummins, Rivers, and Struhsaker, 1962). At the northern end of its range, north of Cape Hatteras, reported depths of occurrence range from 33 to 44 m (Merrill, see footnote 4). At Bermuda, the calico scallop occurs in less than 2 m of water (Kirby-Smith, see footnote 3).

The calico scallop inhabits open marine water and does not usually occur in estuarine areas as do the nucleus scallop and the Atlantic bay

[5] Thomas R. Waller, Associate Curator, Division of Invertebrate Paleontology, Smithsonian Institution, Washington, D.C. Personal communication, 1970.

[6] Robert Cummins, Jr., Chief, National Marine Fisheries Service, Southeast Fisheries Center, Brunswick Laboratory, Brunswick, Ga. Personal communication, 1971.

scallop (Waller, 1969). At Bermuda, however, calico scallops were found in an almost completely enclosed sound (Neumann, 1965; Kirby-Smith, see footnote 3).

Environment

Factors that probably influence distribution and/or growth of the calico scallop include currents, temperatures, salinities, substrates, and food supply.

Currents may be of primary importance in controlling distribution of scallop larvae and, ultimately, the positioning of the scallop beds. Kirby-Smith (1970) suggested that North Carolina populations of scallops may be at least partially maintained by larvae transported from Florida scallop grounds via the Gulf Stream. The greatest concentrations of calico scallops are found near coastal prominences such as Cape San Blas and Cape Kennedy, Fla.; and Cape Lookout, N.C. Bullis and Cummins (1961) suggested that the Cape Kennedy projection causes "interruption and eddying" that produces "repetitive settling of scallop larvae . . . creating a permanent resource." The scallop beds are generally distributed along the flow lines of currents (National Marine Fisheries Service)[7] and are thus oriented parallel to the coastline. On the Cape Kennedy grounds, scallops are irregularly distributed but "occur in long narrow bands" (Bullis and Cummins, 1961). Some bands or beds are more than 800 m long and several hundred meters wide (Roe, Cummins and Bullis, 1971). An elliptical-shaped bed 16 km long near Cape Lookout was reported by Cummins, Rivers, and Struhsaker (1962). A bed 16 km long and 8 to 16 km wide near Cape San Blas was reported by Bullis and Ingle (1959).

The importance of temperature in controlling reproduction and survival, and thus geographic distribution, of marine bivalves, including the calico scallop, was emphasized by Pulley (1952). Waller (1969) suggested that calico scallop distribution is limited primarily by temperature. According to Parker (1956), the calico scallop is one of a faunal assemblage in the northern Gulf of Mexico that inhabits waters deep enough to avoid winter cooling. Bottom temperatures associated with calico scallops range from 9.9°C (Merrill, see footnote 4) to 33.0°C (Waller, 1969). Vernberg and Vernberg (1970) observed, however, that calico scallops collected near the northern end of their range, off North Carolina, did not survive 48-hr exposure to laboratory water temperatures of 10°C, and have "tropical affinities." Near Cape Lookout, a calico scallop bed was "usually dominated by Carolinian coastal waters" (Wells, Wells, and Gray, 1964), although bottom temperatures in this area show considerable fluctuation in conjunction with winter and spring meanders of the Gulf Stream (Grassle, 1967). North of Cape Hatteras, the existence of calico scallops may coincide with a mass of relatively warm water (Merrill, see footnote 4).

Salinities from areas where calico scallops occur are fairly stable and range from about 31 to 37‰ (Anderson, Moore, and Gordy, 1961; Hulings, 1961; Grassle, 1967; Pequegnat and Pequegnat, 1968).

The substrates required or preferred by the calico scallop may vary with scallop size. Young scallops up to about 25 mm in height are found byssally attached to whole or broken mollusk shells. Although commonly attached to dead scallop shells (Commercial Fisheries Review, 1962), they are also found on dead shells of other mollusks (Allen)[8] and on live scallop shells (Wells, Wells, and Gray, 1964). Shells may be necessary for successful settlement of small scallops (Kirby-Smith, 1970), but spat may compete with adults for optimum substrate (Roe, Cummins, and Bullis, 1971).

Larger scallops, usually unattached, are reported from bottoms composed of hard sand (Rivers, 1962a), sand and shell (Sastry, 1962; Cummins, Rivers and Struhsaker, 1962), quartz sand (Hulings, 1961), smooth sand-shell-gravel (Struhsaker, 1969a), fairly clean, medium-

[7] National Marine Fisheries Service (in cooperation with state, industry, and university groups in Florida, Georgia, South Carolina, and North Carolina). 1971. Joint plan for the calico scallop fishery. Unpublished report, 115 p., filed at the National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, Miami, Fla. 33149.

[8] Allen, D. M. 1971. Ecology of the calico scallop, *Argopecten gibbus*, as determined by spat monitoring. Unpublished manuscript filed at the National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, Miami, Fla. 33149.

grained quartz sand (Hulings and Hemlay, 1963), and sand and dead shell (Drummond, 1969). Grassle (1967) found calico scallops associated with a mud sediment that contained a high percentage of quartz and shell.

Essentially nothing is known concerning the food requirements of the calico scallop. This subject was discussed by Kirby-Smith (1970), who suggested that zooplankton may be an important source of nutrition. Where scallop abundance is greatest, plankton concentration may be high, since upwelling in the general areas of Cape San Blas, Cape Kennedy, and Cape Lookout is reported respectively by Gaul, Boykin, and Letzring (1966), Taylor and Stewart (1959), and Wells and Gray (1960).

On the Cape Kennedy grounds, the locations of individual scallop beds vary from year to year and probably are determined by environmental conditions which control setting and survival of larval scallops (National Marine Fisheries Service, see footnote 7). Personnel of the Miami Laboratory are attempting to relate scallop abundance and growth to substrate types, and to water temperatures and currents now being monitored on the Cape Kennedy grounds.

Relative Abundance

The relative abundance of calico scallops varies between areas. The greatest known abundance is located off the Florida east coast near Cape Kennedy, with lesser concentrations near Cape Lookout, N.C., and in the northeastern Gulf of Mexico near Cape San Blas, Fla. Concentrations were also reported from the eastern Gulf of Mexico between Sanibel Island and Dry Tortugas (Bullis and Ingle, 1959; Carpenter, 1967). Generally fewer scallops are found elsewhere within the calico scallop range.

Abundance also varies within areas. Young calico scallops in the northeastern Gulf of Mexico were more abundant on fouling arrays anchored 18 km offshore in 31 m than on those anchored 3 km offshore in 19 m and 40 km offshore in 46 m (Pequegnat and Pequegnat, 1968). Variations in average abundance of commercial size scallops off the Florida east coast for 1960 to 1966 were given by Drummond (1969) as follows: Scallops were most abundant on the southern portion of the grounds in 28 to 65 m (Fig. 3). At these depths, the average rate of catch with a 2.4-m (8-ft) scallop dredge ranged from 3.9 to 12.8 bu per hour. For these catches, 1 bu equaled 36 kg (80 lb.) of scallops in the shell. The rate of catch was highly variable; within one area, catches ranged from 0 to 54 bu per hour. Within a scallop bed, also located off the Florida east coast, average scallop densities were about 43 individuals per square meter (4 per square foot) (Cummins, 1971), but densities may exceed 108 per square meter (10 per square foot) (Roe, Cummins, and Bullis, 1971).

Abundance varies with scallop size, although this is poorly documented. Dense concentrations of scallop spat are caught in spat traps, e.g., 107 individuals per liter (3,000 per cubic foot) per 2-month period (Allen, see footnote 8). While density of spat set naturally on the bottom is probably much less, catches of small scallops with dredges at times exceed catches of large individuals (Commercial Fisheries Review, 1968).

Abundance varies both seasonally and annually. Monthly changes in scallop abundance by area off the Florida east coast were shown by Drummond (1969). On these grounds, abundance (as measured by catch rate) was highest from September to December in 1967 and 1968 (Roe, Cummins, and Bullis, 1971). Abrupt yearly differences in scallop abundance have been reported for the grounds off North Carolina (Cummins, 1971; Lyles, 1969) and in the northeastern Gulf of Mexico (Bullis and Ingle, 1959; Hulings, 1961).

Reproduction

The calico scallop is hermaphroditic. When this species spawned in the laboratory, the sperm and eggs (in that order) were ejected separately into the water where fertilization took place (Costello et al.).[9]

We observed, based on gonadal color (see below), that some calico scallops as small as 19 mm in height are ripe, which indicates either ripeness at a very early age or that these small scallops are older than suspected (see footnote 2). Roe, Cummins, and Bullis (1971) stated that spawning of the calico scallop "is related to age rather

[9] Costello, T. J., J. H. Hudson, J. L. Dupuy, and S. Rivkin. 1971. Larval development of the calico scallop, *Argopecten gibbus*. Unpublished manuscript filed at the National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, Miami, Fla. 33149.

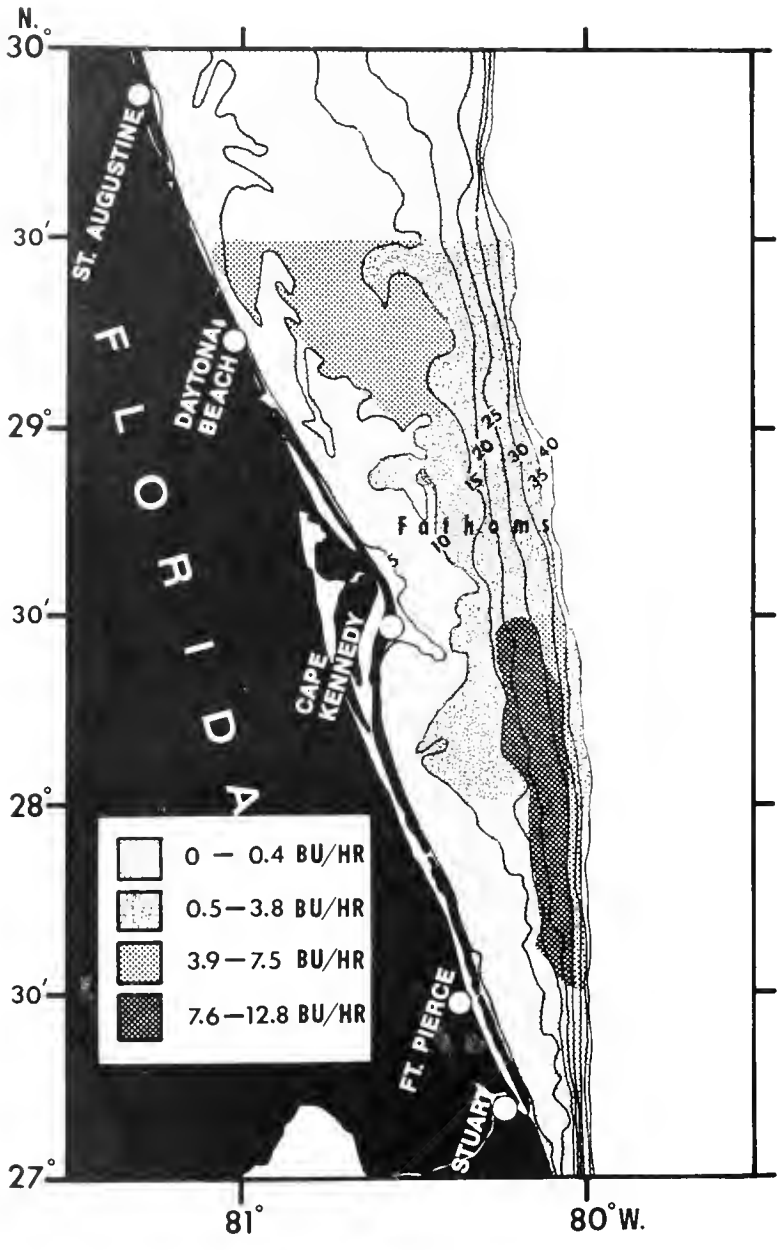

Figure 3.—Relative abundance of the calico scallop, Cape Kennedy grounds, 1960-1966. One fathom equals 1.8 m. (Modified from Drummond, 1969.)

than size," and suggested that spawning can begin at a young age.

Spawning in the calico scallop, similar to that in certain other bivalves, is perhaps controlled primarily by water temperatures and may be initiated by rising temperatures (Roe, Cummins, and Bullis, 1971). The gonads of scallops caught on the Cape Kennedy grounds in October 1969 and maintained in the laboratory at about 25°C changed color from light pink to orange-red within 2 weeks. These scallops were then induced to spawn (Fig. 4) by rapidly raising the ambient water temperature to 30°C (Miller and Drummond).[10] Conversely, low temperatures may terminate spawning (Roe, Cummins, and Bullis, 1971).

Several methods have been used to determine the seasonal pattern of spawning of the calico

[10] Miller, G. C., and B. R. Drummond. 1969. Report on gonadal color change and spawning of calico scallops at TABL, October 23-November 13, 1969. Unpublished report, 5 p., filed at the National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, Miami, Fla. 33149.

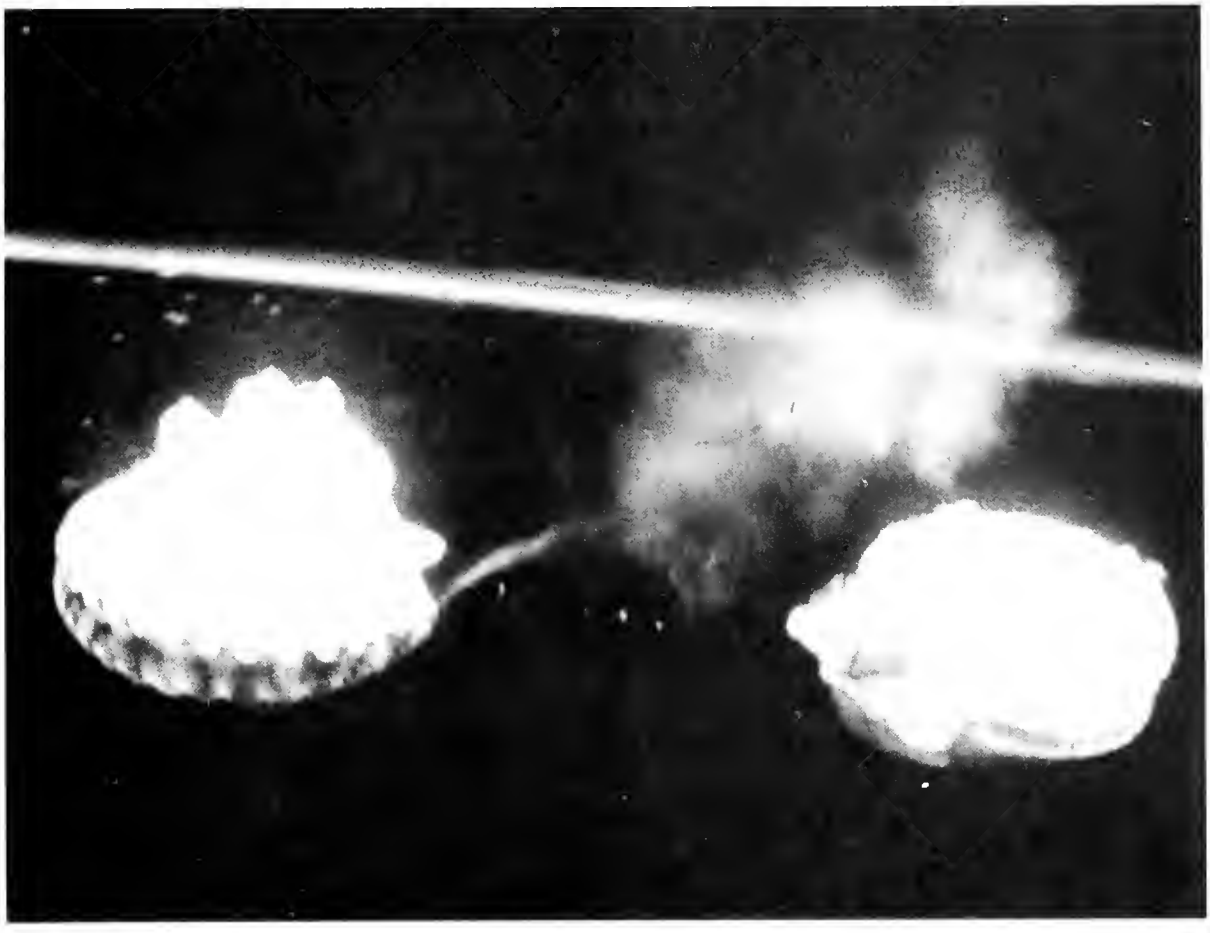

Figure 4.—Spawn, ejected by the calico scallop on the left, appears as a milky cloud. (Photo by George C. Miller, National Marine Fisheries Service.)

scallop. The color of calico scallop ovaries varies with the degree of ripeness and is useful to determine maturation and spawning time. Resting ovaries are whitish-yellow, maturing ovaries are yellow-orange, and ripe ovaries are bright reddish-orange, according to Roe, Cummins, and Bullis (1971). The seasonal distribution of scallops of known age may also provide some insight concerning spawning time. Preliminary growth data for young scallops (see section on Age and Growth) suggest that scallops 2 months old are about 17 mm in shell height. Consequently, occurrence of scallops of this size or smaller may indicate recent spawning. In addition, spawning time may be determined by exposure of spat collecting traps for known time periods throughout the year (Fig. 5).

Techniques dependent upon the minimum sizes of scallops and on the catches of spat traps may not be valid for determining spawning time for a particular area if scallop larvae are transported into the area from great distances as suggested by Kirby-Smith (1970).

Off the Florida east coast, maturation, based on ovarian color, begins in late summer and culminates in the spring, with spawning extending from late February to June (Roe, Cummins, and Bullis, 1971). These authors concluded, however, that protracted spawning occurs in some areas because small scallops were found throughout most of the year. Our observations on ovarian color, minimum sizes, and spat trap collections also indicate that some spawning occurs year around (see footnote 2).

Off North Carolina, observations on scallop gonads indicated that spawning took place from May to June (Kirby-Smith, 1970). Small scallops 10 mm or less in height, however, were

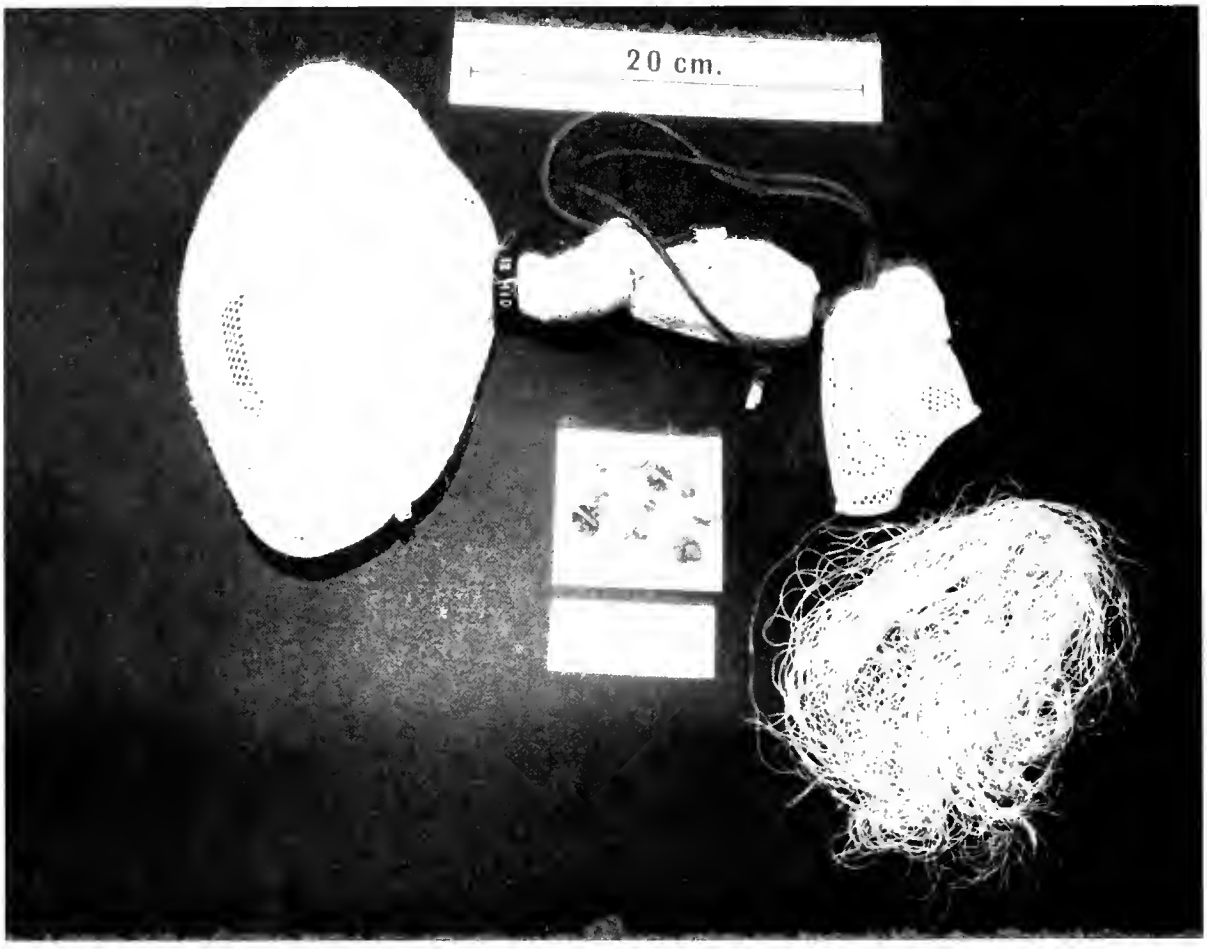

Figure 5.—A spat trap is a nylon mesh bag (top) containing unlaid polyethylene line (bottom right). Young scallops enter the bag as larvae, grow, and are permanently trapped when their size (center) exceeds that of the mesh opening. Spat traps are used to monitor spawning success by season and area.

observed in April (Wells, Wells, and Gray, 1964); in May (Commercial Fisheries Review, 1962); and in May, June, and October (Kirby-Smith, 1970). According to Kirby-Smith (1970), the fall occurrence of small scallops in the absence of local spawning may indicate larval transport into North Carolina waters.

In the northeastern Gulf of Mexico, gonads of calico scallops were highly developed in the spring, and spawning was presumably finished by late summer, according to Bullis and Ingle (1959). Small calico scallops,[11] however, were found attached to fouling arrays from September to July (Pequegnat and Pequegnat, 1968).

In the eastern Gulf of Mexico, calico scallops about 12 mm in shell height were abundant in late July (Joyce),[12] indicating that spawning occurred at least in the late spring or early summer.

Age and Growth

Rate of growth of the calico scallop probably varies with size, season, and environment.

Larval development was described from laboratory studies (Costello et al., see footnote 9). These authors reported that the length of planktonic larval life from fertilization to settlement

[11] Specimens reported as *Aquipecten gibbus nucleus* by Pequegnat and Pequegnat (1968) were later identified as *Argopecten gibbus* (Waller, see footnote 5).

[12] Edwin A. Joyce, Jr., Supervisor, Marine Research Laboratory, Florida Department of Natural Resources, St. Petersburg, Fla. 33731. Personal communication, 1971.

is about 14 days and that the spat are about 0.25 mm in shell height when first set.

A few observations have been made on the shell growth of young calico scallops following setting. Calico scallops (apparently small specimens) collected from fouling arrays in the northeastern Gulf of Mexico grew at a minimum rate of 3.1 mm (presumably in shell height) per week in April (Pequegnat and Pequegnat, 1968). Off the Florida east coast, young calico scallops found in spat collecting traps after 10 weeks' exposure time had a maximum size of 27 mm in shell height (Allen, see footnote 8).

Shell growth of large scallops was estimated by Bullis and Ingle (1959) for calico scallops caught in the northeastern Gulf of Mexico. From reportedly "inadequate" size frequency data, they tentatively estimated that scallops averaging 54 mm (probably in shell diameter) were 24 months old.

Growth of calico scallops from the North Carolina grounds was estimated using several techniques and reported as increases in shell depth by Kirby-Smith (1970). In this case, shell depth refers to shell height (Kirby-Smith, see footnote 3). For scallops ranging from about 19 to 28 mm in height, maximum growth (converted from the daily rate) was 2.2 mm per month. Calico scallops from North Carolina that ranged from 43 to 61 mm in shell height were estimated to be 2 years old (Wells, Wells, and Gray, 1964).

Roe, Cummins, and Bullis (1971) estimated growth rates from size frequencies of calico scallops collected off the Florida east coast. They reported that growth (in shell diameter) increases rapidly up to about 50 mm. For scallops having mean sizes from 13.9 to 37.8 mm, average growth was 4.0 mm per month. For scallops having mean sizes from 63.5 to 65.5 mm, average growth was 0.3 mm per month. These authors concluded that the calico scallop becomes senile at a size of 75 to 80 mm, that maximum size is 80 mm, and that maximum age averages 18 to 20 months and does not exceed 24 months.

In a recent innovation, calico scallops were marked with a quick-setting cement to measure growth increments over known time periods (Hudson).[13] Preliminary studies on the Cape Kennedy grounds indicate that marked scallops reach 40 to 45 mm in shell height in 6 to 8 months (Miller and Hudson).[14] Age-growth estimates shown by Weeks (1970) are in error.

Mortality

The disappearance of calico scallops from an area is common (Bullis and Ingle, 1959; Hulings, 1961; Commercial Fisheries Review, 1962; Kirby-Smith, 1970; Roe, Cummins, and Bullis, 1971; Porter and Wolfe, in press; Joyce, see footnote 12) and has often been attributed to mortality or migration, although the ability of calico scallops to migrate has not been shown. Mortality or poor recruitment is indicated when only empty scallop shells are found on formerly productive scallop grounds.

Very heavy natural mortality of calico scallops was reported to occur in late winter on the northern two-thirds of the Cape Kennedy grounds (Bullis and Cummins, 1961). The joined valves containing scallop flesh indicated very recent mortality. At the same time, live scallops were fairly abundant on the southern third of the Cape Kennedy grounds. Therefore, these authors concluded that factors affecting mortality may be limited to distinct areas.

The causes of mass mortalities of calico scallops are not known. Near Cape Hatteras, N.C., where calico scallops occur, drastic fluctuations of water temperature may cause mortalities of benthic invertebrates (Cerame-Vivas and Gray, 1966). Some mortalities may be a result of predation. For example, sea stars (*Asterias*), which have been observed feeding on scallops, occur in vast numbers on the Cape Kennedy grounds (Roe, Cummins, and Bullis, 1971). Extremely large scallops which are "often in poor condition" and may be "at the end of their life span" are present year around on the Cape Kennedy grounds; the adductor muscle in these scallops is small, discolored, and often too weak to close the shell (Bullis and Cummins, 1961). According to Carpenter (1967), calico scallops in the northeastern Gulf of Mexico die in the late summer, "presumably after spawning" and following

[13] Hudson, J. H. Marking scallops with quick-setting cement. Submitted to Proc. Natl. Shellfish Assoc. for 1971, vol. 62, 7 MS p.

[14] Miller, G. C., and J. H. Hudson. 1971. Growth of calico scallops, *Argopecten gibbus*. Unpublished manuscript filed at the National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, Miami, Fla. 33149.

a decrease in the size of the adductor muscle. There were also indications of a postspawning die-off on the Cape Kennedy grounds (Roe, Cummins, and Bullis, 1971).

For the Cape Kennedy grounds, average monthly mortality rates, primarily natural, calculated for the period December to October were about 20% (Roe, Cummins, and Bullis, 1971).

Associated Organisms

Plants and animals associated with the calico scallop undoubtedly influence its setting, growth, and survival.

Calico scallops have been reported to occur in beds of turtle grass, *Thalassia testudinum*, in Bermuda (Kirby-Smith, see footnote 3).

Marine animals associated with the calico scallop are categorized as follows: epifaunal and endofaunal community (Wells, Wells, and Gray, 1964); benthic invertebrates (Grassle, 1967); crustaceans (Hulings, 1961); mollusks (Wells, Wells, and Gray, 1961; Hulings and Hemlay, 1963; Porter and Wolfe, in press); echinoderms (Wells, Wells, and Gray, 1961, 1964; Hulings and Hemlay, 1963; Gray, Downey, and Cerame-Vivas, 1968); and fishes (Moe, 1963; Anderson and Gehringer, 1965; Struhsaker, 1969a). A few animals associated with calico scallops on the Cape Kennedy grounds are shown in Figure 6.

Marine invertebrates that live on and in the calico scallop "probably reduce growth or reproductive potential . . . rather than cause the scallop's death," according to Wells, Wells, and Gray (1964). Sindermann (1971) reported, however, that "barnacles, tube worms, and corals can reduce survival of calico scallops." We have noted that fouling by barnacles may prevent complete closure of the valves and thus predators can be admitted more easily (see footnote 2).

Invertebrates reported as parasites (in some cases, commensals) of the calico scallop are a nematode *Porrocaecum pectinis* (Hutton, 1964); a trematode *Proctoeces* sp. (Sindermann)[15]; the polychaetes *Ceratonereis tridentata* and *Polydora websteri* (Wells and Wells, 1962); the decapod crustaceans *Pontonia margarita* and *Pinnotheres maculatus* (Wells, Wells, and Gray, 1964); and the gastropod mollusks *Odostomia seminuda* (Wells and Wells, 1961) and *Odostomia bisutalaris* (Cheng, 1967).

Predators of the calico scallop are poorly known and observations on food habits of the many associated species would be useful. Reported as known predators are the starfishes *Astropecten articulatus* (Wells, Wells, and Gray, 1961) and *Asterias* (Roe, Cummins, and Bullis, 1971), and puffers *Sphoeroides* (Roe, Cummins, and Bullis, 1971). Scallops held in cages on the Cape Kennedy grounds were drilled by unidentified gastropod mollusks (see footnote 2).

Reported as possible predators are the gastropod mollusks *Cantharus multangulus* and *Murex fulvescens* (Wells, Wells, and Gray, 1964); and the thorny stingray *Dasyatis centroura* (Struhsaker, 1969b). In addition, the Florida horse conch *Pleuroploca gigantea* and an unidentified octopus may be predators (see footnote 2).

Behavior

Calico scallop larvae are planktonic and apparently occur at all levels in the water column since young scallops were found attached to fouling arrays distributed from surface to bottom in 46 m of water in the northeastern Gulf of Mexico (Pequegnat and Pequegnat, 1968).

Small calico scallops attach byssally to a variety of surfaces, including mollusk shell, tile, and various synthetic materials. Although byssal attachment is most pronounced in small scallops (those less than about 25 mm in height), scallops up to about 54 mm in height attached to a fiber glass-coated water table (Allen, see footnote 8).

Several observations have been made on the swimming activity of the calico scallop. According to Mellon (1969), the calico scallop "has heavy valves and swims only rarely." Zahl (1969) reported, however, that the calico scallop is a "champion" swimmer. From a submersible on the Cape Kennedy grounds, "sporadic" swimming by some calico scallops was noted al-

[15] Carl J. Sindermann, Laboratory Director, National Marine Fisheries Service, Northeast Fisheries Center, Sandy Hook Laboratory, Highlands, N.J. 07732. Personal communication, 1970.

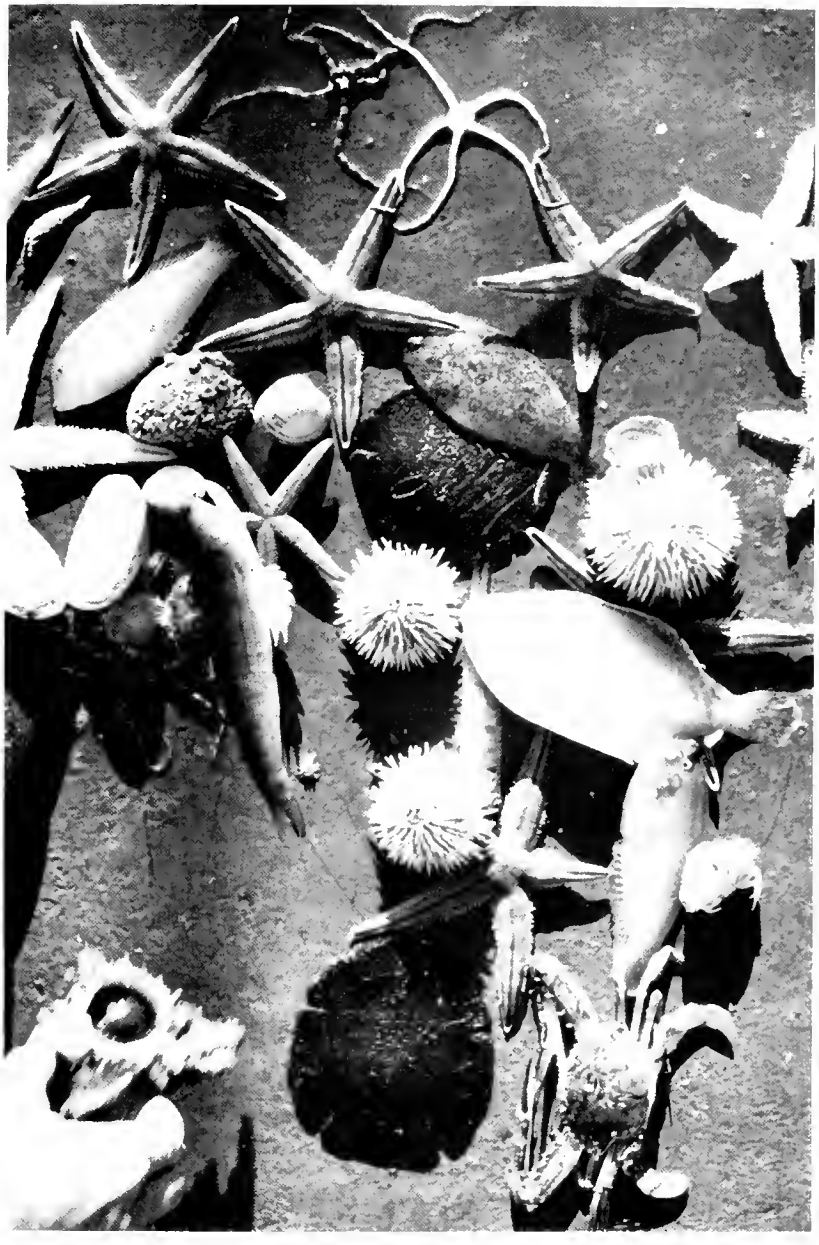

Figure 6.—Animals associated with calico scallops on the Cape Kennedy grounds, Florida, include shrimp, crabs, gastropod and bivalve mollusks, starfish, brittle stars, sea urchins, sand dollars, and fish. (Photo by George C. Miller, National Marine Fisheries Service.)

though most remained inactive.[16] Swimming ability, however, may be enhanced by the relatively flat, lightweight valves of small scallops as compared with the convex, heavy valves of large scallops (Waller, 1969) which are often heavily fouled (Cummins, see footnote 6). In the laboratory, small scallops swim more readily than large scallops (Fig. 7). On the Cape Kennedy grounds, scallops 10 to 20 mm in shell diameter swam "up to the camera" of RUFAS (Remote Underwater Fisheries Assessment System)[17] and scuba divers observed a scallop about 40 mm in shell height swim to 1 m off the bottom (see footnote 2). From a submersible, lying in a dense concentration of adult scallops on the Cape Kennedy grounds, a few individuals were

[16] Bureau of Commercial Fisheries (now National Marine Fisheries Service), Brunswick, Ga., Quarterly Report 12/31/69.

[17] Bureau of Commercial Fisheries (now National Marine Fisheries Service), Pascagoula, Miss., RV *George M. Bowers* Cruise 93, 6/1-3 and 6/17-25/70, July 10, 1970.

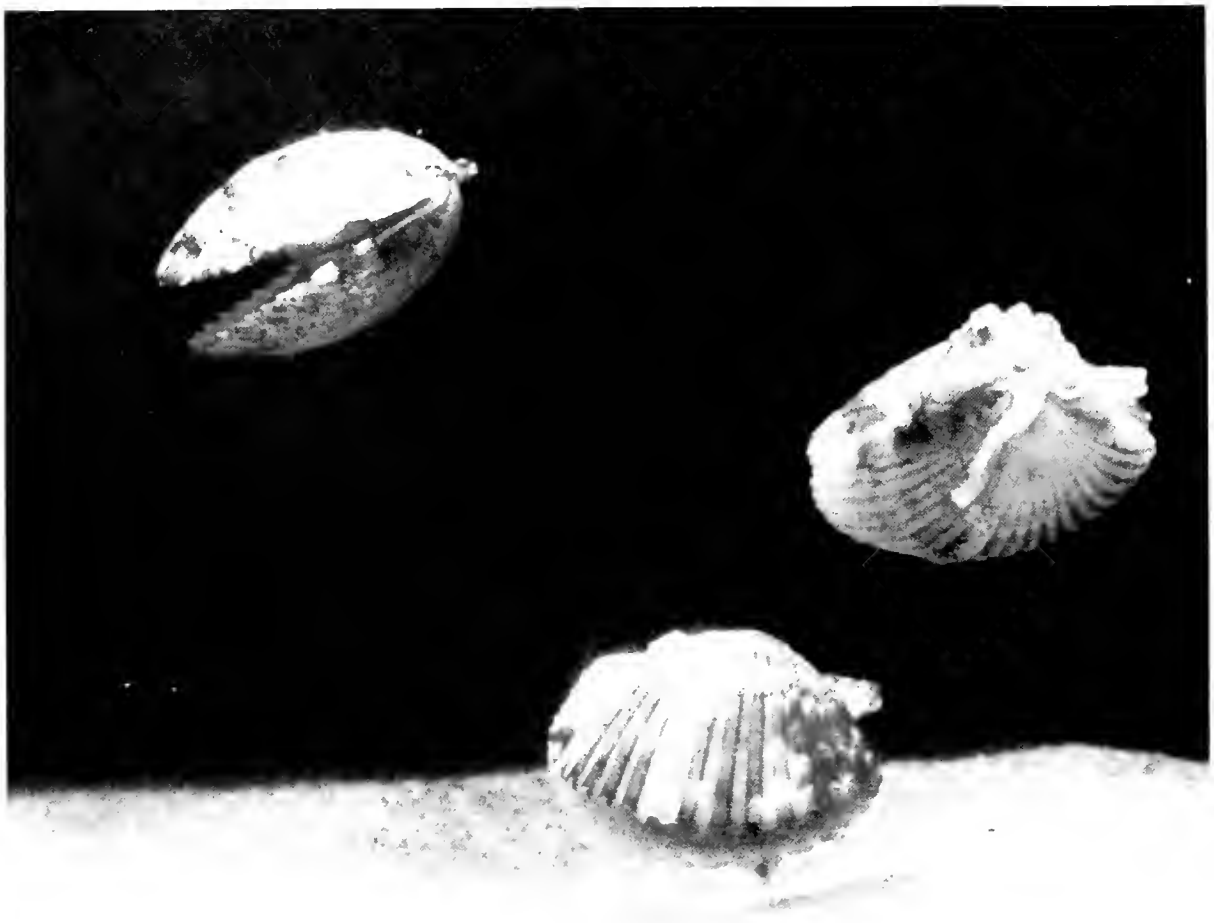

Figure 7.—Juvenile calico scallops swimming in aquarium.

observed to swim to about 46 cm off the bottom and then resettle about 30 cm away (Cummins, see footnote 6).

Calico scallops are often found in depressions on the sea bottom, as suggested by Rivers (1962a). Video tapes of the bottom off Cape Kennedy produced by RUFAS show that generally, scallops (size not given) were in furrows that run in a northwest-southeast direction or "settled individually in small conical depressions" (Commercial Fisheries Review, 1970).

FISHERY

General

The locations of the calico scallop fishing grounds off North Carolina and the Florida east coast and in the northeastern Gulf of Mexico are shown in Figure 8. Production and value of calico scallops for these areas are given in Table 1. Scallops landed in Georgia were caught off the Florida east coast.

The commercial production of calico scallops remains relatively low and fluctuates markedly in all three fishing areas. This condition is apparently caused by yearly variations in location and productivity of scallop beds compounded by problems of sorting, shucking, and eviscerating scallops (National Marine Fisheries Service, see footnote 7). The size and shape of the calico scallop generally prevent economical shucking by hand (Commercial Fisheries Review, 1960); and there is only one locality (near Cape Lookout, N.C.) where hand-shucking was feasible for an extended period (Cummins, 1971). This has led to the development and use of shore-based processing equipment that automatically shucks and eviscerates scallops, and to factory-type scallop vessels (Fig. 9) with machinery to sort the

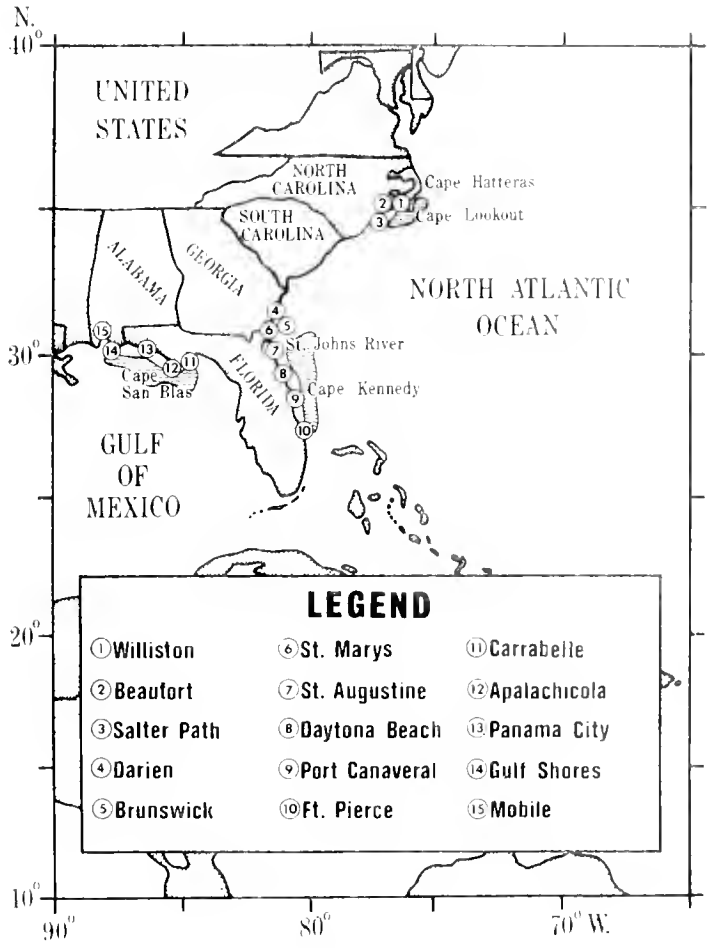

Figure 8.—Locations of calico scallop fishing grounds (wavy lines), and cities referred to in text (numerals). (Modified from Cummins, 1971.)

Table 1.—Annual production and value of calico scallops, southeastern United States 1959-1970.

[In thousands of pounds of meats and thousands of dollars (ex-vessel price).]

Year	North Carolina		Georgia		Florida East Coast		Northeastern[1] Gulf of Mexico	
	Pounds	*Dollars*	*Pounds*	*Dollars*	*Pounds*	*Dollars*	*Pounds*	*Dollars*
1959[2]	6	3	--[3]	--[3]	--[3]	--[3]	No data	No data
1960	112	45	--	--	--	--	No data	No data
1961	22	9	--	--	4	1	No data	No data
1962	--	--	--	--	1	--	16	5
1963	--	--	--	--	--	--	--	--
1964	--	--	--	--	--	--	--	--
1965	871	245	1	1	--	--	--	--
1966	1,857	369	--	--	--	--	--	--
1967	1,389	309	--	--	21	8	--	--
1968[4]	--	--	59	28	30	13	--	--
1969	--	--	2	1	181	172	16	8
1970	1,574	498	63	34	196	196	--	--

[1] In the Gulf of Mexico, calico scallop production began in 1958. Until 1962, however, calico scallops were included with and listed as bay scallops in the U.S. Fish and Wildlife Service Statistical Digests (Carpenter, 1967).
[2] 1959-1967 data from U.S. Fish and Wildlife Service Statistical Digest Nos. 51-61.
[3] Dash indicates less than 500 pounds or 500 dollars.
[4] 1968-1970 data rounded off from North Carolina Landings, Georgia Landings, and Florida Landings, published by Bureau of Commercial Fisheries for 1968 and 1969, and National Marine Fisheries Service for 1970 (in cooperation with state agencies). Data shown for 1970 are preliminary and subject to change.

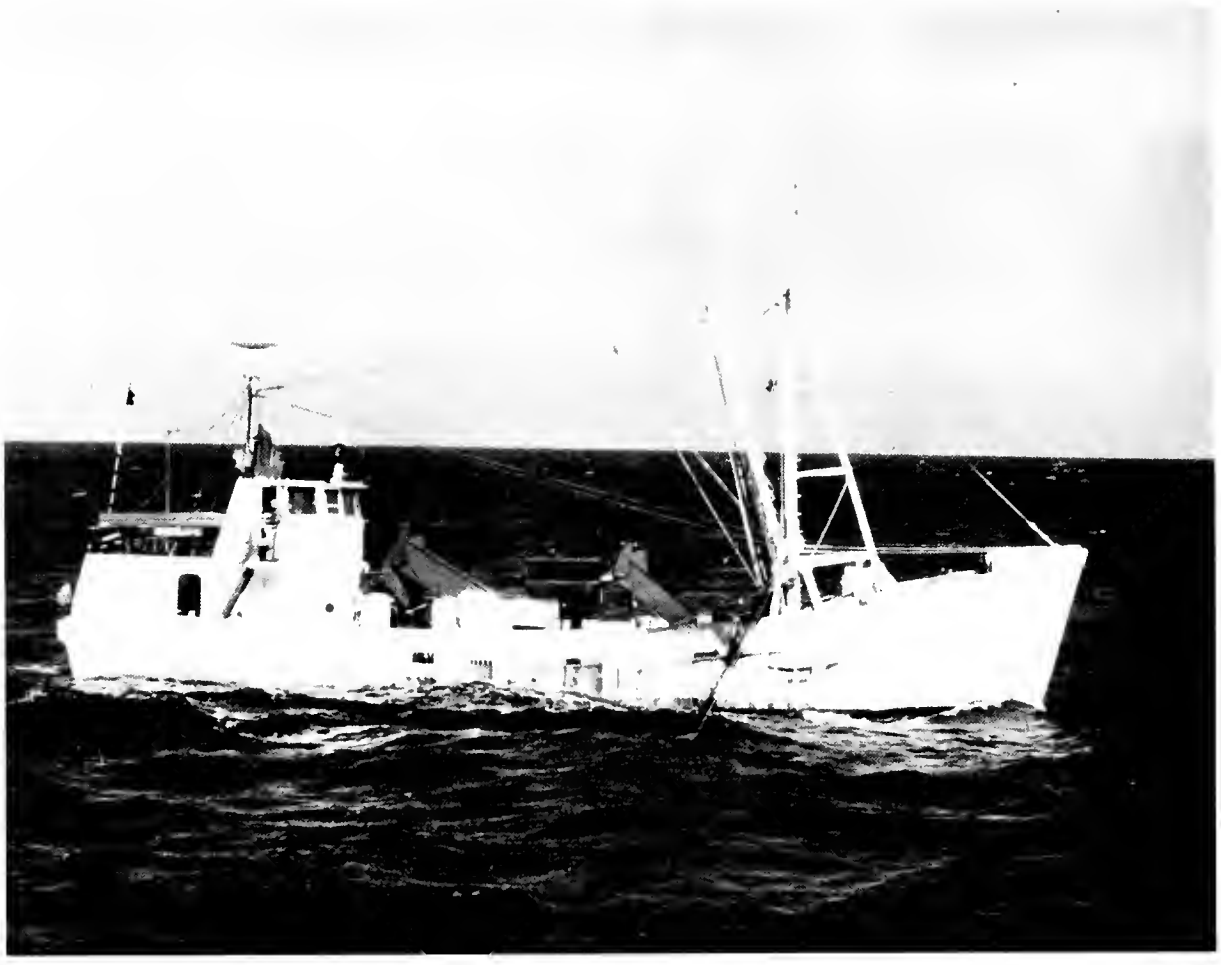

Figure 9.—A factory-type scalloper, with sorting and shucking machinery mounted on deck. (Photo by George C. Miller, National Marine Fisheries Service.)

catch and shuck and eviscerate live scallops at sea (Anon., 1968; Anon., 1969; Cummins and Rivers, 1970; Cummins, 1971).

Insofar as the resource is concerned, the following is pertinent to the fishery. Catches of calico scallops are considered commercially significant when 20 bu (in the shell) or more are caught per hour. Furthermore, to be harvestable, these scallops should be 40 mm (1.6 inches) in shell diameter or larger (Drummond, 1969). The weight of a bushel of scallops in the shell is variable and has been reported as 36 kg (80 lb.) (Drummond, 1969) and "about 70 pounds" [31 kg] (Cummins, 1971). From 1.75 bu, an average of about 3.6 kg (8 lb.) of meats (adductor muscles) can be obtained, but this figure varies with scallop condition and size, according to Cummins (1971). Meats as large as 101 count per kilogram (46 count per pound) have been reported (Commercial Fisheries Review, 1968). Minimum sizes of meats acceptable for hand-shucking are 198 count per kilogram (90 count per pound) (Cummins, 1971). Machine-processed meats as small as 341 count per kilogram (155 count per pound) are large enough for commercial use (Bullis).[18]

Uses for calico scallops are expanding. In addition to the market for scallop meats, the orange roes are sold in Europe (Cummins, 1971). The scallop viscera, with or without the adductor muscles, are excellent when steamed in the shell

[18] Office memorandum, dated November 28, 1969, to Acting Regional Director, Bureau of Commercial Fisheries Region 2, St. Petersburg, Fla., from Harvey R. Bullis, Jr., Director, Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base, Pascagoula, Miss.

or deep-fried (Miller).[19] The viscera, now usually discarded, can be used for animal feeds, and the shells in poultry feed and as a filler in concrete products (Bullis and Love, 1961). In addition, the shells have been used for oyster cultch.

The possibility exists that the resource may be adversely affected if large quantities of scallop shell, a natural cultch for scallop spat (see section on Environment), are removed from the scallop grounds by the fishery.

North Carolina

Calico scallops have long been known from the vicinity of Cape Hatteras and Cape Lookout in depths over 19 m. In April 1949, abundant quantities of calico scallops were located in 19 m southwest of Cape Lookout by the Institute of Fisheries Research of the University of North Carolina. The small size of the scallops and lack of information on distribution and abundance delayed development of a fishery in this area (Chestnut, 1951).

According to Cummins (1971), the North Carolina fishery began in 1959, following explorations by the Bureau of Commercial Fisheries (now the National Marine Fisheries Service). The results of exploratory scalloping, and a description of a scallop concentration off Cape Lookout in 31 to 37 m were given by Cummins, Rivers, and Struhsaker (1962).

The North Carolina fishery was described by Cummins (1971). The principal scallop grounds are located northeast and southwest of Cape Lookout in 19 to 37 m (Cummins, Rivers, and Struhsaker, 1962; Porter and Wolfe, in press). The scallops were first caught with scallop dredges which were soon replaced with scallop trawls that function better than dredges on the hard sand of North Carolina beds (Rivers, 1962a). Although these trawls can catch up to 60 bu of shell stock per 5-min drag, average catch-per-boat-per-day is 400 to 600 bu (Cummins, 1971). The scallops are deck-loaded and landed the same day in the shell. They were all hand-shucked in the fishing communities near Cape Lookout until recently when increasing numbers of scallops were machine-processed in shore-based plants located at Williston, Beaufort, and Salter Path, N.C. In 1970, two factory-type scallop vessels worked the North Carolina beds.

In North Carolina waters, the supply of calico scallops fluctuates widely between years. No scallops were available in 1962, 1963, and 1964; but overall production increased greatly in 1966 and 1967. Again, no scallops were available in 1968 and 1969 but in 1970 scallops became available and production was resumed.

Florida East Coast

Large quantities of calico scallops were discovered by the Bureau of Commercial Fisheries off Daytona Beach, Fla., in January 1960 (Taylor, 1967). Subsequent explorations by the Bureau showed that the area of commercial abundance extended from the St. Johns River south to Ft. Pierce in 19 to 74 m of water (Cummins, 1971). Explorations from 1960 to 1968 showed variable areas of greatest concentration, all between 28 and 65 m (Bullis and Cummins, 1961; Drummond, 1969; Roe, Cummins, and Bullis, 1971). In this area, catch rates and meat yields are highest from September to December (Roe, Cummins, and Bullis, 1971).

The types of vessels used to catch scallops on the Cape Kennedy grounds have included shrimp trawlers, New England scallopers, Chesapeake Bay dredgers, and factory-type scallopers (Cummins and Rivers, 1970; Cummins, 1971). The scallops are caught with dredges and trawls. Although Rivers (1962b) reported that "dredges generally outfish the trawls" on the softer bottoms of the Cape Kennedy grounds, it was learned from more recent trials that "the North Carolina type scallop trawl is an excellent device for catching scallops on the Florida grounds, and that catch rates exceed those of smaller dredges" (Commercial Fisheries Review, 1967). The tumbler dredge is superior to the Georges Bank dredge when used on the Cape Kennedy beds (Bullis and Cummins, 1961).

An indication of catch rates and production on the Cape Kennedy grounds may be obtained from the following observations. A New England scalloper with a single 2.4-m (8-ft) tumbler dredge made catches ranging from 735 to 1,500 bu of scallops per 24-hr period (Cummins, 1971). Factory scallopers processed a maximum of

[19] George C. Miller, Zoologist, National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, Miami, Fla. Personal communication, 1970.

about 1,816 kg (4,000 lb.) of scallop meats per 24 hr (Cummins and Rivers, 1970).

Shell stock from the Cape Kennedy grounds has been landed at Darien, Brunswick, and St. Marys, Ga.; and at St. Augustine, Port Canaveral, and Ft. Pierce, Fla. A shore-based plant for machine-processing is located at Port Canaveral.

According to one estimate, a total of 20 million lb. (9,080,000 kg) of scallop meats could be produced annually on the Cape Kennedy grounds by 40 vessels (National Marine Service, see footnote 7). Despite this potential, commercial operators have had problems both in locating concentrations of scallops and in the use of the mechanical shucker-eviscerators. These factors are reflected in the production figures.

Northeastern Gulf of Mexico

Exploratory fishing by private organizations from 1954 to 1958 located commercial concentrations of calico scallops in the northeastern Gulf of Mexico in the general area of Cape San Blas, Fla. (University of Miami Marine Laboratory[20]; Bullis and Ingle, 1959; Carpenter, 1967). Exploratory fishing by the Bureau of Commercial Fisheries from 1957 to 1960 revealed extensive beds of scallops in 19 to 46 m between Carrabelle, Fla., and Mobile, Ala. Heaviest concentrations were in depths less than 37 m off Cape San Blas and off Gulf Shores, Ala. (Carpenter, 1967).

Beginning in March 1958 a large bed of scallops in 13 to 37 m of water northwest of Cape San Blas was fished commercially. Scallops were caught at first using scallop trawls and later with dredges (Bullis and Ingle, 1959). The scallops were landed in Panama City, Fla., and shucked by hand (Carpenter, 1967). By September 1958, the yield of meat per scallop had declined to where fishing was no longer profitable. These scallops disappeared from the bed sometime prior to the summer of 1959 (Hulings, 1961).

[20] University of Miami Marine Laboratory. 1954. Shrimp exploration - report of cruise No. 1 - trawler *Goodwill*, June 17-July 10, 1954. Mar. Lab., Univ. Miami, unpublished circular 1 prepared for Tampa Shrimp Producers' Assoc. and Fla. State Board Conserv., 3 p., ML 7876.

Production in the northeastern Gulf area since 1958 has been restricted by poor market price (Bullis and Ingle, 1959), inadequate shucking facilities (Captiva, 1966) and by fluctuating stocks of scallops. Recently, a shore-based plant for machine-processing was constructed at Apalachicola, Fla.

SUMMARY

1. The calico scallop, *Argopecten gibbus*, supports a small, developing fishery off the southeastern coast of the United States and in the Gulf of Mexico. This report summarizes available information concerning calico scallop biology and the fishery.

2. The calico scallop is separated from closely related species within its range by shell characteristics. Shell morphology of the calico scallop varies with locality. The valves are well inflated and there are 17 to 23 ribs on the right valve. Shell color is variable, usually with red or maroon mottling or banding on a white or yellow background. Maximum size is about 80 mm in shell diameter.

3. This species apparently is restricted to the western North Atlantic Ocean. Its known range is from the northern side of the Greater Antilles and throughout the Gulf of Mexico to Bermuda and slightly north of Cape Hatteras. It is generally found in open marine water on continental or insular shelves. Depths of occurrence, however, range from less than 2 m to 370 m.

4. Environmental factors that probably influence distribution and/or growth of the calico scallop include currents, temperatures, salinities, substrates, and food supply. Scallop larvae are transported by currents, and eddies formed by coastal projections may cause repeated settling of the larvae, resulting in great concentrations of scallops near capes. Scallop beds are generally distributed along the flowlines of currents. Bottom temperatures associated with calico scallops range from 9.9° to 33.0°C; salinities from about 31 to 37‰. Scallops are generally found on sand-shell substrates, and shell may be necessary for successful settlement of small scallops (spat). Scallop abundance may be dependent upon plankton concentration, and possibly related to upwelling.

5. The greatest known abundance is off the Florida east coast near Cape Kennedy. Lesser

concentrations are found near Cape Lookout, N.C., and in the northeastern Gulf of Mexico near Cape San Blas, Fla. Scallop densities may exceed 108 per square meter (10 per square foot). Abrupt yearly differences in scallop abundance have been reported for the grounds off North Carolina and in the northeastern Gulf of Mexico.

6. Maturation and spawning time can be determined from ovarian color. Spawning activity may be controlled by water temperature. Spawning on the Cape Kennedy grounds probably occurs year around, with maximum spawning in the spring. For North Carolina waters, there is no evidence of winter spawning.

7. The length of planktonic larval life from fertilization to settlement is about 14 days. The spat are about 0.25 mm in shell height when first set. The rate of shell growth per month decreases as size increases. Growth may vary between areas. For the Cape Kennedy grounds, preliminary studies indicate that scallops reach 40 to 45 mm in shell height in 6 to 8 months. Maximum age averages 18 to 20 months and does not exceed 24 months.

8. The causes of mass mortalities of calico scallops are not known. Drastic water temperature fluctuations and predation may be factors. In addition, there is a postspawning die-off.

9. Numerous marine animals, including parasites and predators, have been listed as associates of the calico scallop.

10. Calico scallop larvae occur at all levels in the water column. The young scallops (spat) attach to a variety of substrates. Swimming ability is apparently most pronounced in small scallops. On the bottom, scallops settle in depressions or furrows.

11. Development of the fishery has been slow and erratic due to problems related to stock availability and processing. Greatest production has been in North Carolina, and this is related to the proximity to shore of the scallop grounds, and to the availability of processing facilities. The history of the fishery in North Carolina and in the northeastern Gulf of Mexico indicates that in those areas, fluctuations in stock availability from year-to-year will be a continuing problem. The apparent large concentrations of scallops off the Florida east coast, and the introduction and improvement of processing machines suggest that the harvest of calico scallops will increase in the next few years.

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