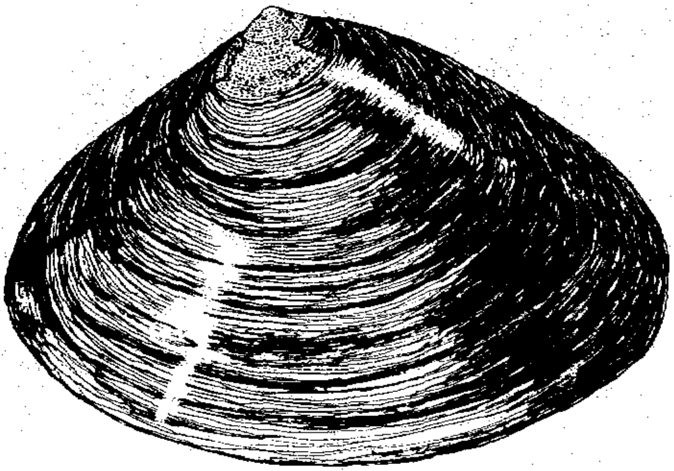


BIOLOGICAL & FISHERIES DATA ON SURF CLAM, *Spisula solidissima* (Dillwyn)

FEBRUARY 1980

Biological and Fisheries Data on the Atlantic Surf Clam, *Spisula solidissima* (Dillwyn)

by

John W. Ropes

Woods Hole Laboratory
Northeast Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Woods Hole, Massachusetts 02543

Tech. Ser. Rep. No. 24

February 1980

CONTENTS

1. IDENTITY

Page

2. DISTRIBUTION

3. BIONOMICS AND LIFE HISTORY

Page

4. POPULATION

Page

5. EXPLOITATION

6. PROTECTION AND MANAGEMENT

FIGURES

TABLES

SYMBOLS USED

bu = bushels
cal = calorie
C = Celsius
dm = decimeter (0.1m)
g = gram
hr = hour
kg = Kilogram (10^3gm)
km = Kilometer (10^3m)
L = length
M = natural mortality rate
m = meter
min = minute
mm = millimeters
mt = metric tons
ppb = parts per billion
ppm = parts per million
ppt = parts per thousand
t = time
W = weight
X^2 = chi-square
% = percent
0/00 = per thousand
u = micron (10^{-3}mm)

1. IDENTITY

1.1 Nomenclature

1.1.1 Valid Name

Spisula solidissima (Dillwyn 1817)

1.1.2 Objective Synonymy (from Whiteaves (1901))

Spisula solidissima Dillwyn 1817

Mactra similis Say 1882

Mactra gigantea Lamarck 1830

Mactra solidissima Gould 1841

Mactra ponderosa Phillippi 1844

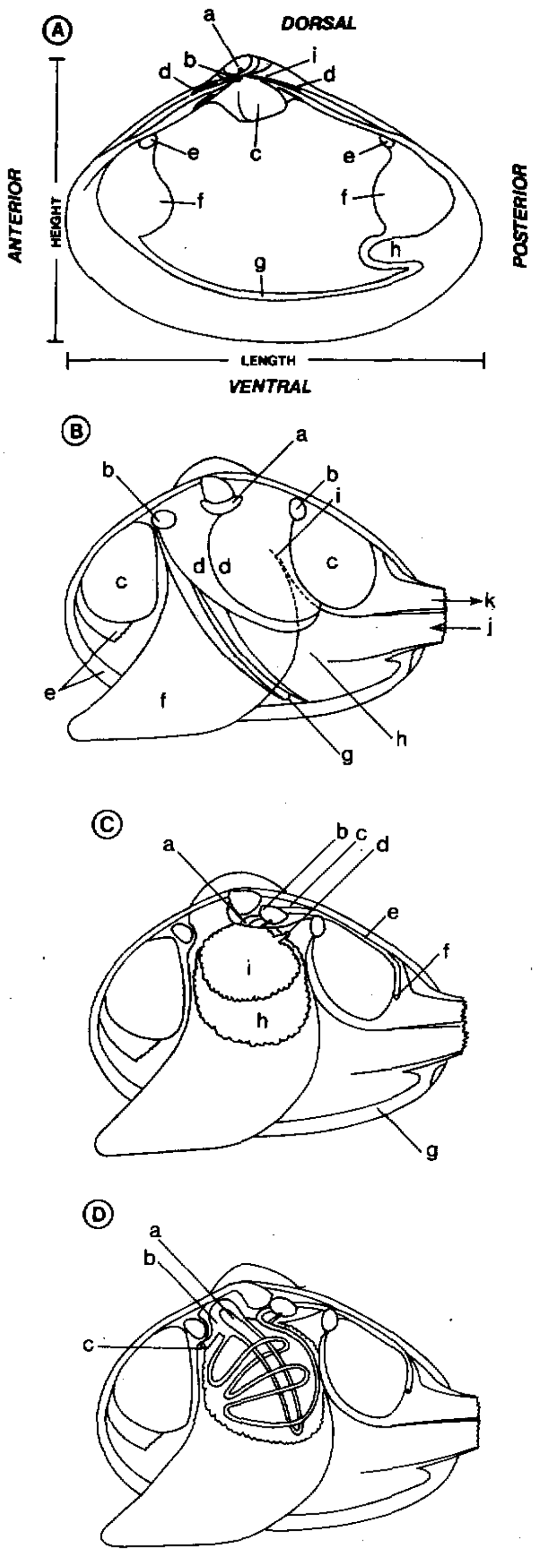
Hemimactra solidissima Conrad 1868

Spisula (*Hemimactra*) *solidissima* Dall 1895

1.2 Taxonomy

1.2.1 Affinities

Class--	Bivalvia Linnaeus 1758
Subclass--	Heterodonta Neumayr 1884
Order--	Veneroida H. and A. Adams 1858
Superfamily--	Mactracea Lamarck 1809
Family--	Mactridae Lamarck 1809
Subfamily--	Mactrinae Lamarck 1809
Genus--	*Spisula* Gray 1837
Species--	*solidissima* Dillwyn 1817



A. External and internal shell structures and dimensions of common shell measurements.

a. umbo - earliest shell growth
b. paired cardinal teeth
c. chondrophore (holds the resilium, a wedge-shaped elastic portion of the hinge)
d. lateral teeth
e. foot retractor muscle scar
f. adductor muscle scar
g. pallial line
h. pallial sinus
i. external hinge ligament

B. Anatomy of the soft body after removal of the left valve, mantle and mantle edge.

a. kidney
b. foot retractor muscle
c. adductor muscle
d. gills
e. cut mantle edge
f. foot
g. palps
h. infrabranchial chamber
i. epibranchial chamber
j. incurrent siphon
k. excurrent siphon

C. Anatomy of the soft body after removal of the gills and palps.

a. intestine
b. heart
c. pericardial chamber
d. genital papilla (exaggerated)
e. rectum
f. anus
g. mantle edge
h. digestive diverticula which overlaps i.
i. gonad

D. Anatomy of the soft body after cutting into the soft body.

a. crystalline style and sac
b. stomach
c. mouth

FIGURE 1. Shell structures and anatomy of the surf clam, Spisula solidissima.

1.2.2 Taxonomic Status

The family Mactridae includes clams with a glossy periostracum covering the smooth or concentrically sculptured outer surfaces. The valves gape slightly. The pallial line has a sinus (Figure 1). The siphons are united to their tips. Records date from the Upper Cretaceous to the present. Subfamily characteristics are subequilaterally-shaped shells with a well developed hinge bearing two somewhat joined cardinal teeth in the right valve. The siphons are wholly retractile within the shells. Generic features are shells trigonal or ovate in shape, but not gaping, and the shell surfaces concentrically striated. A lunule and escutcheon are delimited, but the hinge ligament and resilium are not separated by a shelly lamella. The pallial sinus is oval. Records date from the Tertiary period and Mactridae have a cosmopolitan distribution (Moore and Pitrat 1969).

1.2.3 Subspecies

Taxonomic literature is equivocal about the existence of a subspecies of *Spisula* on the continental shelf of the northwestern Atlantic. Abbott (1974) states in a recent manual on marine mollusks of the Americas that *S. raveneli* may be a synonym for the subspecies *S. s. similis*. Earlier malacologists used several species names (*Mactra similis*, *M. raveneli*, and *S. raveneli* and *S. s. similis*) for surf clams some considered "submature" or "pathologic" forms, because of their small size, irregularities in growth and shell shape, and other morphological shell features (Dall 1894; Henderson and Bartsch 1914; Jacot 1919; Johnson 1934). These have usually been reported inhabiting littoral zone locations, such as Rockaway Beach, Long Island, New York; Cape May, New Jersey, and Chincoteague Island, Virginia. In recognition of differences in the maximum size of surf clams throughout their geographic range, Merrill and Webster (1964) thought the small variety found south of Cape Hatteras, North Carolina, should be "known by the varietal or subspecific name *raveneli*."

Jacobson and Old (1966) provided supportive evidence listing subspecies synonyms for S. solidissima and S. raveneli and locating the respective distributions of the two species north and south of Cape Hatteras.

1.2.4 Standard Common Names, Vernacular Names

Several common names are in use within local geographic areas along the northwestern Atlantic coast: bar clam in Canada; hen clam in Maine; sea clam, surf clam, beach clam, or skimmer in the middle Atlantic states of New York through Virginia.

1.3 Morphology

1.3.1 External Morphology (Shell)

Shells oval to trigonal; gape slight; no external sculpture; ligament spisuloid; lateral teeth complement is complete; granular scuplturing or cross striations on some or all contact surfaces of the lateral teeth, if apparent at all; the shallow pallial sinus is not larger than the posterior adductor muscle scar (Chamberlin 1954).

1.3.2 Cytomorphology

None available.

1.3.3 Protein Specificity

None available.

2. DISTRIBUTION

2.1 Total Area

Wigley and Emery (1968) charted and discussed the general geographic distribution of surf clams from Cape Hatteras, North Carolina, on Georges Bank, and throughout the Gulf of Maine. A more detailed latitudinal range for the species from the southern Gulf of St. Lawrence to the northern Gulf of Mexico is reported by Merrill and Ropes (1969) and Ropes et al. (1969). In the northern latitudes it is commonly abundant in the turbulent waters of oceanic beaches, just beyond the breaker zone. It has occasionally been found to depths of 128 m on Georges Bank and to 61 m on the Middle Atlantic continental shelf. Abundant concentrations, sought after commercially, are in near shore to 55 m depths. A generally smaller surf clam (S. *ravaeneli*, cf. Sec. 1.2.3) inhabits the waters south of Cape Hatteras. These have been found at inshore, shallow water depths, but their occurrence offshore is largely unknown. S. *polynyma*, another species which could be confused with S. *solidissima*, was found distributed northward from off Long Island, New York, in deeper and colder waters by Chamberlin and Sterns (1963). In a discussion of the distribution of *Spisula* species in the continental shelf of eastern North America, Merrill and Ropes (1969) believe that mixing of known species (S. *solidissima*, S. *raveneli*, and S. *polynyma* is unlikely in the Middle Atlantic Bight fishery.

2.2 Differential Distribution

The species is predominantly oceanic, but settlement can occur at entrances of estuaries in relatively high-salinity water (Carriker 1951, 1959; Castagna and Chanley 1966; Maurer et al. 1974).

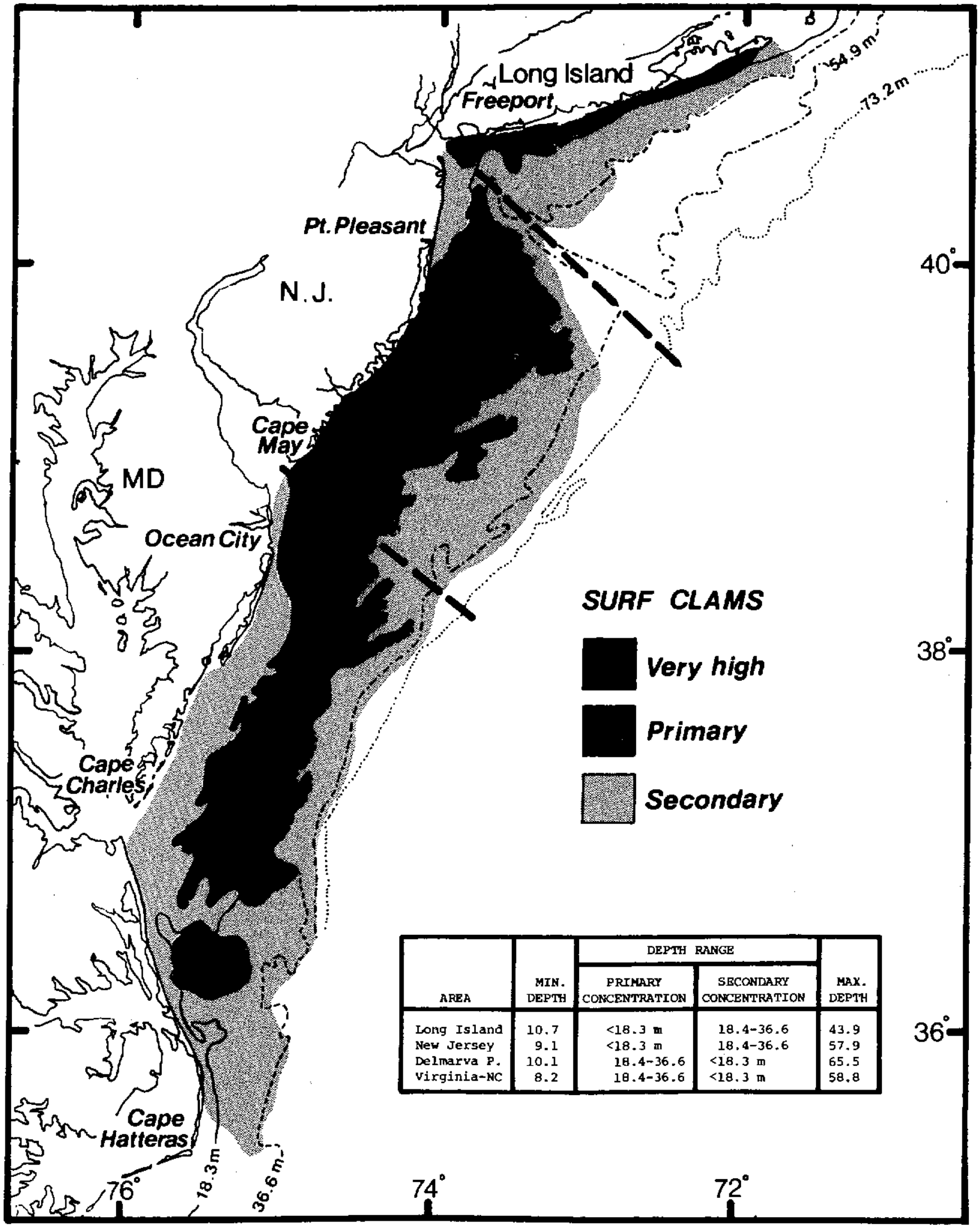
The depth range of surf clams has been delineated in the Middle Atlantic Bight from several sources (June and Reintjes 1957; Merrill and Webster 1964; Merrill and Ropes 1969, 1971; Ropes and Merrill 1971, 1976; Franz 1976a, 1976b; Haskin and Merrill 1973; Loesch and Ropes 1977) in a recent review by Ropes (1979a). Off Long Island, New York, they occur from the beach zone to 43.9 m; off New Jersey, from the beach zone to 57.9 m; off Delmarva Peninsula (the coastal portions of Delaware, Maryland, and Virginia), from 10.1 to 65.5 m; and off Virginia-North Carolina, from 8.2 to 58.8 m (Figure 2). Concentrations were greatest at less than 18.3 m depths off Delmarva Peninsula and Virginia-North Carolina.

Several studies provide detailed evidence of surf clam distribution at specific locations in their range:

Emery et al. (1965) photographed surf clam shells off Long Island during a sampling program to delineate the geology and biology of the sea floor on the continental shelf and slope off the northeastern United States.

From collections of benthic invertebrates of the continental shelf off North Carolina, Cerame-Vivas and Gray (1966) found surf clams in the Virginian and Carolinian biotic provinces, but not the Tropical province. The marine climates in the three provinces were discussed.

Dexter (1968) reported finding surf clams in subtidal locations at Cape Ann, Massachusetts. They were present in sandy habitats of Ipswich Bay, the north branch of the Annisquam River,



AREA	MIN. DEPTH	DEPTH RANGE		MAX. DEPTH
		PRIMARY CONCENTRATION	SECONDARY CONCENTRATION	
Long Island	10.7	<18.3 m	18.4-36.6	43.9
New Jersey	9.1	<18.3 m	18.4-36.6	57.9
Delmarva P.	10.1	18.4-36.6	<18.3 m	65.5
Virginia-NC	8.2	18.4-36.6	<18.3 m	58.8

FIGURE 2. The distribution of surf clams, Spisula solidissima, in the Middle Atlantic Bight. The categories of concentrations (very high = 5 bu or more; primary = < 5 to 1 bu; secondary = < 1 bu. Meter depths shown correspond to 10 fathoms increments. An occurrence at a minimum or maximum depth may represent only a single clam (Adapted from Ropes, 1979a).

Little River, and Gloucester Harbor, but were absent in the muddy bottom of the south branch of the Annisquam River.

Olsen (1970) studied the ecology of surf clams in shallow water beds on Coanicut Island and Easton Beach, Rhode Island, in 1969. Surf clams were evenly distributed in small aggregations of well sorted sand and gravel sediments. The population at Coanicut Island was dominated by clams 130 and 150 mm in length, but size was highly variable within an aggregation. Hydrographic forces concentrated the larvae in shallow water along the beach. Two explanations were proposed for the numerical dominance of clams larger than 130 mm: (1) the population was stable; and (2) the dominant size class represented 1 to 6 successful sets occurring 6 to 12 years ago. At Easton Beach, hydrographic forces also concentrated the larvae and location of sets. Clams from overcrowded beds, a condition that impeded growth, washed onto the beach.

Caddy (1970) recorded the occurrence of surf clams in scallop-dredge hauls from the Bay of Fundy, Canada. Dead shells and occasional live individuals were found in tows on sand bottom at depths of 55 m and shallower off the Nova Scotia coast.

Wigley and Theroux (1970) reported intact shells and fragments of surf clams from sea-bottom photographs and macrobenthic collections from the continental shelf off Massachusetts.

Flowers (1973) designed a study to determine patch-distribution characteristics of surf clams in the Harbor of Refuge, Point Judith, Rhode Island. Patch pattern was density-dependent, with patches of high density tending toward "complete aggregation", but medium and low densities were randomly distributed discrete patches.

Steimle and Stone (1973) conducted a qualitative and quantitative survey of the inshore benthic fauna off southwestern Long Island, New York. The surf clam was one of the dominant organisms encountered and was among organisms classified as a medium sand assemblage. The mean number of organisms collected from the medium sand sediment ranged from 49 animals/m^2 to 2,030 animals/m^2. The total number of species generally increased with depth from 11 to 54.

Garlo and Hondo (1973) reported on a benthic invertebrate sampling program in the vicinity of a proposed nuclear-generating site off New Jersey. The surf clam was the dominant species in and near the site in samples taken in 1972 with a Ponar bottom grab and a clam dredge. The sampling program was continued throughout 1973 by Garlo et al. (1974). Again the surf clam was a dominant species and densities of newly settled spat were high.

Merrill and Edwards (1975) observed mollusks among the fouling organisms attached to navigational buoys. Surf clams were not one of the nine pelecypods found on the buoys, but they were in samples taken from the sea floor at the buoy site.

Pearce et al. (1976) compared the distribution and abundance of benthic organisms sampled during 1973 and 1974 in the New York Bight area. The fauna in coastal and inshore shoal waters were characterized by the bivalves, *Tellina agilis* and *Spisula solidissima*, and the sand dollar, *Echinarachnius parma*. These were considered typical of high-energy coastal marine environments.

Franz (1976a) conducted an intensive survey of the Long Island, New York, inshore population of surf clams in 1974. Selected locations were resampled in 1975. His summary follows:

> "East of Shinnecock Inlet adult clams occurred at densities between 0.5 and 3.0 bushels per dredge haul. West of Shinnecock adults declined gradually, reaching a minimum west of Jones Inlet to East Rockaway Inlet. Abundances increased precipitously off Rockaway Beach.
>
> "Highest densities of juveniles occurred at 0.5 mi and decreased rapidly farther offshore. Juveniles were more abundant at the west end of Long Island, particularly inshore at 0.5 mi. Higher densities of juveniles here may result from accumulation of larvae produced farther east and transported westward via longshore currents. The convergence of tidal and longshore currents may effectively "trap" larvae off western Long Island.
>
> "Clam stocks off eastern Long Island probably are older than 9 years and are mostly composed of 1-3 age classes. Clam stocks off the Rockaways appear younger. The commercial fishery is apparently dependent on massive settlements of larvae occurring irregularly and infrequently."

Franz (1976b) analyzed benthic molluscan assemblages in relation to sediment gradients in Northeastern Long Island Sound, Connecticut, in 1973. The surf clam was among 52 mollusks encountered. They were at stations designated as low-diversity, high-energy habitats and in areas of severe tidal surge. Sediments were fine to coarse sand, with silt/clay levels less than 5%.

2.3 Determinants of Distribution

Determinants of distribution for *S. solidissima* are poorly known. Henderson (1929) reported a high maximum lethal temperature of 37°C for large surf clams. A lethal temperature limit of 30°C was found by Schlieper et al. (1967) in recent investigations of *S. solida*, a related mactrid species in Europe. The clam was also the least heat-resistant species tested and was described as a cold stenotherm inhabiting coarse sands at 15-30 m depths in the North Sea. Saila and Pratt (1973) gave 26 to 28°C as an upper lethal temperature limit for adult surf clams, and noted that younger clams can survive higher temperatures, but became inactive at 4°C. Savage (1976) observed an inability of surf clams to establish pedal anchorage at temperatures over 30°C and thought a condition like the critical thermal maximum had been reached.

In experiments on the freezing resistance of gill tissue, survival of *S. solida*, as indicated by gill cilia activity, was the lowest of seven North Sea species tested at 30°/00 salinity and -10°C (Theede 1965). A narrow, low cellular osmotic freezing resistance range at salinities between 14 and 52°/00 was found for the clam, "but its resistance against concentrated seawater was relatively higher than would be expected because of its low freezing resistance." Such low temperature conditions would probably never be encountered by *S. solidissima* in their relatively deep water, oceanic habitat. Those living in the beach zone may be marginally affected, especially if they are washed onto the air-exposed beach.

Dupal and Webb (1974) reported an increase in alanine concentration of surf clam gill tissues held under increased salinity conditions. Metabolic pathways for this accumulation appeared similar to those described for invertebrate faculative anaerobiosis.

Castagna and Chanley (1973) reported minimum salinities of 12.5 and 16°/00 for adult and larval surf clam survival, respectively.

Loosanoff and Davis (1963) found surf clam larval development was best at 22°C, rather than lower (14°C) and higher (30°C) values. Since the larval period may last for 19 days at 22°C, movement of larvae by water currents has an important influence on surf clam distribution. Specific studies on the effects of environmental currents distributing surf clam larvae are unavailable, mostly because of difficulties experienced in identification of the larvae in plankton collections. Sandine et al. (1973) sampled zooplankton during September 1972 - January 1973 at and near a proposed nuclear generating site off New Jersey. The available evidence suggested that surf clam larvae were probably in the samples, but in the enumeration of meroplanktonic forms was categorized only as bivalve larvae. Bivalve larvae were very numerous in November samples, although a change in the type of sample net used may have influenced results. The conditions necessary for successful settlement of larvae and survival thereafter are largely unknown. Merrill and Ropes (1977) discussed the conditions affecting bivalve larval development and formation of shellfish beds, such as bottom substrata, reproductive and feeding biology, water quality, and causes of mortality.

Some experimental results are available on the effects of heavy-metal exposure on surf clams. Thurberg et al. (1975) exposed larval, juvenile, and adult clams to silver. During 96-hr exposures, larvae survived concentrations up to and including 50 ppb, levels between 50 and 100 ppb caused juvenile deaths, and concentrations greater than 100 ppb were lethal to adults. Silver-induced increases in oxygen consumption occurred for each life stage. Silver increased rhythmic valve movement, an activity closely related to respiration and filtration. These findings have been summarized by Calabrese et al. (1977).

Oceanic clams have been affected by man's waste-disposal practices. The U.S. Department of Health investigated ocean waste-disposal in the New York Bight and off Delaware Bay in 1966 and 1967 (Buelow 1968). Positive coliform values were reported in seven of ten surf clam samples taken off Delaware Bay, all clam samples were high in chromium, and four were high in nickel. In a report on the effects of solid waste disposal on benthic communities in the New York Bight, Pearce (1972) found normal populations were decidedly affected. Surf clams were a dominant bivalve out of the dump site areas and along the northern New Jersey coast in medium to coarse sand. They were part of a low diversity, high dominance fauna characteristic of high energy, wave swept, coastal environments. South and east of the disposal areas, the animal community was diverse and little affected by solid waste disposal activities. The impoverished fauna in the dump areas was believed due to toxins in the sediments and water. O'Connor (1976) discussed the effects of contaminants on the biota of the New York Bight. He noted the general degradation of benthic invertebrate assemblages and the rarity of commercial-size surf clams in about 1,550 Km^2 of the bottom surrounding the Apex dump sites. Lear et al. (1973) reported concentrations of iron and copper in surf clams collected near sewage and acid waste dumpsites off the mouth of Delaware Bay. More recently the Environmental Protection Agency investigated the effects of ocean-disposal activities off Delaware and Maryland (Lear and Pesch 1975). An affected area of at least 3,600 sq km was found containing potentially toxic metals in the bottom sediments and organisms. Although values for surf clams were not in the report, elevated concentrations of vanadium were found in ocean quahogs (*Artica islandica*) and sea scallops (*Placopecten magellanicus*) and evidence is given for mortalities of ocean quahogs in areas of accumulated waste metals. Reynolds (1979) reported on trace metal monitoring at the Delaware ocean disposal sites. Sea scallops and ocean quahogs were the principal bivalves analyzed, since they occurred most often in the samples. Cadmium, copper, nickel, vanadium, chromium, and zinc levels were given for surf clams taken incidentally in 1975 samples, but the significance was not discussed because too few were available for analyses. Grieg and Jones (1976) identified six metals in the tissues of surf clams from several locations to develop baseline data, but did not comment on the significance of the values obtained. A special symposium focused scientific attention on the Middle Atlantic continental shelf and New York Bight (Gross 1976). Sources of contamination and effects on the ecosystem, fish and shellfish, and man were examined in detail. Apart from the obvious necessity of closing some areas for public health reasons, the continued flow of contaminants is having probable effects on all life-history stages of marine organisms, causing mortalities, abnormalities, and other physiological disturbances. The known problems had probable impact in evaluating two proposed alternate sewage sludge dump sites in the New York Bight. Potential commercial shellfish resources, including the surf clam, distributed in and near the proposed dump areas, did not favor selecting either site (Gunnerson and Swanson 1975; Swanson 1976). Wenzloff et al. (1979) reported concentrations of silver, arsenic, cadmium, copper, chromium, mercury, nickel, lead, and zinc in tissues of surf clams collected during an extensive mid-Atlantic coast survey in 1974. Silver, arsenic, and zinc concentrations decreased significantly in the southern latitudes, but no statistically significant trends were found for other metals in surf clams. Mean arsenic levels of 1.46 to 2.63 ppm exceeded the Australian National Health and Medical Research Council's recommended concentration (1.14 ppm). Except for arsenic, the concentrations of other metals did not exceed existing levels recommended by agencies responsible for establishing action limits. The investigators believe that large areas of the mid-Atlantic coast may be affected by heavy metals, but that consumers of surf clams need not be unduly concerned at this time.

Despite the concern for fishery resources, loss of clam-harvesting areas has resulted from sizeable closures in the ocean. A closure in May 1970 of a 380-sq-km circular area in the approaches to New York Harbor contained active dump sites (Verber 1976). By April 1974, an additional 450 sq km was closed by extending lines form the periphery of the former closed area to the Long Island, New York, and New Jersey shores. Off the mouth of Delaware Bay, dumping resulted in closure to shellfishing of a 380-sq-km area in May 1970. All dumping at this site was prohibited after May 1973, but a new site was located offshore. The former site was reopened for shellfishing in January 1975. The new offshore site was not immediately closed to shellfishing, but by December 1976 a warning notice to harvesters created two closed areas totaling 486 sq km. Similar action has been taken within the jurisdictional limits (ca. 4.8 km) of the New Jersey shore. Babinchak et al (1977) delimited a fecal coliform contaminated area in the New York Bight contiguous with the sewage sludge disposal site and extending northeastward 11 km and southward in the Hudson Shelf Valley 37 km. Almost 40% (ca. 267 sq km) of that state's total area has been closed to surf clamming because of nearshore ocean outfall contamination (Ritchie 1977). Ocean-area closures, then, have removed about 1,580 sq km from shellfish harvesting in the Middle Atlantic Bight.

A major impact occurred on surf clams in 1976. Anoxic water developed over the beds from the combined effects of meteriological and hydrographic conditions, organic loading of coastal waters, and a massive bloom and die off of the dinoflagellate Ceratium tripos (Steimle and Sindermann 1978; Ropes et al. in press). A loss of 147 thousand mt of surf clam meats was estimated in an intense kill area of 6,750 sq km and at depths from nearshore to 36.6 m. This was about 62% of the New Jersey resource. It was supposed that surf clams reacted like the European mactrid, Spisula solida, when it was experimentally subjected to oxygen-deficient water treated to create a hydrogen sulfide condition (Theede et al. 1969). Its survival was seriously affected and it was the least resistant species tested. Low oxygen conditions seriously affected surf clam burrowing by slowing the rate of activity (Savage 1976). The loss had an important effect on commercial landings of surf clams. Ocean quahogs *Arctica islandica* and sea scallops *Placopecten magellanicus* were marginally affected because they were mostly distributed outside the area of low oxygen concentrations.

Garlo et al. (1979) reported on the impact of hypoxic conditions in the vicinity of Little Egg Inlet, New Jersey, in the summer of 1976. Although the surf zone was hypoxic by mid-July, no mortalities of megabenthos were observed and the surf clam was the most abundant species collected. In September samples, mortalities of surf clams ranged from 0 to 100% and averaged 7%. Most of the dead surf clams were at locations of low density and at depths greater than 9 m.

Mortalities of marine organisms off the New Jersey coast have occurred in the recent past before 1976 (Ogren and Chess 1969; Ogren 1969; Young 1973). Low oxygen levels and mortalities of surf clams were recorded in the two earliest reports.

Zoellner (1977) reviewed water quality problems related to molluscan shellfish and effectiveness of present-day laws. The study focused on the specific needs of molluscs for survival and propagation. Natural phenomenon, dredging, chemical contamination, and other water quality problems affect shellfish, but domestic waste discharge was considered to have the greatest negative impact on the sanitary condition of growing areas. Overcoming problems in implementing existing laws was recommended.

2.4 Hybridization

Hybridization has not been reported, but may be possible under laboratory conditions for at least the three species of *Spisula* (*S. solidissima*, *S. polynyma*, and *S. raveneli*) found along the northwestern Atlantic coast.

3. BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.1.1 Sexuality

The sexes are separate (dioecious) and hermaphroditism is a rare anomaly (Ropes 1968a).

3.1.2 Maturity

Surf clams mature at an early age. They can contain ripe gonads and spawn one year after setting, but reach full sexual maturity during the second year (Ropes, 1979b). Although the smallest fully mature clam can be 45 mm long, growth to a size larger than other clams of the same age is important in early development of sexuality.

3.1.3 Spawning

In a bed of clams, spawning is probably a synchronous, annual event (Ropes 1968b). Thermal stimulation seems to be an important factor in initiating the spawning act but subtle nervous and hormonal conditions may have important interrelationships. Stickney (1963) described an egg reservoir in the gonad of surf clams and noted the faster response of surf clams to spawning stimuli than soft clams (*Mya arenaria*).

Hormones and enzymes have been reported in the eggs, sperm, and gonadal tissues. Hagerman (1956) found that estradiol added *in vitro* had no effect on the metabolism of surf clam ovaries, but Hagerman et al. (1957) found appreciable amounts of an estrogenic material in the ovaries. Eble (1969; 1970; 1971) reported high levels of glycogen in gonadal alveolar epithelium and sex cells of male and female surf clams. Enzyme systems of the testes and ovary were examined and related to the reproductive stages of gonadal development.

3.1.4 Fertilization

Fertilization occurs after gametes unite externally in the water over the beds. The gametes have been used by numerous investigators studying physiological responses and cleavage activities (Allen 1953; Rebhun 1959; Schecter 1956 are a few of the many available references of research on surf clams using the light microscope). Longo (1973) reviewed the extensive literature on ultrastructural research of the events during fertilization for the surf clam, the mussel (*Mytilus edulis*), the sea urchin (*Arbacia punctulata*), and the rabbit (*Oryctolagus cuniculus*).

Sperm incorporation into the egg and associated events, male pronucleus development, morphogenesis of the male pronucleus following its formation, development of the sperm aster, migration of the pronuclei, fate of the sperm mitochondria, fate of the sperm flagellum, fate of the perinuclear structures of the spermatozoon, morphogenesis of the maternal chromatin, germinal vesicle breakdown and formation of the first meiotic apparatus, formation of the first and second polar bodies, development of the female pronucleus, and pronuclear association were discussed in more detail than can be presented herein.

3.1.5 Fecundity

No observations on fecundity are known.

3.1.6 Spawning Seasons

The gonads of more than 1,500 clams were collected from offshore New Jersey during 1962-1965 and histological preparations were studied to determine the annual frequency and duration of spawning (Ropes 1968b). In 1962, 1963, and 1964, two annual spawnings occurred. The first (major) spawning was in mid-July to early August and the second (minor) spawning was in mid-October to early November. In 1965, however, only a single spawning was observed during mid-September to mid-October.

From records taken daily at a lightship near the New Jersey sample area, bottom-water temperatures seemed to influence the spawning cycle according to Ropes (1968b). During the first six months of 1962-1964, a gradual warming trend of bottom water coincided with a gradual ripening of the clam gonads. In 1965, when only one reproductive cycle and spawning was observed, temperatures were generally lower than in the previous years when two annual spawnings occurred. Ropes (1968b) reviewed the literature on spawning of surf clams.

Observations on juvenile surf clam settlement suggest the spawning season will be earlier at more southern latitudes than off New Jersey. Williams and Porter (1971) studied the meroplankton in North Carolina estuaries. From 3 to 21 postmetamorphal surf clams are listed in a table for the months of April, May, and June in 1963 and 1964 at shell lengths of 1.1 to 2.5 mm.

3.1.7 Eggs

The unfertilized eggs have a diameter of 56μ, measuring from the inside of the vitelline membrane; the germinal vesicle is about 31μ in diameter and is somewhat eccentric (Allen 1953). The spherical eggs are composed of several layers. An outermost "jelly layer," about 2μ thick, is usually invisible in unstained living eggs.

3.2 Larval History

The following describes larval development to the juvenile stage under experimental laboratory conditions. An average water temperature of 21.7°C (range 18.3-24.9°C) was maintained during all stages of the culture.

Soon after egg fertilization, an inner, tough and very visible vitelline membrane elevates from the plasma membrane surrounding the dense cytoplasm to form a clear perivitelline space; the germinal vesicle around the nucleus dissolves and leaves in its place a light central area (Figure 3A); and the transparent nucleolus within the nucleus disappears leaving the opaque nucleolinus. This latter structure begins its spindle-forming role at this time (Allen 1951; 1953).

Cellular changes after sperm penetration proceed fairly rapidly and the earliest stages have been timed, photographed, and described in Schecter (1941) and Allen (1953). Both the first and second polar bodies extrude at the plane of the first cleavage as preliminary steps in the division of the egg. These events take place within 70 minutes after fertilization.

Thereafter, the cleavage stages rapidly succeed one another. Each stage was recognized at 70, 90, 110, and 120 minutes, respectively (Table 1), and photographed (Figures 3B-3E).

An unequal division of the eggs into blastomeres differing greatly in size is most evident after each of the early cleavages. Subsequent spiral-type cleavages are rapid and difficult to follow. Swimming gastrulae, found 5¼ hours after fertilization (Figure 3F), are formed by epiboly. During epiboly, small ectodermal cells proliferate by rapid division over the larger, yolk-filled endodermal

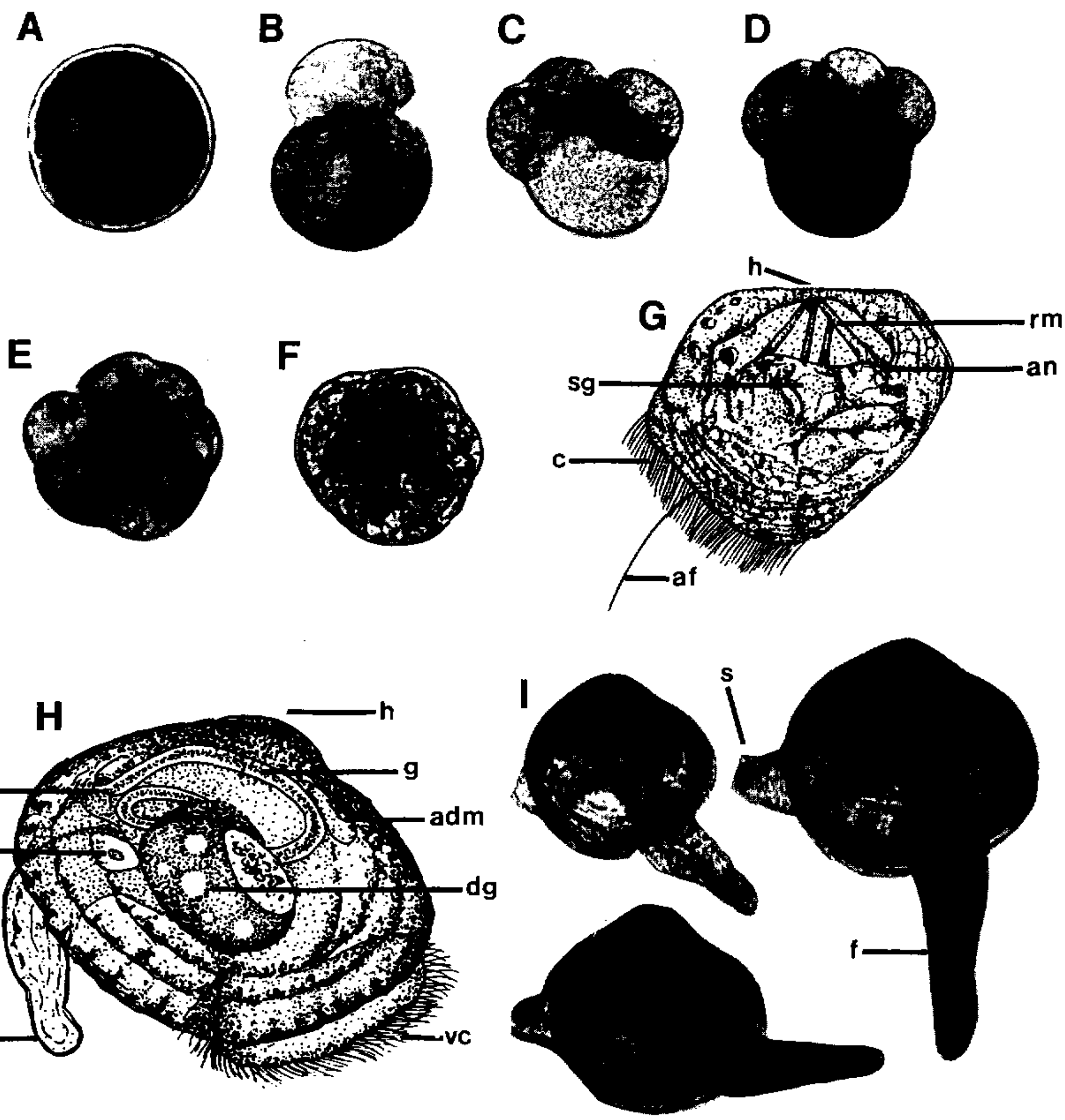


FIGURE 3. Stages in the early development of a surf clam, Spisula solidissima: (A) Fertilized egg; (B) First cleavage; (C) Second cleavage; (D) Third cleavage; (E) Many celled; (F) Gastrula; (G) A D-shaped or straight-hinged veliger, showing h.-hinge, rm.-retractor muscle, an.-anus, sg.-stomach and gut, vc.-vellum fringed with cilia, and af.-apical flagellum; (H) A prediveliger, showing h.-hinge, g.-gut, adm.-anterior adductor muscle, dg.-digestive gland, vc.-velum fringed with cilia, pam.-posterior adductor muscle, an.-anus, m.-mesoderm, and f.-foot; and (I) Fully metamorphosed juveniles, showing f.-foot, and s.-siphons.

Table 1. Elapsed time after fertilization for the appearance of developmental stages of surf clam, Spisula solidissima, larvae held at an average temperature of 21.7°C. In part from Costello et al. (1957).

Stage of Development	Time
First cleavage	70 minutes
Second cleavage	90 minutes
Third cleavage	110 minutes
Many-celled	120 minutes
Swimming gastrula	5¼ hours
Trochophore	9 hours
Straight-hinge veliger	19-20 hours
Pediveliger and Juvenile	18-21 days

cells, but an opening is left into the archenteron called the blastopore (Costello et al. 1957; Wada 1957).

Trochophore larvae, which were not photographed, occurred 9 hours after fertilization. Costello et al. (1957) described trochophores as having a pyramidal shape. The expanded base of the trochophore is the later site of velum formation. Young veliger larvae, formed by 19-20 hours, had bivalved shells and a straight-hinge line, hence the name D-shaped or straight-hinge veliger (Figure 3G). During active movements and feeding, the larvae extended a well developed velum with cilia and apical flagellum beyond the shell margin. Retractor muscles immediately ventrad to the hinge were conspicuous when the velum was everted. These muscles appeared to be in a cavity above the prominent and centrally located stomach. A rudimentary intestine was present off the stomach at the anterior end, but a mouth was not clearly recognized. The stomach sometimes contained algal cells. Cilia fringed the velum when it was exposed, and a long apical flagellum was prominent. Both the cilia and flagellum actively propelled the larvae during locomotor activities which usually turned them in a counterclockwise direction. The retractor muscles quickly drew the velum and soft body parts into the shell and after closing the shell the larvae sank toward the bottom.

Anatomical structures of the soft body of larvae only 48-hours old and older were partly obscured by the shell, but growth was often obvious as a rim of new shell deposited along the ventral margin.

Shell measurements at stages of larval development and metamorphosis were made for comparison with similar data in the literature (Table 2). Veliger larvae seen one day after fertilization had an average shell length of 89µ, a shell height of 71µ, and a hinge line of 55µ. These are measurements about midway between the values reported by Sullivan (1948) and Loosanoff et al. (1966). Additional shell growth was slight 7 days after fertilization, but 10 days later the larvae averaged 213 x 194µ. A pediveliger was first seen on the 18th day and its measurements (245 x 230µ) were larger than most reported by Loosanoff et al. (1966), although they saw some both larger and smaller (Fig. 3H). An even larger pediveliger (261 x 239µ) was seen 21 days after fertilization, and most larvae had metamorphosed into crawling juvenile clams (303 x 267µ) (Figure 3I). The metamorphosed clams were larger than

Table 2. Larval shell measurements during the development of surf clams, *Spisula solidissima*, and comparison with measurements in the literature.

Number of larvae measured	Time in days	Average shell measurements, length x height x hinge line (in microns)	Literature reference of shell measurements (L = length, H = height, in microns)
11	1	89 x 71 x 55	85L, Loosanoff and Davis (1963); 80L x 65H, Loosanoff et al. (1966); 95L x 80H, Sullivan (1948).
11	2	89 x 76 x 54	
15	7	94 x 79 x 54	
10	17	213 x 194[a]	
1	18[b]	245 x 230	160L x 165H was the smallest pediveliger seen by Loosanoff et al. (1966).
1	21[c]	261 x 239	Most were 215L, and a few 260L were still swimming.
6	21[d]	303 x 267	270L x 245H, Sullivan (1948); most were 230-250L. Average from graph, 263L x 245H, Loosanoff et al. (1966).

---

[a] Umbones obscured hinge line.

[b] First appearance of a pediveliger, velum used mostly for locomotion.

[c] Pediveligers few in culture.

[d] Footed clams most numerous in culture.

those reported by Sullivan (1948) and Loosanoff et al. (1966).

Direct evidence about the type of larval development by Spisula solidissima in the natural environment and throughout its distributional range is not available. From a review by Mileikovski (1971), most of the marine bottom invertebrates have a pelagic development and the numbers of species having such development increases near the equator and in shallow-shelf waters. These general criteria apply to the surf clam. Based on the types of pelagic development proposed by Thorson (1950), surf clam larvae are probably planktotrophic, (live in the floating plankton), since the yolk material in laboratory-reared larvae was indistinguishable after 24 hours of their early life and some of the D-shaped larvae had algal cells in the stomach. During the remaining 95% of their larval life, the larvae fed on algal cells. An enzyme for digesting algal cells is probably present early in the larval life of the clam, equipping it for a planktonic existence. Laster and Strittmatter (1968) found a tenfold increase in maltase activity in developing surf clam larvae. It coincided with the appearance of the esophagus, stomach, intestine, and digestive gland. This would be at the D-shaped stage. Larvae of a European mactrid, S. subtruncata, were obtained in plankton samples and raised to an identifiable size by Jorgensen (1946).

The problem of species identification of larval bivalves collected in plankton samples, commented on by Loosanoff and Davis (1963) and Loosanoff et al. (1951; 1966), has resulted in the development of techniques for rearing larvae under laboratory conditions. In general, the youngest and smallest larval forms lack distinctive shell and body structures for clear separation. For this reason investigators have reared larvae collected in plankton samples to larger sizes before claiming species identity (Jorgensen 1946; Landers 1954). This technique can result in greater accuracy, but is time consuming and requires additional facilities. More recently several species of bivalve larvae, including S. solidissima, have been reared from known parents, examined microscopically during development for distinctive features, systematically measured, and the observations compared between species (Loosanoff and Davis 1963; Loosanoff et al. 1966; and Chanley and Andrews 1971). The latter investigators provided a key for the identification of 23 species inhabiting the Middle Atlantic Bight and made recommendations for identifying larval bivalves.

Cable and Landers (1974) reported on results of egg and embryo development of surf clams in synthetic seawater which were comparable to natural seawater. Rhodes et al. (1975) summarized information on the availability, maintenance, conditioning, and spawning of adult surf clams used in rearing the embryos and larvae and observation on the growth of juveniles.

3.3 Adult History

3.3.1 Longevity

Age determinations of surf clams by counting the number of growth rings on the shell have been attempted by several investigators (Kerswill 1944, at Prince Edward Island, Canada; Caddy and Billard 1976, at Buctouche, Canada; Belding 1910, at Cape Cod, Massachusetts; Westman and Bidwell 1946, at Long Island, New York; Welch 1963, off Point Pleasant, New Jersey; Chang et al. 1976, off Barnegat Inlet, New Jersey, and Ocean City, Maryland; Ropes et al. 1969, at Chincoteague Inlet, Virginia; Loesch and Ropes 1977, off Virginia; Jones et al. 1978, off Virginia and New Jersey). Three records of the oldest surf clam are a mean length of 163 mm at age 17 (Westman and Bidwell 1946); 147 mm at age 20 (Loesch and Ropes 1977); and 164 mm at age 25 (Jones et al. 1978). Although the latter reported a maximum age of 30 years for some, no shell length values were given. As seen in section 3.3.6 below, a much larger surf clam has been reported. Since growth is generally slower at ages older than 10 years, longevity may be greater than 17 years.

An estimate of longevity was computed using the 226 mm maximum length and the von Bertalanffy age/length relationship computed by Chang et al. (1976), as follows:

$$L_t = 174.8\ (1-e^{-0.19(t+0.81)})$$

$$t = \frac{1}{K} \log_e \frac{L_\infty}{L_\infty - l_t} + t_o$$

$$t = \frac{1}{0.19} \log_e \frac{174.8}{174.8-226} + (-0.81)$$

$$t = \text{Age}_\infty = 26 \text{ years}$$

3.3.2 Hardiness

No data are available on hardiness of surf clams. Commercial plants that process the meats of this clam, however, usually complete their operations within a 24-hour period after landing the catch, and many hold it in refrigerated rooms until processing can be started. The clam is prone to injury by the water jets of the dredges used to harvest them, since it gapes slightly at the siphon end. The removal of surf clams from their burrows adversely affects survival, because an elastic resilium in the hinge constantly forces the shells open, contributing to an eventual fatigue of opposing muscles. The valves gape open exposing the soft body to disication in air and to predators in the marine environment and normal body functions, such as respiration, feeding, and elimination of waste metabolites, are disrupted in either situation. Surf clams would rate low on a scale of hardiness compared to hard clams, Mercenaria mercenaria, which close their shells tightly.

3.3.3 Competitors

A variety of benthic organisms occur in the beds with surf clams. It is not known how these may compete, but most would utilize space in the bottom, form a smothering mat over it, or utilize the available foods.

Survey samples have occasionally taken large numbers of surf clams per tow from inshore beds. Clams in these samples frequently exhibit a roughened shell surface: older shell deposits appear raised over new in a shingle-like fashion; some have a decidedly blunted posterior end. These shell irregularities suggest that normal growth was somehow interrupted. A smaller size at their maximum age than offshore clams is discussed later (in section 4.1.2.2). The physical closeness of clams in a dense bed conceivably results in marginal food intake per clam and slower growth, but there may also be actual contact between adjacent shells. Wilbur (1964) discussed experimental observations that localized stimulation of mantle cells resulted in a large area of shell regeneration in some molluscs. Thus, repeated irritating contacts and injury of the delicate shell producing mantle edge seem possible from movements of surf clams in their burrows at locations of high densities. Irregular and slower shell growth of some inshore clams may, then, be visible effects of competition within the species.

3.3.4 Predators

Moon snails, *Lunatia heros* and *Polinices duplicatus*, were recognized by early biologists as predators of surf clams (Leidy 1878; Belding 1910). The characteristic countersunk hole bored by the snail's radula is usually found near the hinge and apex of the shell. Under experimental conditions, low temperature and salinity affected feeding of both species (Hanks 1952). *Polinices* ceased at 5°C or lower and 6°/00 salinity; *Lunatia* had a reduced rate of feeding at 2°C and ceased at salinities of 10°/00 or lower. The latter species was considered a predator able to feed throughout the annual temperature range of New England and in the oceanic waters where surf clams are abundant. Extensive windrows of small dead surf clams were found on the exposed beach at Wallops Island, Virginia, and 50% were bored (Ropes et al. 1969). Edwards (1974) reported a food list for *Polinices* which included surf clams and a preference for larger prey and certain species tested (*Mytilus* and *Mya*). Off Long Island, New York, Franz (1977) found that *Lunatia* tends to select clams less than 80 mm in shell length. In laboratory experiments, Pratt (1974) found that the boring snail, *Urosalpinx cinerea*, when confined with surf clams in running seawater made some contacts, but drilled no holes; many more contacts were made in standing water and holes were drilled in some shells. Carriker (1977) observed that the snails, *Urosalpinx cinerea*, bored to the same average depth in the calcitic shells of *Crassostrea virginica* and the aragonitic shells of *Spisula solidissima* and *Anomia simplex*. Wells et al. (1961) reported 17 species of pelecypods in the stomach contents of the sea-star, *Astropecten articulatus*, from off Ocracoke Inlet, North Carolina, but surf clams were not included; Porter (1972) also examined the stomach contents of this species, with the same results for surf clams. Tagatz (1968) found three mactrid species other than the surf clam in the stomachs of blue crabs, *Callinectes sapidus*, from Florida. These latter observations suggest that starfish and crabs are potential predators of surf clams.

Fish can be predators of surf clams. Surf clam shells have been found in the stomachs of haddock, *Melanogrammus aeglefinus* (Clapp 1912; Clarke 1954), and cod, *Gadus callarias* (Bigelow and Schroeder 1953; Clarke 1954).

Several European studies report a variety of invertebrate predators of mactrid species. Hunt (1925) found three species of starfish and the moon snail, *Natica*, had *Mactra sp* in their stomachs. Birkett and Wood (1959) reported that the siphons of the European mactrid, *Mactra stultorum*, were regenerated after the plaice, *Pleuronectes platessa*, had nipped off a portion. They also observed mortalities of *M. stultorum* by *Natica*, *Asterias*, and *Astropecten*. Partially pierced holes from snail boring on some clams were believed due to regeneration of the shell. Thorson (1966) observed that a turbellarian, *Discocelides longi*, ate an average of 3 and 2.6 *S. elliptica* 1-2 mm long per day in laboratory culture dishes. The sea urchin, *Echinocardium cordatum*, included *S. subtruncata* about 1 mm long in its diet and may consume 224 young spat in four weeks during the period when these small sizes are most available. The moon snail, *Natica alderi*, and brittle star, *Ophiura texturata*, also prey upon spat of *S. subtruncata*. The omnivorous hermit crab, *Pagurus bernhardus*, was observed to eat 51 (85%) of the young *Spisula*-spat in 2 sq dm of sand. Muus (1966; 1973) showed an intense set of *S. subtruncata* (ca 8,500/sq m) occurring in June to August rapidly disappeared within two months. Predation was believed the main cause of the disappearance. The starfish, *Astropecten irregularis*, feeds on *S. subtruncata* and Christensen (1970) elaborated on its feeding biology. Three *Spisula* species were found in the stomachs: 422 *S. subtruncata*, 67 *S. solida*, and 39 *S. elliptica* were the maximum number of each found in a single stomach. It was estimated that a medium-sized *Astropecten* may destroy 30,000 *S. subtruncata*-spat annually. Masse (1975) reported on *S. subtruncata* being eaten by *Astropecten aranciacus*. Fretter and

Graham (1962) reviewed the literature on the feeding mechanisms of gastropods and included many of the mactrid prey species given above. Birkett (1973) determined the energy transfer through a food chain centered around *Mactra stultorum* on the Dogger Bank. Although the energy consumed by *Mactra* during the first and second summers of life were high, fish predation of *Mactra*, expressed as an energy rate (g cal/g live wt/day), was highest during the first summer of the clam's life. Asteroid starfish predation of the clam was highest during the second summer of the clam's life, closely followed by predation from *Natica*. Mileikovsky (1974) discussed predation of pelagic larvae and early juveniles of marine bottom invertebrates by adult benthic invertebrates and their passing alive through their predators, but no real significance of this phenomenon for recruitment of a species in the benthos was given. Nielson (1975) observed predation of bivalves by the whelk, *Buccinum undatum*, but found that *S. truncata* and *S. elliptica* leaped away when attacked.

There are, then, various known predators of mactrid species, and although relatively few have been identified for *S. solidissima*, the effects of predation on survival of newly settled juvenile spat may be very significant.

3.3.5 Diseases

Protistan organisms, larval trematodes, larval cestodes, and tumors are among known parasites and diseases of marine commercial clams (Sindermann and Rosenfield 1967). Some of these organisms have been reported as parasites of *Spisula solidissima*. Kudo (1966) listed the thigmotrich, *Sphenophyra dosinae*, found on the gills; Humes and Cressey (1960) reported the cyclopoid copepod, *Myocheres major*, was found in surf clams form Rhode Island; and Cake (1973) found the phyllobothrid plerocercoid cestode of the genus *Echeneribothrium* free in the stomach and digestive diverticula of surf clams from Florida. Heavy infections of an immature anisakid nematode, tentatively identified as *Paranisakiopsis pectinis*, were in surf clams from off Maryland and Virginia and these contained large numbers of the sporocysts of a haplosporidian hyperparasite, *Urosporidium spisula*, which colored the nematodes a dark brown (Perkins et al. 1975; 1977). Lichtenfels et al. (1976) reported an immature nematode resembling *Paranisakiopsis* Yamaguti, 1941, was found in the surf clam, the whelk, *Busycon canaliculata*, and the moon snail, *Lunatia heros*. A similar larval nematode has been collected from scallops from off North Carolina and Florida. Lichtenfels et al. (1977) reported additional information on the identity of the nematode found in the surf clam, whelk, and moon snail. They believe the nematode is identical to *Paranisakis pectinis* found in scallops from off North Carolina, but know it has characteristics like *Sulcascaris sulcatus*, a species infecting marine turtles. Experiments to confirm this are in progress. Payne et al. (1977) reported the results of samples examined monthly from August 1976 to March 1977 for the nematode in surf clams. Large clams off Virginia were more heavily infected than clams off New Jersey. Lichtenfels et al. (1978) identified the anisakid nematode found in surf clams (*Spisula solidissima*), calico scallop (*Argopecten gibbus*), Atlantic bay scallop (*Argopecten irridians*), and whelk (*Busycon canaliculata*) to the genus *Sulcascaris*. He states that *Sulcascaris sulcata* is the only known species of this nematode genus to parasitize the green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtle. These turtles occur in the area where the nematode parasitizes the molluscs. An anatomical description of the nematode is included. Kern (in preparation) found the larval nematode in 13% of 1,293 clams examined; the hyperparasite was present in 96% of the worms. Nematode prevalence increased from 2% in clams from off New Jersey and Maryland to 32% in clams from off Virginia. It was mostly in the visceral mass, but was also in the foot, adductor muscles, and mantle tissues. An unidentified trematode, mentioned by Yancey and Welch (1968) was found by Ropes (1968b) as the cause of distended surf clam gonads, sometimes when uninfected gonads were in a shrunken and spent condition.

Several other parasites have been reported for mactrid species related to *S. solidissima*: Nicoll (1906a; 1906b) reported the trematode *Himasthla leptosoma* in *Mactra stultorum*; Sindermann (1970) included the spores of the gregarine, *Nematopsis schneideri*, found in the gills of *Mactra solida* by Leger (1903) and Leger and Duboscq (1913); Gallien (1949) reported *Proboscidosaccus enigmaticus* (of uncertain taxonomic position) in *S. solida* from France; Humes and Cressey (1958) reported the copepod *Conchyliruus torosus* in *Mactra gallbrato* from Pointe-Noire, Congo; Sindermann and Rosenfield (1967), and Sindermann (1970) included the copepod *Mytilicola mactrae* as a parasite of the Japanese *Mactra veneriformis* found by Hoshina and Kuwabara (1959); Cheng (1967) listed *Ancistrum japonica*, a ciliate, in *Mactra sulcataria* and *M. veneriformis*; Chun and Kim (1969) reported encysted metacercariae of the trematode genus *Echinostoma* in Korean *Mactra sulcataria*; and Humes and Stock (1973) listed the copepod *Paranthesis* sp in *Mactra sulcataria* from Japan and *Herrmannella rostrata* in *Mactra stultorum* from France.

A few commensal and symbiotic organisms have been found in mactrid species. The commensal nemertean, *Malacobdella grossa*, has been found in *Mactra sachalinensis* from Japan by Takahura (1897); in *Mactra stultorum* from Europe (Coe 1943); in *Mactra secta* (Cheng 1967); and in the siphonal plates of *Tresus nuttallii* (Stout 1970-1971); but was not found in *S. solidissima* by Ropes and Merrill (1967). The pea crab, *Pinnotheres pisum*, has been found in association with *Mactra stultorum* (Dalgliesh 1934), and Christensen (1968) found soft-shelled specimens in *Spisula solida* from Denmark and the first crab stage in the same clam species off the west coast of Sweden.

Toxins and organisms pathogenic to man have been found in surf clams. Buelow (1968) showed positive results for total coliforms in surf clams from the New York Bight disposal area. Since survival of enteric organisms in marine muds has been reported, surf clams in and near the sump site may be contaminated with pathogenic bacteria and viruses from sewage sludge. The pathogen, *Vibrio parahaemolyticus*, was found in 1 of 100 samples of the bar clam, *S. solidissima*, and none in 74 samples of processed meats from the Canadian Atlantic coast by Varga and Hirtle (1975). Paralytic shellfish poisoning (PSP) of humans in Canada resulting from eating surf clams containing toxins of the dinoflagellate *Gonyaulax tamarensis* has been reported by Medcof et al. (1974) and Bond and Medcof (1957). Medcof et al. (1947) found that surf clams retained the PSP toxin longer than any other mollusk tested and may retain it from one year to the next. Prakash et al. (1971) presented the available information on the paralytic shellfish poisoning problem in Canada. Bar clams (Spisula solidissima) were not considered a serious hazard, although they are sometimes very toxic in the Bay of Fundy. The toxin was highest in the gills and digestive gland relative to the adductor muscles, siphons, and other parts of the clam. The toxin was eliminated slowly by the clams and may remain in some from year to year. Blogaslawski and Stewart (1978) examined the anatomical localization of the toxin and developed methods of exposing toxin-bearing clams to ozone. Rapid detoxification was exhibited in all tissues after 2 weeks exposure.

Leibovitz et al. (1976) reported finding a pedunculated tumor on the foot of a surf clam. After an examination of histologically prepared tissues, the tumor was interpreted as a polypoid myoma. An earlier reference of a foot lesion in a surf clam was included.

Goldberg (1978) observed significant mortalities of surf clams exposed to gas-supersaturated seawater. Gas-laden tissue blisters formed in the siphons and membranous tissue blisters and abnormal shell depositions were observed. The relevance of air supersaturation to the bivalve culturist was discussed.

3.3.6 Greatest Size

A shell length of 226 mm is the greatest size reported for a surf clam to date (Ropes and Ward 1977). It was among clams measured by NMFS personnel gathering catch data at the Point Pleasant, New Jersey, port and from the commercial clam vessel, HAROLD F. SNOW, on August 1, 1974. The vessel operated at 73°54.5' W Long. and 39°48.5' N Lat. east of Barnegat Inlet in 21.3 m of water and caught 290 bu of clams. The 226 mm clam was in a sample of 10 averaging 193.3 mm; the smallest in that sample was 178 mm.

3.4 Nutrition and Growth

3.4.1 Feeding

Feeding is intimately related with the currents of water drawn in through and expelled from the siphons for respiratory and excretory purposes, since the water may carry food particles eventually ingested by the clam. Open siphons of surf calms have been seen at or in a depression slightly below the sand-water interface (Ropes and Merrill 1966) and thus unwanted particles of sand or other debris may sometimes be washed into the clam. Morse (1919) and Jacobson (1972) described in detail the siphonal structure and behavior of surf clams during pumping activities. They observed the number and action of papillae fringing the siphons and two stout papillae (one is bifurcated) in the branchial (incurrent) siphon. Jacobson (1972) described the closing action of the siphonal openings of a clam in its burrow when a wave flowed past. This was considered a defensive mechanism to prevent the ingestion of sand. Belding (1910) included a brief account of the feeding habits of surf clams, which was expanded upon by Kellogg (1915). He described the directional flow of food particles and other materials trapped in the mucous-covered surfaces of the soft body parts, such as the gills, palps, visceral mass, and mantle. Cable (1973) observed a valvular membrane in the exhalent siphon of surf clams. Prior (1974) elaborated on the morphology and responses of the incurrent siphonal valve and adductor muscles which coordinate to clean debris trapped in the siphonal cavity.

The crystalline style of surf clams is a prominent structure that, in addition to mechanical stirring in the stomach, functions enzymatically to aid digestion and assimilation of ingested foods. Lavine (1946) demonstrated a cellulolytic property; Patton and Quinn (1973) found a lipase which was more versatile on primary wax esters and menthol esters than hog pancreatic lipase, and Shallenberger et al. (1974) reported larinaranace activity. Shallenberger (1975) studied the carbohydrases of the style that lyse cellulose and initiate hydrolysis of the carbohydrate reserves--laminaran and starch--to sugars. Powders prepared from the styles appeared to be stable and may have scientific, technological, and industrial uses. Lindley and Shallenberger (1976;1977) purified, characterized, and tested two hydrolase enzymes from surf clam styles as steps in determining potential use in dissolving entrapped polysaccharides in filter mats used in the production of beer.

Neurophysiological studies have been conducted on the gut movements in surf clams. Nystrom (1967) demonstrated tonic and phasic spontaneous contractions of longitudinal, nonstriated muscles in the cardiac (rectal) segment of the intestine; Smucker and Nystrom (1970) were unable to demonstrate an extrinsic (outside) innervation of the gut posterior to the stomach or the cardiac and esophagus segments as well. The control of gut motility was described as an interaction of components within the neural plexus and associated muscles (Smucker and Nystrom 1970; 1972).

3.4.2 Food

Leidy (1878) made observations on the contents of the digestive tract of surf clams from a New Jersey beach. He was surprised "at the number of different genera and species of diatoms found" but mentioned only *Amphiprora constricta* and a suspected ciliated infusorian, *Tintinnus*, in the brief remarks. He observed changes in the diatoms due to digestion and the lack of contents before they passed from the rectum. Belding (1910) included diatoms as the food of surf clams. Loosanoff and Davis (1950; 1963) used mixed plankton cultures to feed larval surf clams and discussed various conditions for raising larval bivalves related to food. Stephens and Schinske (1961) observed the removal of amino acids, such as glycine, glutamic acid, tyrosine, methionine, phenylalanine, and arginine, by surf clams, although the nutritive significance was considered speculative.

3.5 Behavior

3.5.1 Local Movements

The surf clam is considered a sedentary, infaunal, and benthic creature which spends most of its life buried in the sea floor substrata (Ropes and Merrill 1973). Due to its relatively short siphon, it is generally believed that it burrows to a depth about equal to its shell length. A diver found surf clams with the uppermost portion of the shell about 1/2-in (12.7mm) below the surface (Ropes and Merrill, 1966).

They described the burrowing action of surf clams in aquaria and natural situations.

Edwards and Emery (1968) reported an observation of a large surf clam leaping about 18 in (457 mm) off the bottom during dives in the research submersible ALVIN. It landed 2 or 3 ft (609-914mm) away from its starting point.

Several factors, such as the size of the clam, temperature, and shock, influence the speed of burrowing by surf clams, Spisula solidissima, in laboratory experiments and are significant with respect to bed formation in the natural environment (Ropes in preparation). Small clams burrowed more actively than large clams by making fewer digging cycles. Under cold temperature conditions (1.8°C), some clams failed to begin digging activities, while others were inhibited in beginning and completing burial. Mechanical shock induced digging at temperatures of 4°C. Burrowing activities of clams acclimated to a 14°C increase were only slightly affected, but a 22°C rise in temperature from 4°C caused gaping, lethargy, and eventual death. The seasonal warming trend in the spring significantly increased burrowing activities, but the subsequent increase in temperature during the summer had little effect. Based on these experiments, the greatest disruption of surf clams would be expected during the cold months of the year, and small clams are probably most affected by surf zone currents because of their lower weight in water.

Hunter and Grant (1962) tested the ligament of surf clams in relation to mode of life. An opening moment was determined (mean of 608.89 mm/ml) and was about 3.5 times more powerful than the ligament of soft clams, Mya arenaria. The mechanical differences were said to reflect the modes of life of the two species. The opening moment of the hinge ligament in a surf clam functions to actively maintain a burrow, which is often relatively unstable sand substratum. A relationship between the action of the hinge ligament and hardiness has been discussed (cf. section 3.3.2). Kahler (1976) also reported on the form, function, chemical analysis, and mechanical properties of the ligament of surf clams.

Locomotion by postmetamorphal surf clams is a remarkably active behavior. The foot can be extended beyond the valve margins to a length almost equal to the shell height and is used to pull the young clam over the bottom or is probed into the bottom substratum (Figure 3I). In laboratory cultures, the clams can move actively over the glass bottom of a beaker, sometimes pulling with them other clams and shells. The end of the foot is ciliated and may have a means of physical adhesion to such surfaces as smooth as glass. Attachment by a byssus thread has not been demonstrated for juvenile surf clams, but has been found for a Japanese relative, S. sachalinensis (Hayashi and Terai 1964). Yonge (1962) reviewed the primitive significance of the byssus for bivalves and noted its absence in adults of the superfamily Mactracea, which includes the surf clam.

3.5.2 Schooling

Not a behavior of clams.

3.5.3 Stimuli

Several neurophysiological investigations described nerve pathways affected by stimuli. Kennedy (1960) found the pallial nerves of surf clams contained a single afferent nerve fiber. It responded to illumination and apparently mediated the "shadow" response of siphon retraction. The clams were more responsive to decreases in intensity than sudden increases in illumination. Mellon (1965) examined nerual pathways controlling reflex withdrawal of the siphons in surf clams. The pathways were among the fastest in the relevant nerve trunks and he was able to account for symmetrical siphonal withdrawal. Mellon and Prior (1970) studied the fast portion of the posterior adductor muscle of surf clams and found Type I motor neurons. Prior (1972a) found local reflexes which mediate localized siphonal contractions in response to tactile stimulation. Prior (1972b) studied the behavioral sequence involving local reflexes, siphon retraction, and valve adduction. Discrimination between low and medium stimulus intensities was observed. Mellon (1972) studied the electrophysiology of touch sensitive neurons in surf clams. He found stomata of first-order tactile neurons are located in the central nervous system and elaborated on their form and function. Prior and Lipton (1977) studied the ultrastructure of peripheral neurons and associated non-neural structures in surf clams. Synaptic topography was described and anatomical correlates of previous physiological observations were provided. Prior et al. (1979) observed an evasive jump response of surf clams by touching the siphons with the tube feet of a starfish (Asterias forbesi). Small clams (2.0-5.0cm) were most responsive, medium clams (5.4-11.5cm) were moderately responsive, and large clams (12.0-18.0cm) were unresponsive. They considered small clams were more susceptible to predation than large clams because of shorter siphons which permit only shallow burrowing. The neural basis for the evasive jump response was investigated.

Temperature has been used to hasten gonadal development in surf clams. Clams moved from the natural environment during the late fall, winter, and early spring, to warm-water laboratory conditions, stimulated gonadal development to a ripe condition (Loosanoff and Davis 1963). Sapwning was induced by thermal and chemical stimulation, although thermal stimulation alone was sufficient on several occasions. Normal larvae for culture purposes "out-of-season" were produced on many occasions. The influence of temperature as a stimulus in the natural environment was recognized in studies of gonadal development (Ropes 1968b). Gametogenesis proceeded to a ripe gonad condition during warming trends in the spring and early summer. Spawning coincided with abrupt increases in bottom-water temperature.

Temperature also influenced burrowing activities in surf clams. Burrowing rate was stimulated by increasing temperature to about 20°C, but was depressed by higher temperatures (Savage 1976).

Low dissolved oxygen can be a stimulus. During the summer of 1976, low oxygen in the bottom water off New Jersey was a stimulus prompting some surf clams to vacate their burrows (Ropes et al. in preparation). Scuba diver observations and catches of dead and dying clams in otter trawl samples were evidence for this unusual behavior. Low oxygen conditions severely depressed burrowing activities of surf clams (Savage 1976).

4. POPULATION

4.1 Structure

4.1.1 Sex Ratio

Data for determining the sex ratio of surf clams were from two sources: (1) the study of the reproductive cycle of the clam off New Jersey during 1962-1965 (Ropes 1968b); and (2) random collections of gonads taken during survey cruises in 1965 and other miscellaneous sources. The latter samples were prepared for microscopic examination in the same manner as was done in the study of the reproductive cycle above (Table 3). In a chi-square test to determine if the samples were from a population having a 1:1 sex ratio, X^2 values of 2.2218 and 0.4902 obtained for the two respective sources of data were non significant at the 5% level. Therefore, the hypothesis was accepted that the samples were drawn from a population in which the sex ratio 1:1.

4.1.2 Age Composition

Age-size relationships for surf clams have been derived by several means of observing shell growth and for widely separated geographic areas and years (Table 4). Age was determined from "rings" or "ridges" seen on the external shell surfaces by Belding (1910) at Cape Cod, Massachusetts; Kerswill (1944) at Prince Edward Island, Canada; Westman and Bidwell (1946) at Long Island, New York; Welch (1963) at Central New Jersey; and Caddy and Billard (1976) at Buctouche, Canada. In refined analyses of Westman and Bidwell's (1946) and Welch's (1963) data, Loesch and Ropes (1977) reported that the latter were used in approximating surf clam growth in part of the fishery off Virginia.

In 1975, NMFS investigators developed methods to more clearly observe marks deposited in the shells of surf clams. The shells were cut from the umbo to ventral margin and the cut surfaces were polished. This procedure exposed marks that were related to

Table 3. The number of surf clams, *Spisula solidissima*, by sex.

Year	Number of samples	Number of Male	Number of Female	Totals
A. Samples taken during a study of the reproductive cycle (Ropes 1968b).				
1962	8	74	98	172
1963	20	244	246	490
1964	20	240	244	484
1965	14	170	198	368
Totals	62	728	786	1,514
B. Random samples from survey cruises and miscellaneous sources.				
1965S	19	78	93	171
1965F	23	101	87	188
Misc	8	43	57	100
Totals	50	222	237	459

S = spring; F = fall

TABLE 4. Mean shell length (mm) at external (ext.) or internal (int.) growth marks and measurements of yearly growth of surf clams, *Spisula solidissima*, from various geographic locations and years.

Source	Location, Type of Bed, & Number of clams	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV	XXV
Belding (1910)	Monomoy Point; inshore; not given; (ext.)	25.4	40.6	81.3	91.4	101.6	108.0	114.3																		
Kerswill (1944)	P.E.I., Canada; offshore; 100; (ext.)	15.9	34.9	57.2	76.2	92.1	101.6	111.1	117.5	120.7	123.8	127.0														
Westman & Bidwell (1946)	Long Island, N.Y.; offshore; ca. 100; (ext.)	34.0	60.0	79.0	92.0	103.0	112.0	120.0	127.0	133.0	138.0	143.0	147.0	151.0	155.9	158.0	161.0	163.0								
Welch (1963)	Central New Jersey; offshore; 10; (ext.)	45.7	78.7	99.1	116.8	124.5	132.1	137.2	139.7	142.2	143.2	144.8	147.3													
Caddy & Billard 1976	Buctouche, Canada; inshore; 155; (ext.)	15.0	31.0	49.0	65.0	81.0	96.0	109.0	119.0	128.0	134.0	139.0	143.0	145.0	149.0	150.0	151.0									
Loesch & Ropes (1977)	Offshore Virginia; Welch's data used.	47.2	79.2	100.8	115.8	125.7	132.6	137.4	140.5	142.7	144.3	145.3	145.8	146.3	146.6	146.8	147.1	147.1	147.1	147.3						
NMFS 1975 Chang et al (1976)	Barnegat, N.J.; inshore; 39; (int.)	34.0	56.0	73.0	88.0	102.0	109.0																			
NMFS 1975 Chang et al (1976)	Ocean City, Md.; offshore; 36; (int.)	39.0	57.0	94.0	113.0	126.0	136.0	143.0	148.0	152.0	156.0	159.0	161.0	163.0												
Jones et al (1978)	Pt. Pleasant, N.J.; inshore; 54; (int.)	38.0	62.0	79.0	88.0	94.0	97.0	102.0	106.0	108.0	109.0	110.0														
Jones et al (1978)	Pt. Pleasant, N.J.; offshore; 30; (int.)	29.0	55.0	81.0	99.0	112.0	122.0	130.0	135.0	140.0	144.0	147.0	148.0	149.0	151.0	152.0	153.0	153.0	155.0	156.0	157.0	160.0	161.0	162.0	164.0	164.0
NMFS 1965-67 Ropes et al (1969)	Chincoteague Inlet, Va.; inshore; annula shell measurements; 846.	44.2	68.6	90.5																						

"rings" on the external valve surface of the cut and uncut shells. The method appeared to be more accurate than simply examining the external valve surface, because some internal marks were found but corresponding "rings" on the external surface were poorly defined. Chang et al. (1976) reported age-size relationships from data compiled using this technique on surf clams from inshore and offshore locations (Table 4). Later, Jones et al. (1978) reported on a study of aging inshore and offshore surf clams using the same technique.

Three mean yearly increments of surf clam growth have been derived from measurements of the shell lengths of a discrete settlement discovered in Chincoteague Inlet, Virginia, on October 1, 1964. A total of 366 clams from Wallops Island Beach averaged 21.1 mm in shell length on October 28, 1964. Thereafter, 311 clams from this beach averaged 42.4 mm on July 7, 1965; 405 averaged 68.6 mm on July 18, 1966; and 75 averaged 90.5 mm on August 7, 1967 (Table 4). After January 29, 1968, clams were unavailable from this source, due to heavy losses from predation and storms. Ropes, Chamberlin and Merrill (1969) reported on these data and included a projected size at 4 years of 110 mm.

Ropes and O'Brien (1979c) reported on a method of thin-sectioning the chondrophore in the hinge of surf clams to expose growth marks. Correspondence was found between marks in the chondrophore and valve. They believe the techniques of preparing study specimens were simple and that growth increments were more easily observed and measured than in sectioned valves. They discussed the problem of assigning a year's growth to each observed growth mark.

4.1.2.1 Age composition of landings

Analyses are in progress summarizing age-size relationships of surf clams landed by area and years. The results are too preliminary to report at this time. As indicated by the size composition of landings (cf sec. 4.1.3.1), large and probably old clams were fished from offshore Point Pleasant, N.J., and Ocean City, Md., during 1965-74, but off Virginia, the fishery concentrated on much smaller clams from a settlement found in 1969 (cf sec. 5.2.1).

4.1.2.2 Variations with depth

Mean length at age, determined by the method of cutting shells, provides observations on 39 clams from an inshore Barnegat, New Jersey, location and 36 clams from an offshore Ocean City, Maryland, location (Table 4). The depth at these respective locations was 11.6 m and 18.3 m. Although these are not wide differences in depth, the age-size relationship of the oldest clams at the Barnegat site was 5 years and 109 mm and at the Ocean City site was 12 years and 163 mm. Growth at 5 years by the Ocean City clams exceeded the Barnegat clams by 27 mm.

Jones et al. (1978) provided similar observations of variation in growth of surf clams with depth (Table 4). For two sites east of Point Pleasant, New Jersey, 54 clams were collected from an inshore location 1.8 km from shore and at a 15-m depth, and 30 clams from an offshore location 17.5 km from shore and at 28m. The age-size relationship for the oldest clams at the inshore site was 11 years and a mean of 110 mm, and at the off-shore site was 25 years and a mean of 164 mm. Growth of the offshore clams at 11 years exceeded the inshore clams by 37 mm.

4.1.2.3 Age-length and age-weight relationships

Chang et al. (1976) determined the relationships between age and length, total weight and drained meat weight for the Middle Atlantic Bight surf clam. The respective equations are:

Age and shell length (mm) -- $L_t = 174.8\ (1-e^{-0.19(t+0.81)})$

Age and total weight (g) -- $W_t = 762.7\ (1-e^{-0.11(t-3.13)})$

Age and drained weight (g)-- $W_t = 263.2\ (1-e^{-0.14(t-2.05)})$

Caddy and Billard (1976) determined the age-length relationship for the surf clam at Buctouche, Canada, as:

Age and shell length (cm) -- $L_t = 17.0656\ (1-e^{-0.1553(t-0.628)})$

Ropes (1979a) included a generalized age-length graph in a discussion about aging surf clams (Fig. 4).

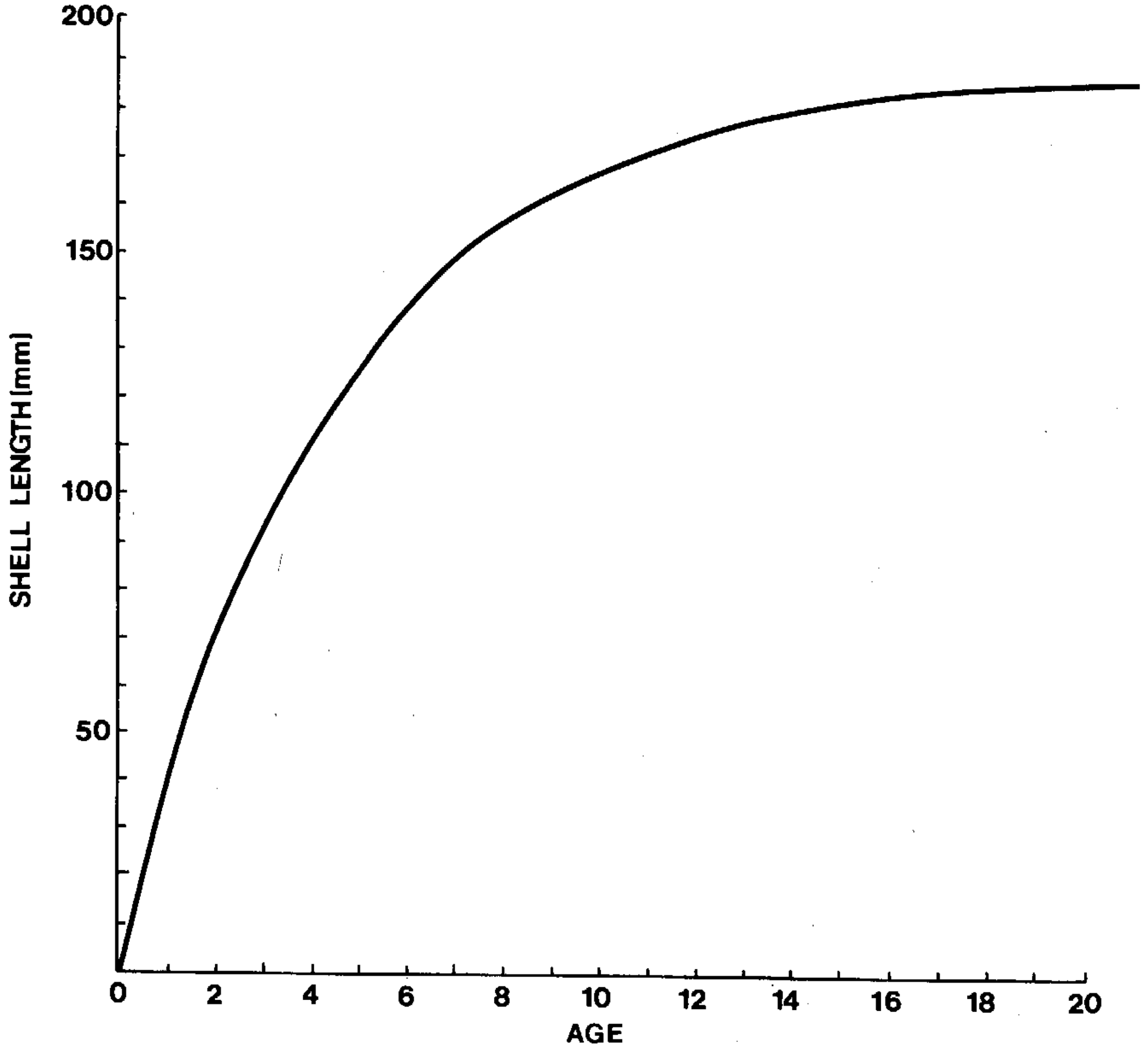


FIGURE 4. General age and growth relationship for surf clams, Spisula solidissima. (From Ropes, 1979a).

4.1.3 Size Composition

4.1.3.1 Size composition of landings

Measurements of surf clams have been taken during interviews of vessel captains landing their catches in 1965-74 (Groutage and Barker 1967a,b; Yancey 1968, 1970; Barker and Ropes, Merrill, and Ward 1975; Ropes and Ward 1977). Mean shell lengths and range of sizes have been derived from these measurements (Table 5). Mean clam size at the Point Pleasant, New Jersey, port was consistently large and increased from 151 mm after 1965. The size of the clams was considered typical for the offshore resource. At Cape May - Wildwood, New Jersey, catches from both an inshore and offshore resource were landed. The sizes from the inshore resource were small (ca. 130 mm); those from the offshore resource were large (ca. 155 mm). Landings at Ocean City, Maryland, were from the offshore resource and large clams (ca. 155 mm). At Virginia ports, clams of a small mean size (ca. 133 mm) were landed, but these were from a recent settlement that were harvested before they reached the more typical large offshore size. Shell lengths range from about 100 to 200 mm in most commercial landings, although smaller and larger individuals are sometimes taken.

4.1.3.2 Variations with depth

Ropes et al. (1972) report surf clam catch by depth and distance from shore. The data were from 370 interviews of vessel captains at Cape May - Wildwood, New Jersey, in 1972. Clams from beds at 8.2, 10.1, 22.1, and 23.6 m depths and 3.0, 4.6, 27.8, and 29.9 km from shore averaged 113.3, 127.1, 155.5, and 163.4 mm in shell length, respectively. For those samples shell length clearly increased directly with depth and distance from shore. The smaller clams at the nearshore and shoal locations were considered inshore stocks in opposition

Table 5. The mean shell lengths and (range of) sizes of surf clams, Spisula solidissima, measured in samples during NMFS interviews of vessel landings, 1965-74.

	New Jersey			Maryland	Virginia
		Cape May - Wildwood			
Year	Pt. Pleasant	Inshore	Offshore	Ocean City	Cape Charles
1965	151(120-180)		139(105-180)		
1966	151(105-189)		130(100-160)		
1967	149(110-185)		141(095-178)		
1968	153(109-184)		147(111-195)		
1969	155(116-203)	131	157(109-187)		
1970	157(126-171)	128	160(113-173)	141(095-200)	
1971	157(110-184)	129	159(098-190)	151(100-198)	
1972	158(110-185)	127	158(087-191)	159(104-194)	133(106-160)
1973				161(107-198)	135(086-170)
1974	186(145-226)			160(106-192)	132(097-188)

to offshore stocks of larger clams further from shore and in deeper water. The larger size, faster growth, and greater age (cf. section 4.1.2.2) of offshore than inshore clams suggests that conditions for growth are more optimum offshore.

4.1.3.3 Size at first harvest

Prior to the development of mechanical processing equipment in the early 1970's, the fishery attempted to exclude catching clams less than 125 mm in shell length. Some smaller clams occurred in the catches and were usually rejected during the shucking operations by hand methods. At the present time there are no restrictions on gear to limit the catching of small clams (cf. sec. 6.1). Size at first harvest can be less than 100 mm and some as small as 87 mm have been measured (cf. 4.1.3.1).

4.1.3.4 Size at maturity

Cf. sec. 3.1.2

4.1.3.5 Maximum size

Cf. sec. 3.3.6

4.1.3.6 Length and weight relationships

Chang et al. (1976) determined the relationships between surf clam shell length (L) and total weight, dry shell weight, and drained meat weight for the Middle Atlantic Bight. The respective relationships are:

$$\ln W_t = -10.3188 + 3.21034 \ln L$$

$$\ln W_t = -8.25149 + 2.7168 \ln L$$

$$\ln W_t = -8.97583 + 2.766297 \ln L$$

Relationships were also developed between shell length vs. shell height, width, chondrophore length, and shell cross-section, and chondrophore and shell cross-section measurements. These latter were derived from measurements of annular rings exposed by cutting the clam shells (cf. sec. 4.1.1).

Caddy and Billard (1976) determined the relationship between shell length and drained meat weight for surf clams from Buctouche, Canada, as follows:

$$W_t = 0.1063(L)^{2.5996}$$

Murawski and Serchuk (1979) determined the relationship between shell length and drained meat weight for surf clams from commercial samples off Delmarva Peninsula, as follows:

$$\log_{10} W = -3.5876 + 2.6224 \log_{10} L$$

4.2 Abundance and Density

4.2.1 Estimation of Population Size

Caddy and Billard (1976) estimated the production of bar clams in an unexploited population at Buctouche, New Brunswick, Canada. Production estimates were based on an estimated virgin biomass of 58.8 mt of drained meat. From their analyses, a prediction was that small local populations can probably sustain full-time harvesting by 1 or 2 fishermen using diving gear.

4.2.2 Changes in Relative Abundance

Serchuk et al. (1978) reported trends in research survey relative abundance indices for surf clams in the major offshore fishing areas of the Middle Atlantic during the 1965 through 1977 period. The survey indices were compared with annual landings in each area (Figures 5A-D). Recruitment in these areas is reported in section 4.3.3.

In northern New Jersey, relatively high abundance indices in 1965-1967 steadily declined to low levels by the mid-1970's (Figure 5A). Correspondingly,

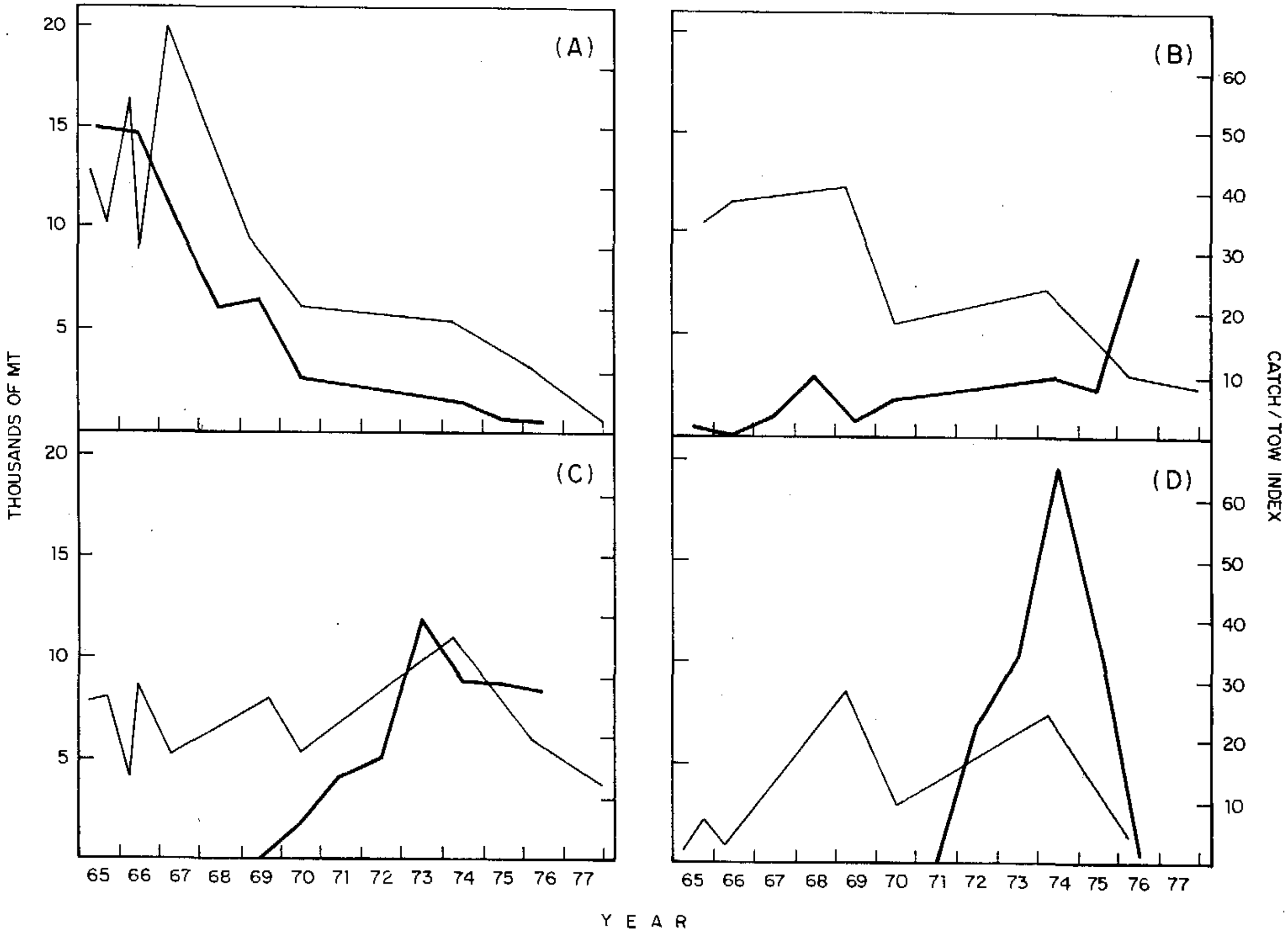


FIGURE 5. Estimated annual landings of surf clam (*Spisula solidissima*) meats in metric tons (solid lines) and catch per tow indices in mean number of clams (broken lines) from the offshore Fishery Conservation Zone and: (A) northern New Jersey, (B) southern New Jersey, (C) Delmarva, and (D) Virginia - North Carolina. (Adapted from Serchuk et al. 1979).

landings declined by 96% between 1965 and 1976. A massive clam kill in 1976 reduced survey indices to a low of 2.7 clams per tow by 1977. The estimated loss was almost 62% of New Jersey's surf clam biomass (cf. section 2.3).

In southern New Jersey, high survey indices in 1965-1969 stabilized at slightly lower levels during 1970-1974 (Figure 5B). Annual landings in the same 10-year period were moderate, averaging 1,588 mt of meats. Thereafter, landings of 2,268 to 8,845 mt meats in 1975 and 1976 reflected an increase in fishing effort and survey indices declined.

Off Delmarva, surf clam abundance indices during 1965 to 1976 were the most stable of any area surveyed, ranging from 13.8 to 36.9 and averaging 24.1 clams per tow (Figure 5C). Annual landings from offshore beds increased after 1972 and averaged 8,525 mt of meats. The moderately high abundance indices recorded for the area were in part (cf. section 4.3.3) considered an indication that a stable fishery might result at annual harvest levels of about 8,100 mt of meats. A 50% decline in the 1977 survey indices from 1976, however, suggested that the 8,100 mt level may be too high.

Off Virginia - North Carolina, abundance indices were the most variable of any area surveyed (Figure 5D). The indices increased ten-fold in 1969 from relatively low levels in 1965 and 1966, declined sharply in 1970, increased sharply in 1974, and decreased to a low level in 1976. Annual landings from the area were insignificant before 1972, but increased to 19,777 mt of meats by 1974. Landings decreased sharply in 1975 and the negligible amount landed in 1976 indicated the collapse of the fishery.

Murawski and Serchuk (1979) analyzed the 1976 to 1978 research survey relative abundance indices for surf clams in the major offshore fishing areas of the Middle Atlantic. Off northern New Jersey, indices for commercial-sized clams ($\geq$ 12 cm shell length) remained relatively low and no apparent trend was observed in the indices for off southern New Jersey. Off Delmarva, all relative abundance indices declined between 1976 and 1977 and those for commercial-sized clams remained low throughout a December 1978 survey. In effect, then, no significant increase was observed in the commercially exploited biomass for any of the survey areas. Most (92% and about 13,000 mt of meats) of the 1978 landings of surf clams were from the Delmarva area, nearly all of the rest (8% and about 1,100 mt of meats) was from off New Jersey, and a small amount (0.2% and about 270 mt of meats) was from off Virginia-North Carolina.

4.3 Natality and Recruitment

4.3.1 Reproductive Rate

Unknown

4.3.1.1 Annual egg production rates

Unknown

4.3.1.2 Egg and larval survival rates

Unknown

4.3.2 Factors Affecting Reproduction

4.3.2.1 Density-dependent factors

Unknown

4.3.2.2 Physical factors

4.3.2.2.1 Temperature

Temperature was not clearly reported as a stimulus for spawning of surf clams by Ropes (1968b). Some spawning was observed before abrupt temperature increases were observed and when bottom values were 12°C or less. The gradual gonadal development to ripeness before spawning, accompanied by the probable production of neurosecretory products, were thought of as important conditions influencing spawning. Nevertheless, a minimum temperature threshold eliciting the spawning response is likely, although not clearly known. Under laboratory conditions, spawning of ripe clams can usually be easily induced by a simple rapid increase in temperature. Instances of spontaneous spawning by individuals held under constant temperature conditions, however, have been observed.

In the laboratory, Loosanoff and Davis (1963) induced spawning of surf clams at temperatures of 18-25°C, but at 30°C and above, the survival of clams and eggs were unfavorably affected.

Loosanoff and Davis (1963) reported on larval development of surf clams at two temperatures and a salinity of 27 ppt. At 14°C, fertilized eggs reached the straight-hinge stage after 72 hr; at 22°C the same stage was reached after only 28 hr. Metamorphosis was first observed after 35 and 19 days at the two respective temperatures. Development was not only slower at the colder temperature but the larvae were smaller than those raised at 22°C.

4.3.2.2.2 Water movements

It is suspected that ocean water currents transport surf clam larvae, since they have relatively weak self-locomotory abilities. Bumpus (1965, 1973) and Bumpus and Lauzier (1965) described the residual surface and bottom drift of water currents along the continental shelf of the Middle Atlantic Bight. They reported a coastal current flows predominantly southwesterly and southward, with reversals expected between April and September in years when river runoff is abnormally low (Bumpus 1969).

4.3.2.2.3 Anoxic factors

Cf. section 2.3.

4.3.3 Recruitment

Serchuk et al. (1979) reported trends in research survey relative abundance indices for recruiting surf clams (9.0-11.9 cm shell length) in the major offshore fishing areas of the Middle Atlantic during 1965-1977; Murawski and Serchuk (1979) provided similar indices for surveys during 1976-1978 (Table 6). Off northern New Jersey, recruitment was low in 1965 to January 1978, but in the December 1978 survey, the index was 27.8 clams per tow, a 28-fold increase over the low January 1978 value. Off southern New Jersey, recruitment indices in 1965 and 1966 were only slightly higher than off northern New Jersey, but declined thereafter through 1976. Only a slight increase was observed in the 1977 and two 1978 survey values. Off Delmarva, recruitment values were low, but relatively steady, throughout 1965 to January 1978. In the December 1978 survey, the

Table 6. Relative abundance (mean number per tow) of recruiting (9.0-11.9 cm in shell length) surf clams, *Spisula solidissima*, for NMFS surveys during 1965-1978 in the offshore Fishery Conservation Zone from northern New Jersey, southern New Jersey, Delmarva, and Virginia-North Carolina. (Data from Serchuk et al. 1979; Murawski and Serchuk 1979).

Cruise Period	Northern New Jersey	Southern New Jersey	Delmarva	Virginia-N. Carolina
1965-Spring	3.1	5.9	4.6	1.1
1965-Autumn	1.6	7.6	4.3	2.9
1966-Spring	4.4	ND	2.3	1.0
1966-Summer	2.8	2.4	4.2	ND
1967-Spring	3.5	0.0*	0.8	ND
1969-Spring	1.2	1.7	2.0	5.6
1970-Summer	1.1	0.8	1.2	1.0**
1974-Spring	0.8	0.8	4.6	3.1
1976-Spring	1.0	0.2	3.5	0.2
1977-Winter	0.9	0.8	1.5	ND
1978-Jan.	0.9	1.6	2.6	ND
1978-Dec.	27.8	2.0	394.2	ND

* Only 5 stations
** Only 11 stations
ND No data

recruitment index was 394.2 clams per tow, the largest value recorded to date for an offshore area. The small clams were distributed in a 1,300 km^2 area at 9 to 27 m depths off Ocean City, Maryland and in 7,560 km^2 area at 27 to 46 m depths off Chincoteague to Cape Charles, Virginia. Off Virginia - North Carolina, recruitment indices were low in six surveys, but the index recorded in 1969 was an indication of an earlier important settlement. Ropes (1979a) reported that 76% of the clams caught during the 1969 survey ranged from 61 to 99 mm and by 1974, 73% ranged from 121 to 149 mm. Clams landed at Virginia ports in 1972 to 1974 averaged 132 to 135 mm and were from the settlement found in 1969. The fishery relied heavily on clams from this settlement, harvesting them at unprecedented rates (Ropes and Ward 1977). The fishery was most active for about four years and then collapsed (cf section 4.3.3). For the small clams found off New Jersey and Delmarva in late 1978, Murawski and Serchuk (1979) predicted probable recruitment to the fishery in 1981 to 1982 and they discussed the need to monitor natural mortality of the pre-recruits to assess their impact on harvestable resource abundance.

4.4 Mortality and Morbidity

4.4.1 Mortality Rates

A natural mortality rate (M) for surf clams was assumed to be 0.2 by Caddy and Billard (1976), Chang et al. (1976) and Murawski and Serchuk (1979) used 0.25.

4.4.2 Factors Causing or Affecting Mortality

The predators and parasites of surf clams and conditions determining or having possible influence on distribution have been reviewed (cf. sections 2.3, 3.3.4, and 3.3.5), but their effects on mortality of the larval, juvenile, and adult forms in the ocean are largely unknown or only suspected. Mortalities of large numbers of surf clams washed ashore on beaches have been the subject for newspaper articles and other reports (Barnes 1910; Jacot 1920; Sieling 1960; Smithsonian 1970). Newspaper reports are most common for such occurrences on New Jersey beaches. Prodigious numbers of clams have been photographed and estimated. Often severe storm conditions are implicated as the cause of the mortalities. Although not entirely unimportant, the phenomenon occurs with unpredictable frequency and involves small local segments of the total resource. The clams often inhabit the shoal turbulent surf zone that cannot be fished by the dredges in the fishery. These unpredictable mortalities result from equally unpredictable settlements of the clams and are similar to fluctuations reported for settlements of other bivalve species in the littoral zone by Coe (1953; 1956). He found "no satisfactory indication of long-term periodic or rhythmical cycles" for the fluctuations.

The direct effects of fishing mortality are obvious and the size of the surf clam biomass and harvestable population have noticeably declined (cf. section 4.2.2). Less obvious effects may be damages to clam habitats from the high water pressures of the dredge manifold. Furthermore, mortalities of clams exposed to the gear, but not harvested, may be high, since the hydraulic action of the dredge can cause misalignment of the clam's hinge, damage to the valves, intrusion of sand in and around the soft body, and severance of the posterior adductor muscle.

4.5 Dynamics of Population (as a whole)

As indicated in section 4.2.1, surf clam populations in some survey areas declined between 1965 and 1978. Although 23,000 mt of meats was a first approximation of the maximum sustainable yield (MSY), based on the average of the commercial catch from 1960-1976, a quota of 14,000 mt was the optimum yield from the Fishery Conservation Zone recommended by the Mid-Atlantic Fishery Management Council (FMP 1977) (cf. section 6.1). The quota was adopted in response to excessive fishing mortality and adverse environmental conditions. During the first full year of operating under the quota system, landings of 14,240 mt in 1978 were a 27% decline from 19,050 mt in 1977 (FMP, No. 2, 1979).

5. EXPLOITATION

5.1 Fishing Equipment

5.1.1 Gear

The earliest methods of harvesting surf clams were by hand-operated rakes or tongs and sometimes by simply gathering clams washed ashore after storms (Parker 1971). Scraper-type dredges towed behind power boats were used during the 1920's, but these were relatively inefficient and broke many clams. During the mid-1940's, scraper-type dredges were designed with a hydraulic jetting system mounted ahead of the knife. Water was pumped through the jets to loosen the bottom sediments. This innovation reduced clam breakage, increased the area fished by the dredge, and was instrumental in establishing the modern-day U.S. ocean clam fisheries. The dredges were initially small and light in weight compared with the present-day dredges (Figure 6). The knife was about 30.5 cm wide and water was supplied to the jet manifold by 6.35 cm diameter canvas fire hose. Now the knife may be 152-305 cm wide and the water is supplied through 15.2-20.3 cm diameter, specially constructed, rubber hose. The large size and weight of the dredge requires powerful vessels, some of which have been specially designed and built for ocean clam fishing (Ropes 1972b). A large dredge, stern ramp, and conveyor system for moving the catch to cages in the hold are usually incorporated in vessels built or converted for surf clamming since 1970. These innovations have greatly increased fishing efficiency (cf. section 5.4.1).

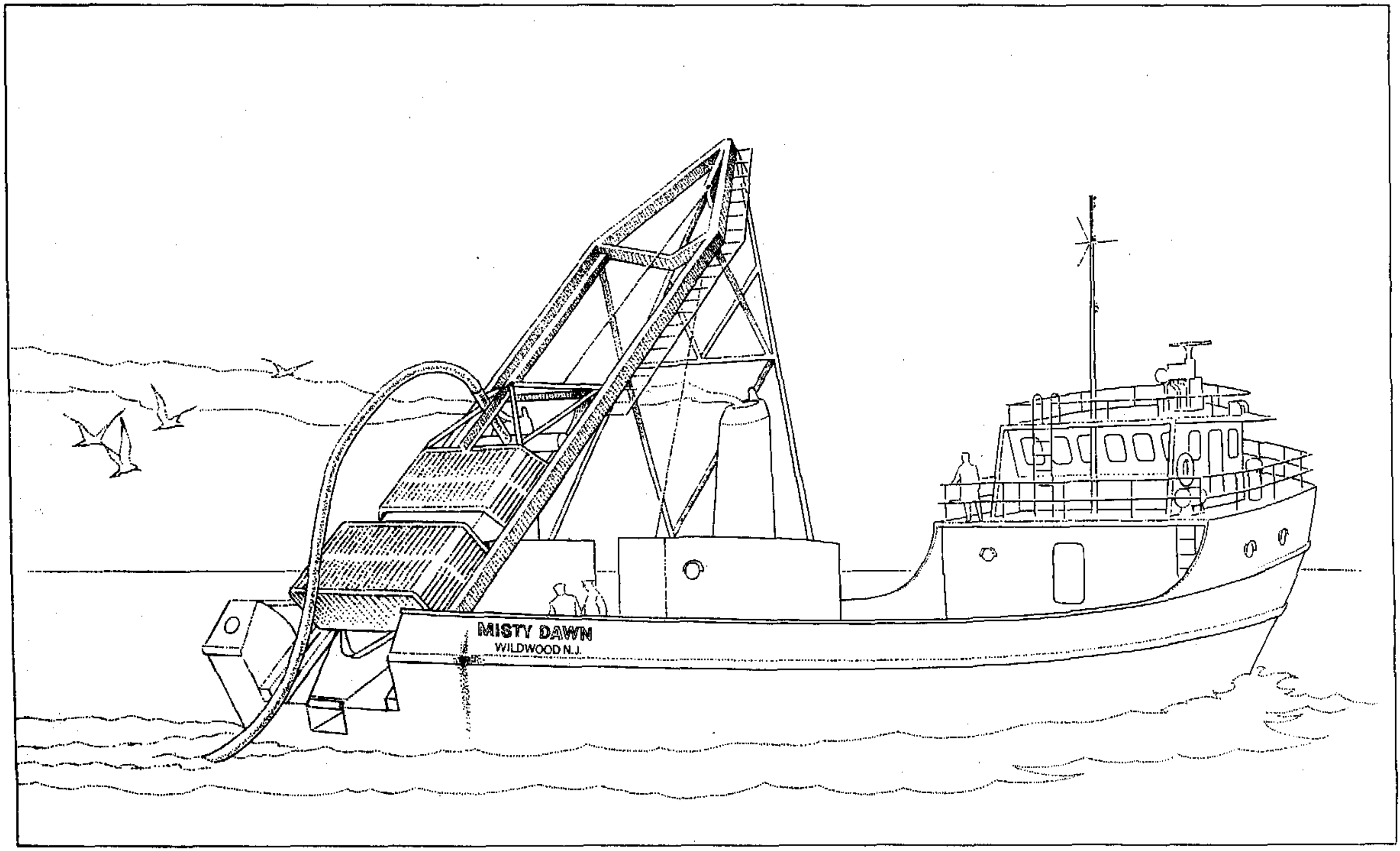


FIGURE 6. A modern commercial surf clam vessel rigged with the dredge on a stern ramp.

5.2 Fishing Areas

5.2.1 Geographic Range

The first organized fishery for surf clams began on Cape Cod in the 1870's, and earlier records indicate the clam was a known source of food (Yancey and Welch 1968). The fishery in the New England region, however, has remained a marginal operation through 1977 (Ropes 1979a). Annual production has been low (< 0.09 metric tons). The rocky bottom topography of the New England coast and expense of modern dredge equipment to operate on small, localized beds have been factors limiting the fishery.

The discovery of the principles of the hydraulic clam dredge and processing technology to remove sand from the meats during the mid-1940's in industry shops on Long Island, New York, were necessary for an expansion of the fishery throughout most of the range of the clam in the Middle Atlantic Bight. This expansion was within the 3-decade period 1945-74 and has been reviewed by Ropes (1979a).

The modern-day fishery for surf clams began on beds off Long Island, New York, from East Rockaway to Fire Island Inlets and from nearshore to about 18.3-m depths. These beds have been fished continuously at relatively low levels of production to the present time. Landings are made at Freeport, the principal New York port.

Industry explorations located beds of surf clams off the New Jersey coast in 1949 and the fishery greatly expanded its operations. Interview records from fishermen and federal survey results begun in the mid-1960's located the beds at depths nearshore to about 40 m. Most of the landings until about 1969 were from depths greater than 18.3 m and of large clams considered an offshore resource. These beds were very important in establishing the fishery as a major industry in the Middle Atlantic Bight. High densities of clams smaller in shell length than those offshore, and considered an inshore resource, were found in beds from the surf zone to about 18.3-m depths off Cape May to Absecon Inlet. These were heavily harvested in the early and mid-1970's.

Ports at Point Pleasant, Barnegat, Atlantic City, and Cape May - Wildwood receive landings and many of the major processing plants operate in the state.

Industry explorations in 1949 also located beds of surf clams off Delaware and Maryland. Interview records from fishermen and federal survey results located beds mostly at depths of 18.4 to 36.6 m. The earliest landings of surf clams on Delmarva. Peninsula were at Ocean City, Maryland, which continues to be a major port. Catches made since 1950 to about 1970 were from shoal depths of the resource, but research surveys indicated significant unfished beds were at deeper depths to the east and off the southern portion of the Peninsula (Ropes and Merrill, 1976). These beds were a basis for expansion of the fishery after 1967.

Ports from Chincoteague to Little Creek, Virginia, were developed for surf clam landings in the late 1960's to early 1970's. Some vessels from these ports fished the resource off southern Delmarva Peninsula, but more from the Cape Charles area began an intensive exploitation of beds to the east of Virginia and Currituck Beaches at 13- to 31-m depths. The clams were from a bountiful settlement identified in a 1969 survey and, although small in shell size, resulted in unprecedented amounts landed for a 4-year period (1972-75). Beds further south have been fished, but production is generally low.

Surf clams were not reported by Cummins (1966) in catches of a nonhydraulic dredge during shallow-water (ca. 7-10m) explorations for hard clams off the southeastern coast of the United States. In a description of an offshore North Carolina fishery for the southern quahog, Mercenaria campechiensis, Porter and Chestnut (1962) reported explorations with a hydraulic clam dredge conducted by the North Carolina Department of Conservation and Development in 1953 and 1958. Samples were taken at about 9 to 27 m depths from Bear Inlet to Oregon Inlet, but the occurrence of surf clams in the catches was not mentioned. Their observations on commercial and other experimental dredging in the area also excluded catching surf clams. In the mid-1970's, industry vessels explored for surf clams south of Cape Hatteras, but returned to their northern ports because a fishable resource was not found. Porter and Wolfe (1971) include living S. solidissima in a table of mollusc species collected from calico scallop grounds in Onslow Bay off the southern coast of North Carolina and well south of Cape Hatteras, but no information was given about station location or numbers caught. In an atlas of the occurrence of North Carolina marine and estuarine molluscs, Porter (1974) mentions holdings of S. solidissima at the Institute of Marine Science, University of North Carolina, from N.E. of Cape Hatteras. The existence of S. solidissima south of Cape Hatteras, then, may be marginal at best and of little commercial significance.

5.2.2 Depth Range

Cf. sec. 2.2

5.2.3 Condition of the Grounds

As indicated in the management plan for the surf clam fishery (FMP 1977) and in a review by Serchuk et al. (1979) intense fishing has severely reduced stocks in the offshore New Jersey to Virginia beds. Levels of abundance of harvestable clams and pre-recruits were particularly low in 1977 and forecasts for the immediate future production were poor.

Specific studies on the effects of hydraulic clam dredges on the condition of the grounds are not available. However, the washing action of the hydraulic system may physically, chemically, and biologically disturb the bottom composition, detrimentally altering conditions for future settlement of clam larvae and their subsequent survival. Clams are found in the catch with adductor muscles severed, shells broken, and sand packed into the mantle cavity. Such injuries may cause mortalities of clams not harvested by the dredges, adding decaying meats to the bed environment or attracting predators.

5.3 Fishing Seasons

The generally sedentary, nonmigratory nature of surf clams after settlement to the bottom and establishment of beds allows fishing operations throughout the year. Unlike oysters, no prohibition of fishing during the spawning season has been established.

5.4 Fishing Operations and Results

5.4.1 Effort and Intensity

Fishing operations are mostly on a day-trip basis during daylight hours. At a fishing location, the dredge, hose, and polypropylene tow line are put overboard, the pump for the hydraulic system started, and the dredge lowered to the bottom with the main winch cable. After allowing slack in the cable, the tow line tightens to begin the tow over the bottom for 10 to 30 min, depending upon the catch of clams, shells, and other bottom materials. At the end of a tow the dredge is winched onboard and opened to release the catch (Ropes 1967; Yancey and Welch 1968). On older vessels the catch is dumped on deck for sorting into 1-bu quantities held in sacks; on more modern vessels the dredge lands on a stern-ramp, the catch is dumped into a bin and moved by conveyor belts to cages of 20 to 32-bu amounts stored in the hold. Annual average daily effort varies somewhat from port to port, but ranges from 6 to 10 hr of actual fishing time (Ropes in preparation).

From interviews with vessel captains during 1965-1974, annual average catch-per-hour values at some ports have declined (Ropes in preparation). In 1965, a high of 307 kg of meats was recorded for the Point Pleasant, New Jersey, port, but reached a low of 143 kg in 1972 (Figure 7). At Cape May - Wildwood, New Jersey, a high of 699 kg was recorded for vessels fishing inshore beds in 1965, declining to a low of 308 kg in 1972; on offshore beds highs of 262 kg were recorded in 1967 and 1971 and a low of 193 kg in 1970. A high catch of 409 kg was recorded for Ocean City, Maryland, in 1970 and a low of 147 kg in 1974. Average catch-per-hour values of 910-1,242 kg for

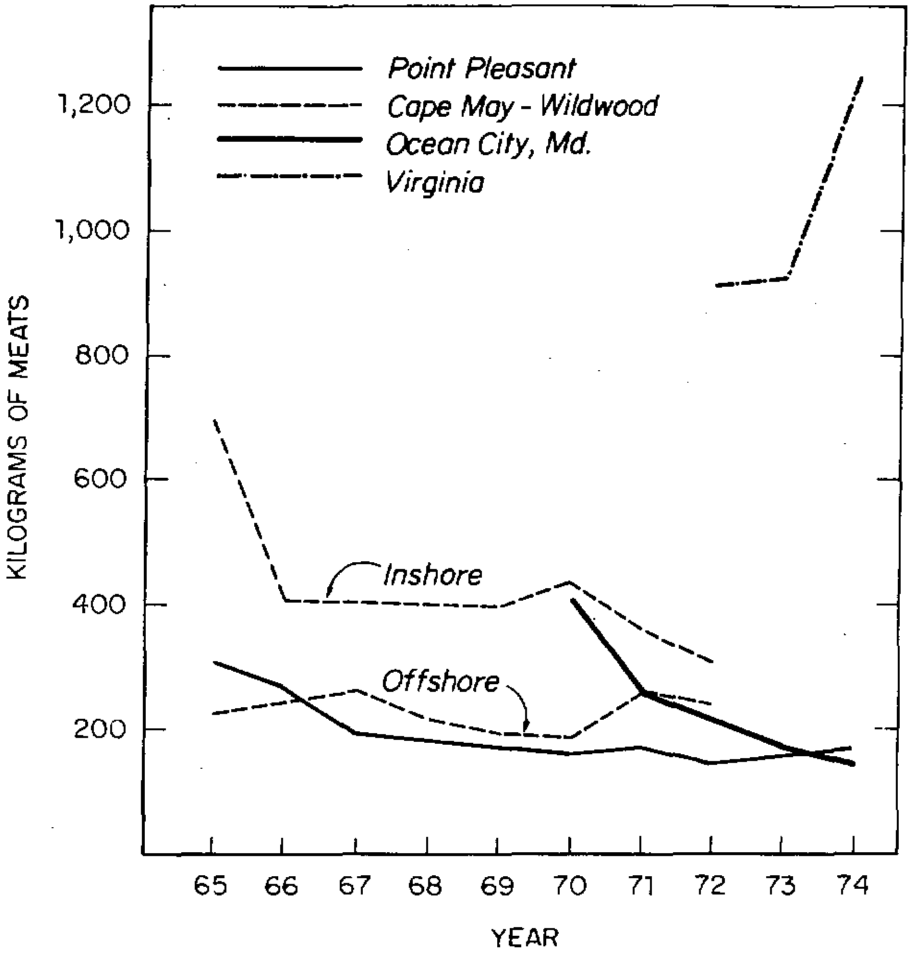


FIGURE 7. The annual mean catch per hour of surf clams, Spisula solidissima, fishing from Point Pleasant and Cape May - Wildwood, N.J., Ocean City, Md., and Virginia ports in 1965-1974.

the Virginia fleet in 1972 to 1974 were the highest recorded for any fleet. The much higher values for the Virginia fleet resulted from the entry of larger more efficient vessels into the fishery (cf section 5.1.1).

5.4.2 Selectivity

Specific studies are unavailable on the efficiency of clam capture by dredges. Also, see cf. section 4.1.3.3.

5.4.3 Catches

(cf section 4.2.1 and Figures 5 A-D).

6. PROTECTION AND MANAGEMENT

6.1 Regulatory Measures

During the United Nations Conference on the Law of the Sea, the Convention on the Continental Shelf of April 29, 1958, defined the natural resources of the shelf and identified coastal states for exploration and exploitation. The natural resources were living, sedentary organisms "which, at the harvestable stage, either are immobile on or under the seabed or are unable to move except in constant physical contact with the seabed or the subsoil" (Young, 1961). Public Law 88-308 on May 20, 1964, enacted prohibitions for foreign fishing on such organisms and on June 23, 1971, the surf clam, Spisula solidissima, was listed among other creatures protected by the act (Federal Register 1971).

On March 10, 1977, the Mid-Atlantic Fishery Management Council accepted a plan developed by state, federal, and industry representatives to rebuild the surf clam (Spisula solidissima) resource and protect the ocean quahog (Arctica islandica) populations in the United States Fishery Conservation Zone (FMP 1977). As stated in the plan:

> "Other than the Fishery Conservation and Management Act of 1976 (P.L. 94-265), no institutions have management authority over surf clams and ocean quahogs throughout their ranges.
>
> "No treaties or international agreements exist relative to surf clams or ocean quahogs.
>
> "The most important federal law relative to the surf clam and ocean quahog fisheries is the Fishery Conservation and Management Act of 1976. This plan was produced pursuant to that statute.

"The Water Pollution Control Act, as amended, is important in maintaining the habitat of surf clams and quahogs.

"Federal law provides for financial assistance for commercial fisheries. Part 251, Title 50, Code of Federal Regulations sets forth this program as operated by the National Marine Fisheries Service. On July 12, 1977, the National Marine Fisheries Service issued a final rulemaking establishing conditional fisheries status for the surf clam fishery. This means that financial assistance in that fishery will be limited to that which does not significantly increase harvesting capacity.

"The States of New York and New Jersey have regulations which cover clams in general and, therefore, relate to sea clams in their inshore waters but these are principally concerned with the prohibition of taking clams from polluted waters and time and location limitations on fishing to help enforce these regulations. In 1975, New Jersey enacted regulations to specifically control the inshore harvest of surf clams. These regulations are now in effect and are designed to control the size and total number of clams harvested from their waters while protecting the economic viability of the individual vessels. These regulations were modified and updated in 1976.

"No local or other applicable laws, regulations, and policies relating to the surf clam and ocean quahog fisheries relative to the Fishery Conservation Zone are known to exist. New Jersey levies a tax on surf clams landed at ports within that State."

Pursuant to the Fishery Management Plan prepared by the Middle Atlantic Regional Management Council, specific restrictions and penalties have been implemented by the Secretary of Commerce relative to:

1. Annual catch quotas
2. Closed areas
3. A moritorium on vessel entries into the fishery

4. Reports and records of catch
5. Vessel licensing and identification
6. Enforcement

On August 9, 1979, an amendment of the management plan for surf clams and ocean quahogs was approved by the Mid-Atlantic Fishery Management Council (FMP No. 2 1979). It updates current data on the fisheries and extends the plan through calendar year 1981, with provisions for vessel restrictions and catch quotas from the New England and Mid-Atlantic areas.

6.2 Control or Alteration of Physical Features

Artificial reefs have been constructed or are proposed on the northwestern United States continental shelf (Anon. 1972). These are shown on navigational charts as fish havens and, although primarily installed to benefit fish, the effect on clams and other benthic organisms is largely unknown. They do cover potential bottom for beds of clams and constitute hazards to fishermen dragging nets or dredges in their vicinity.

Deposits on the continental shelf off the northwestern United States have been inventoried as a future source of large quantities of sand and gravel for beach restoration and stabilization (Schlee 1968; Pearce 1979). These deposits form the substrata for surf clam beds and removal may constitute a major detrimental environmental impact. At this time, little is known of the effects of large-scale operations to alter physical features of the ocean bottom.

6.3 Control or Alteration of Chemical Features

Cf. section 2.3.

6.4 Control or Alteration of Biological Features

Cf. section 2.3.

6.5 Artificial Stocking

Surf clams have been reared successfully through the larval stages to setting by several investigators, but usually for purposes other than providing clams for artificial stocking (cf. section 3.2). Rhodes and Goldberg (1978) maintained surf clams after setting under controlled conditions to observe the effects of substrata and density on growth. Their techniques have possible application in artificial stocking projects, but attempts to do this have not been reported. The fate of releasing small surf clams in the natural environment, then, is largely unknown.

7. ACKNOWLEDGEMENTS

Mr. Steven A. Murawski provided recent information on the fishery and helpful comments on the manuscript; Drs. John L. McHugh and Saul B. Saila critically reviewed the manuscript; Ms. Margaret Mehmel and Linda Pettengill typed the manuscript; Ms. Michele Cox prepared the figures; and Ms. Judith Brownlow verified reference citations.

8. REFERENCES

ABBOTT, R.T.
1974. American Seashells, Second Edition. Van Nostrand Reinhold Co., N.Y. 663 p.

ALLEN, R.D.
1951. The role of the nucleolus in spindle formation. Biol. Bull. (Woods Hole) 101:214 (Abstract).

ANONYMOUS.
1972. Construction of artificial reefs in the Atlantic Ocean off Cape Henry, Virginia. U.S. Natl. Tech. Infor. Ser., Center for Estuarine and Menhaden Res., Beaufort, N.C. Rept. No. ELR-5178.

ALLEN, R.D.
1953. Fertilization and artificial activation in the egg of the surf-clam, Spisula solidissima. Biol. Bull. (Woods Hole) 105:213-239.

BABINCHAK, J.A., J.T. GRAIKOSKI, S. DUDLEY, and M.F. NITKOWSKI.
1977. Distribution of faecal coliforms in bottom sediments from the New York Bight. Mar. Pollut. Bull. 8:150-153.

BARKER, A.M. and J.W. ROPES.
1971. The Atlantic surf clam fishery - 1969. Commer. Fish. Rev. 33(6):35-42.

BARNES, E.W.
1910. The plague of sea clams at Easton's Beach, Newport. 40th Annu. Rep. Comm. Inland Fish., Providence, R.I. (1909): 183-185.

BELDING, D.L.
1910. The growth and habits of the sea clam (Mactra solidissima). Rep. Comm. Fish. Game Mass. 1909. Publ. Doc. 25:26-41.

BIGELOW, H.B. and W.C. SCHROEDER.
1953. Fishes of the Gulf of Maine. U.S. Fish and Wildl. Serv., Fish. Bull. 74. 577 p.

BIRKETT, L. and R.J. WOOD.
1959. Shell and siphon regeneration in Mactra stultorum Linné (Lamelli branchiata). Nature (Lond.) 184:1075-1076.

BIRKETT, L.
1973. Experimental determination of food conversion and its application to ecology. In: Steele, J. H. (ed) Marine Food Chains. Oliver and Boyd, Edinburgh 1970. p. 261-264.

BLOGOSLAWSKI, W.J. and M.E. STEWART.
1978. Paralytic shellfish poison in Spisula solidissima: Anatomical location and ozone detoxification. Mar. Biol. (Berl.) 45: 261-264.

BOND, R.M. and J.C. MEDCOF.
1958. Epidemic shellfish poisoning in New Brunswick. Can. Med. Assoc. J. 79:19-24.

BUELOW, R.W.
1968. Ocean disposal of waste material. Trans. Ocean Sci. Engin. of the Atlantic Shelf. Natl. Symp., Phila., PA., March 19-20, 1978. p. 311-337.

BUMPUS, D.F.
1965. Residual drift along the bottom on the continental shelf in the Middle Atlantic Bight area. Limnol. Oceanogr., Suppl. to Vol. 10, p. R50-R53.

BUMPUS, D.F. and L.M. LAUZIER.
1965. Surface circulation on the continental shelf off eastern North America between Newfoundland and Florida. Am. Geog. Soc., Ser. Atlas Mar. Environ., Folio 7, 4 p., 8 pl.

BUMPUS, D.F.
1969. Reversals in the surface drift in the Middle Atlantic Bight area. Deep-Sea Res., Suppl. to 16, p. 17-23.

BUMPUS, D.F.
1973. A description of the circulation on the continental shelf of the east coast of the United States. Progress in Oceanography, Vol. 6, Chap. 4, Pergamon Press, N.Y. p. 111-157.

CABLE, W.D.
1973. The valvular membrane in young mactrid clams, Spisula solidissima. Nautilus 87:110-111.

CABLE, W.D. and W.S. LANDERS.
1974. Development of eggs and embryos of the surf clam, Spisula solidissima, in synthetic seawater. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 72: 247-249.

CADDY, J.F.
1970. Records of associated fauna in scallop dredge hauls from the Bay of Fundy. Fish. Res. Board Can., Tech. Rep. No. 225, 11p.

CADDY, J.F. and A.R. BILLARD
1976. A first estimate of production from an unexploited population of the bar clam, Spisula solidissima. Canada, Fish. Mar. Serv., Tech. Rept. 648, 13p.

CALABRESE, A., F.P. THURBERG and E. GOULD.
1977. Effects of cadmium, mercury, and silver on marine animals. U.S. Natl. Mar. Fish. Serv. Mar. Fish. Rev. 59(4):5-11.

CAKE, E.
1973. Larval cestode infestations in several edible bivalve mollusks from the vicinity of St. Teresa, Florida. Proc. Natl. Shellfish. Assoc. 63:1 (Abstract).

CARRIKER, M.R.
1951. Ecological observations on the distribution of oyster larvae in New Jersey estuaries. Ecol. Monogr. 21:19-38.

CARRIKER, M.R.
1959. The role of physical and biological factors in the culture of Crassostrea and Mercenaria in a salt-water pond. Ecol. Monogr. 29:219-266.

CARRIKER, M.R.
1977. Penetration of molluscan and nonmolluscan minerals by the boring gastropod Urosalpinx cinerea. Am. Zool. 17:908.

CASTAGNA, M. and P. CHANLEY.
1966. Salinity tolerance and distribution of Spisula solidissima, Mulinia lateralis and Rangia cuneata, Family Mactridae. Am. Malacol. Union, Inc., Annu. Rep. 1966, p. 35 (Abstract).

CASTAGNA, M. and P. CHANLEY.
1973. Salinity tolerance of some marine bivalves from inshore and estuarine environments in Virginia waters on the western Mid-Atlantic coast. Malacologia 12:47-96.

CHAMBERLIN, J.L.
1954. Studies in the Mactrinae. Phd. Thesis, Dept. Biol., Harvard Univ., Cambridge, MA. 46p.

CHAMBERLIN, J.L. and F. STERNS.
1963. A geographic study of the clam, Spisula polynyma (Stimpson). Am. Geogr. Soc. Ser. Atlas Mar. Environ. Folio 3. p. 1-12.

CHANLEY, P. and J.D. ANDREWS.
1971. Aids for identification of bivalve larvae of Virginia. Malacologia 11:45-119.

CHANG, S., J.W. ROPES and A.S. MERRILL.
1976. An evaluation of the surf clam population in the Middle Atlantic Bight. Int. Counc. Explor. Sea. Special meeting on population assessments of shellfish stocks. Paper No. 33, 43 p. U.S. Natl. Mar. Fish. Serv., Northeast Fisheries Center, Sandy Hook, N.J. Lab. Ref. No. 76-1.

CHENG, T.C.
1967. Marine Mollusks as Hosts for Symbioses, with a Review of Known Parasites of Commercially Important Species. In: F.S. Russell (ed.), Advances in Marine Biology. Academic Press, N.Y. vol. 5, p. 1-424.

CHRISTENSEN, A.M.
1968. On the life history and biology of Pinnotheres pisum. Proc. XV Int. Congr. Zool. 16-23 July 1968. p. 267-270.

CHRISTENSEN, A.M.
1970. Feeding biology of the sea-star, Astropecten irregularis Pennant. Ophelia 8:1-134.

CHUN, SEH-KYU and YONG-KIL KIM.
1969. Studies on a trematode parasite of Pelecypoda. Bull. Pusan Fish. Coll. (Nat. Sci.) 9:21-24.

CLAPP, W.F.
1912. Collecting from haddock on the Georges Banks. Nautilus 25:104-106.

CLARKE, A.H., JR.
1954. Shell bearing mollusks off Cape Ann, Massachusetts. Nautilus 67:112-120.

COE, W.R.
1943. Biology of the nemerteans of the Atlantic coast of North America. Trans. Conn. Acad. Arts Sci. 35:129-328.

COE, W.R.
1953. Resurgent populations of littoral marine invertebrates and their dependence on ocean currents and tidal currents. Ecology 34:225-229.

COE, W.R.
1956. Fluctuations in populations of littoral marine invertebrates. J. Mar. Res. 15:212-232.

COSTELLO, D.R., M.E. DAVIDSON, A. EGGERS, M.H. FOX and C. HENLEY.
1957. Methods of Obtaining and Handling Marine Eggs and Embryos. Mar. Biol. Lab., Woods Hole, MA. 247 p.

CREAME-VIVAS, M.J. and I.E. GRAY.
1966. The distributional pattern of benthic invertebrates of the continental shelf off North Carolina. Ecology 47:260-270.

CUMMINS, R., JR.
1966. Hard-clam explorations off southeastern United States. Commer. Fish. Rev. 29(12):33-42.

DAGLIESH, J.G.
1934. Mactra stultorum Linn. in association with Pinnotheres pisum Penn. J. Conchol. London 20:81.

DALL, W.H.
1894. Synopsis of the Mactridae of North America. Nautilus 8:25-28.

DEXTER, R.W.
1968. Distribution of the marine molluscs at Cape Ann, Massachusetts. Mar. Biol. Assoc. India, Proc. Symp. on Mollusca, Part 1, pp. 214-222.

DUPAL, W.D. and K.L. WEBB.
1974. Salinity-induced changes in the alanine and aspartic amino-transferase activity in the marine bivalve molluscs. Arch. Int. Physiol. Biochem. 82:817-822.

EBLE, A.E.
1969. Histochemistry of the ripe surf clam gonad. Am. Zool. 9:583-584. (Abstract).

EBLE, A.E.
1970. Physiology of the ripe, spawning and spent surf clam gonad. Proc. Natl. Shellfish. Assoc. 60:3 (Abstract).

EBLE, A.E.
1971. Histochemistry of gonadal regression and subsequent maturation in the Atlantic surf clam, *Spisula solidissima*. Proc. Natl. Shellfish. Assoc. 61:2-3. (Abstract).

EMERY, K.O., A.S. MERRILL and J.V.A. TRUMBULL.
1965. Geology and biology of the sea floor as deduced from simultaneous photographs and samples. Limnol. Oceanogr. 10:1-21.

EDWARDS, R.L. and K.O. EMERY.
1968. The view from a storied sub The 'Alvin' off Norfolk, Va. Commer. Fish. Rev. 30 (8-9):48-55.

EDWARDS, D.G.
1974. Preferred prey of *Polinices duplicatus* in Cape Cod inlets. Bull. Am. Malacol. Union, Inc. p.17-20.

Federal Register. Subchapter J - Continental Shelf, Part 295. Living organisms of the Continental Shelf. 36(121):11923.

Final Environmental Impact Statement/Fisheries Management Plan for Surf Clam and Ocean Quahog Fisheries. 1977. U.S. Dep. Commer., NOAA, NMFS, 116 p. and Appendices.

Final Supplemental Environmental Impact Statement, Amendment No. 2 for the Surf Clam and Ocean Quahog Fishery Management Plan. 1979. U.S. Dep. Commer., NOAA, NMFS, 114 p. and Appendices.

FLOWERS, J.M.
1973. Pattern of distribution of the surf clam (*Spisula solidissima*) in the Point Judith, Rhode Island Harbor of Refuge. Proc. Natl. Shellfish. Assoc. 63:107-112.

FRANZ, D.R.
1976a. Distribution and abundance of inshore populations of the surf clam, *Spisula solidissima*. *In*: Gross, M.G. (ed) Middle Atlantic Continental Shelf and the New York Bight. Amer. Soc. Limnol. Oceanogr. Spec. Symp. 2:404-412.

FRANZ, D.
1976b. Benthic assemblages in relation to sediment gradients in Northeastern Long Island Sound, Connecticut. Malacologia 15:377-399.

FRANZ, D.R.
1977. Size and age-specific predation by Lunatia heros (Say, 1822) on the surf clam Spisula solidissima (Dillwyn, 1817) off Western Long Island, New York. Veliger 20:144-150.

FRETTER, V. and A. GRAHAM.
1962. Chap. 10. Feeding. British Prosobranch Mollusks. Their Functional Anatomy and Ecology. Bernard Quaritch Ltd., London. p. 240-262.

GALLIEN, L.
1949. Proboscidosaccus enigmaticus nov. g. nov. sp parasite de Mactra solida L. Bull. Soc. Zool. Fr. 74:322-326.

GARLO, E. and J.J. HONDO.
1973. Benthic invertebrates. In: Thomas, D.L. and C.B. Milstein. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic generating station, New Jersey. Ichthyological Assoc., Inc. Prog. Rept. for the period January-December 1972. Part I. 666p.

GARLO, E.V., J.J. HONDO, W.H. BAGOT, G.J. MILLER and F.A. SWIECICKI.
1974. Benthic invertebrates. In: Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic generating station, New Jersey. Ichthyological Assoc., Inc. Prog. Rept. for the period January-December 1973. Vol. 2, 527 p.

GARLO, E.V., C.B. MILSTEIN, and A.E. JAHN.
1979. Impact of hypoxic conditions in the vicinity of Little Egg Inlet, New Jersey in summer 1976. Estuarine and Coastal Mar. Sci. 8:421-432.

GOLDBERG, R.
1978. Some effects of gas super saturated sea water in Spisula solidissima and Argopecten irradians. Aquaculture 14:281-288.

GRIEG, R.A. and J. JONES.
1976. Nondestructive neutron activation analyses of marine organisms collected from ocean dump sites of the Middle Eastern United States. Arch. Environ. Contam. Toxicol. 4 (4):420-434.

GROSS, M.G. (ed).
1976a. Middle Atlantic Continental Shelf and the New York Bight. Amer. Soc. Limnol. Oceanogr. Spec. Symp. 2. 441 p.

GROUTAGE, T.M. and A.M. BARKER.
1976a. The surf clam fishery. Commer. Fish. Rev. 29(2): 55-58.

GROUTAGE, T.M. and A.M. BARKER.
1976b. The Atlantic surf clam fishery in 1966. Commer. Fish. Rev. 29(8-9): 64-67.

GUNNERSON, C.G. and R.L. SWANSON.
1975. Ocean dumping in the New York Bight. U.S. Dept. Comm., NOAA, Tech. Rept. ERL 321-MESA-2, 78p.

HAGERMAN, D.D.
1956. Invertebrate metabolism in vitro not affected by estradiol. Biol. Bull. (Woods Hole) 111: 318-319 (Abstract).

HAGERMAN, D.D., F.M. WELLINGTON and C.A. VILLEE.
1957. Estrogens in marine invertebrates. Biol. Bull. (Woods Hole) 112: 180-183.

HANKS, J.E.
1952. The effects of changes in water temperature and salinity on the feeding habits of the boring snails, _Polinices heros_ and _Polinices duplicata_. In: Fifth Rept. Invest. Shellfish. Mass., Comm. Mass., Dept. Conserv., Div. Mar. Fish. p. 33-37.

HASKIN, H.H. and A.S. MERRILL.
1973. Report under the cooperative agreement dated June 15, 1972 between National Marine Fisheries Service and Rutgers, the State University to conduct an inshore inventory of surf clams along the New Jersey coast. (mimeo). 27 p.

HAYASHI, T. and K. TERAI.
1964. Study of the larvae and youngs of Japanese surf clam, Spisula sachalinensis (Schrenck), at Shikuzu, Muroran City. I. Taxonomy of the pelecypod's veliger larvae in plankton. Sci. Rept. Hokkaido Fish. Exp. Sta. 2:3-37. (Translation by the Div. Foreign Fish., NOAA, NMFS, Wash., D.C.).

HENDERSON, J.B. and P. BARTSCH.
1914. Littoral marine mollusks of Chincoteague Island, Virginia. Proc. U.S. Natl. Mus. 17(2055):411-421.

HENDERSON, J.T.
1929. Lethal temperatures of Lamellibranchiata. Contrib. Can. Biol. Fish. N.S. 4:399-411.

HOSHINA, T. and KUWABARA, R.
1959. In a new commensal copepod, Mytilicola mactrae n. sp. obtained from the intestine of Mactra veneriformis Reeve, J. Tokyo Univ. Fish. 45:33-35.

HUMES, A.G. and R.F. CRESSEY.
1958. Copepod parasites of mollusks in West Africa. Bull. Inst. fr. Afr. noire 20:921-960.

HUMES, A.G. and R.F. CRESSEY.
1960. Seasonal population changes and host relationships of Myocheres major (Williams), a cyclopoid copepod from pelecypods. Crustaceana 1:307-325.

HUMES, A.G. and J.H. STOCK.
1973. A revision of the Family Lichomolgidae Kossman, 1877, cyclopoid copepods mainly associated with marine invertebrates. Smithsonian Contrib. Zool. No. 127, 368p.

HUNT, O.D.
1925. The food of bottom fauna of the Plymouth fishing grounds. J. Mar. Biol. Assoc. U.K. 13:560-599.

HUNTER, W.R. and D.C. GRANT.
1962. Mechanics of the ligament in the bivalve Spisula solidissima in relation to mode of life. Biol. Bull. (Woods Hole) 122:369-379.

JACOT, A.
1919. Some marine mollusca about New York City. Nautilus 32:90-94.

JACOT, A.
1920. Notes on marine mollusca about New York City. Nautilus 34:59-60.

JACOBSON, M.K. and W.E. OLD, JR.
1966. On the identity of Spisula similis (Say). Am. Malacol. Union, Inc., Annu. Rep. 1966, p. 30-31.

JACOBSEN, M.K.
1972. Observations on the siphonal behavior of young surf clams, Spisula solidissima. Nautilus 86:25-26.

JOHNSON, C.W.
1915. Fauna of New England. 13. List of the Mollusca. Occas. Pap. Boston Soc. Nat. Hist. 7:1-231.

JONES, D.S., I. THOMPSON and W. AMBROSE.
1978. Age and growth rate determinations for the Atlantic surf clam Spisula solidissima (Bivalvia: Mactracea), based on internal growth lines in shell cross-sections. Mar. Biol. (Berl.) 47:63-70.

JORGENSEN, C.B.
1946. 9. Lamellibranchia. In: Thorson, G. (ed). Reproduction and larval development of Danish marine bottom invertebrates, with special reference to the planktonic larvae in the sound (Oresund). Medd. Komm. Dann. Fisk.-og Havunders., Ser. Plankton, 4, 523p.

JUNE, F.C. and J.W. REINTJES.
1957. Survey of the ocean fisheries off Delaware Bay. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 222, 55p.

KAHLER, G.A., F.M. FISHER, and R.L. SASS.
1976. The chemical composition and mechanical properties of the hinge ligament in bivalve molluscs. Biol. Bull. (Woods Hole) 151:161-181.

KELLOGG, J.L.
1915. Ciliary mechanism of lamellibranchs. J. Morphol. 26:625-701.

KENNEDY, D.
1960. Neural photoreception in a lamellibranch mollusc. J. Gen. Physiol. 44:277-299.

KERN, F.G.
(in prep.) Distribution and prevalence of larval anasakid nematodes in surf clams from the Middle Atlantic coast.

KERSWILL, C.J.
1944. The growth rate of bar clam. Fish. Res. Board Can., Prog. Rep. Atl. Coast Stn. 35:18-20.

KUDO, R.
1966. Protozoology. 4th ed. C.C. Thomas, Springfield, Ill. 966p.

LANDERS, W.S.
1954. Seasonal abundance of clam larvae in Rhode Island waters, 1950-52. U.S. Fish Wildl. Serv., Spec. Sci. Rept. Fish. No. 117, - 29p.

LASTER, L. and P. STRITTMATER.
1968. Maltase activity in developing embryos and adult tissues of the surf clam, Spisula solidissima. Biol. Bull. (Woods Hole) 134:427-428.

LAVINE, T.F.
1946. A study of the enzymatic and other properties of the crystalline style of clams: evidence for the presence of a cellulase. J. Cell. Comp. Physiol. 28:183-195.

LEAR, D.W., S.K. SMITH and M.L. O'MALLEY.
1973. Environmental survey of two interim dumpsites Middle Atlantic Bight. Operation "Fetch". Cruise Report. 5-10 Nov. 1973. Environ. Protection Agency. 141 p.

LEAR, D.W. and G.G. PESCH.
1975. Effects of ocean disposal activities on mid-continental shelf environment off Delaware and Maryland. Environ. Protection Agency. EPA 903/9-75-015. 29p.

LEGER, L.
1903. Sporozoaire parasite des moules et autres lamellibranches comestibles. Compt. Rend. 137:1003-1006.

LEGER, L. and O. DUBOSCQ.
1913. Le cycle evolutif de Porospora portunidarum Frenzel. Compt. Rend. 156:1932-1934.

LEIBOVITZ, L., J.C. HARSHBARGER, and P. CHANLEY.
1976. A polypoid myoma of the foot of a surf clam (*Spisula solidissima*). Proc. Int. Colloq. Invertebr. Pathol. 1:148-150.

LEIDY, J.
1878. Remarks on *Mactra*. Proc. Acad. Nat. Sci. Phila. 1878:332-333.

LICHTENFELS, J.R., F.G. KERN, III, D.E. ZWERNER, J.W. BIER and P.A. MADDEN.
1976. Anisakid nematode in shellfish of Atlantic Continental Shelf of North America. Trans. Am. Microsc. Soc. 95:266 (Abstract).

LICHTENFELS, J.R., J.F.A. SPRENT, J.W. BIER, P.A. MADDEN and T.K. SAWYER.
1977. New information on identity of anisakid nematode in shellfish of Atlantic coast of North America. Soc. Parasitol., Reno, Nevada, August, 1977 (Abstract).

LICHTENFELS, J.R., J.W. BIER, and P.A. MADDEN.
1978. Larval anisakid (*Salcascaris*) nematodes from Atlantic molluscs with marine turtles as definitive hosts. Trans. Amer. Micros. Soc. 97:199-207.

LINDLEY, M.G. and R.S. SHALLENBERGER.
1976. Purification and characterization of a mollusc B-D-(1→3) - glucan hydrolase. Fd. Chem. 1:149-159.

LINDLEY, M.G. and R.S. SHALLENBERGER.
1977. Enzyme hydrolysis of malt glucans using a mollusc carbohydrase preparation. Fd. Chem. 2:1-6.

LOESCH, J.G. and J.W. ROPES.
1977. Assessment of surf clam stocks in nearshore waters along the Delmarva Peninsula and in the fishery south of Cape Henry. Proc. Natl. Shellfish. Assoc. 67:29-34.

LONGO, F.J.
1973. Fertilization: a comparative ultrastructural review. Biol. Reprod. 9:149-215.

LOOSANOFF, V.L. and H.C. DAVIS.
1950. Conditioning *V. mercenaria* for spawning and breeding in winter and rearing its larvae in the laboratory. Biol. Bull. (Woods Hole) 98:60-65.

LOOSANOFF, V.L., W.S. MILLER and P.B. SMITH.
1951. Growth and setting of larvae of Venus mercenaria in relation to temperature. J. Mar. Res. 10:59-81.

LOOSANOFF, V.L. and H.C. DAVIS.
1963. Rearing of bivalve mollusks. In: F.S. Russell (ed). Advances in Marine Biology. Vol. 1, Academic Press, N.Y. 410 p.

LOOSANOFF, V.L., H.C. DAVIS and P.E. CHANLEY.
1966. Dimensions and shapes of larvae of some marine bivalve mollusks. Malacologia 4:351-435.

MASSE, H.
1975. Feeding biology of Astropecten aranciacus. Cah. Biol. Mar. 16:495-510.

MAURER, D., L. WATLING and G. APRILL.
1974. The distribution and ecology of common marine and estuarine pelecypods in the Delaware Bay area. Nautilus 88:38-45.

MEDCOF, J.C., A.H. LEIM, A.B. NEEDLER, and A.W.H. NEEDLER.
1947. Paralytic shellfish poisoning on the Canadian Atlantic coast. Fish. Res. Board Can. Bull. No. 75, p. 1-32.

MELLON, D., JR.
1965. Nerve pathways and reflex siphon withdrawal in the surf clam. J. Exp. Biol. 43:455-472.

MELLON, D., JR. and D. PRIOR.
1970. Components of a response programme involving inhibitory and excitatory reflexes in the surf clam. J. Exp. Biol. 53: 711-725.

MELLON, D.F., JR.
1972. Electrophysiology of touch sensitive neurons in a mollusc. J. Comp. Physiol. 79:63-78.

MERRILL, A.S. and J.R. WEBSTER.
1964. Progress in surf clam biological research. In: C.J. Sindermann (ed). The Bureau of Commercial Fisheries, Biological Laboratory, Oxford, MD: Programs and Perspectives. U.S. Fish Wildl. Serv., Civc. 200 p. 38-47.

MERRILL, A.S. and J.W. ROPES.
1969. The general distribution of the surf clam and ocean quahog. Proc. Natl. Shellfish. Assoc. 59:40-45.

MERRILL, A.S. and R.L. EDWARDS.
1975. Observations on mollusks from a navigation bouy with special emphasis on the sea scallop, Placopecten magellanicus. Nautilus 89:116-123.

MERRILL, A.S. and J.W. ROPES.
1977. Shellfish Beds. In: Clark, J.R. (ed). Coastal Ecosystem Management. A Technical Manual for the Conservation of Coastal Zone Resources. John Wiley and Sons, N.Y. p. 710-716.

MILEIKOVSKI, S.A.
1971. Types of larval development in marine bottom invertebrates, their distribution and ecological significance: a re-evaluation. Mar. Biol. (Berl.) 10:193-213.

MILEIKOVSKY, S.A.
1974. On predation of pelagic larvae and early juveniles of marine bottom invertebrates by adult benthic invertebrates and their passing alive through predators. Mar. Biol. (Berl.) 26:303-311.

MOORE, R.C. and C.W. PITRAT.
1969. Treatise on Invertebrate Paleontology. Part N., Vol. 2, Mollusca 6, Bivalvia. Geol. Soc. Am., Univ. Kansas, Lawrence, Kansas. p. N491-N952.

MORSE, E.S.
1919. Observations on living lamellibranchs of New England. Proc. Boston Soc. Natur. Hist. 35:139-196.

MURAWSKI, S.A. and F.M. SERCHUK.
1979. An assessment of offshore surf clam, Spisula solidissima, populations off the Middle Atlantic coast of the United States. NMFS, Northeast Fisheries Center, Woods Hole, Lab. Ref. No. 79-13, 15 p.

MUUS, K.
1966. A quantitative 3-year-survey on the meiofauna of known macrofauna communities in the Oresund. Vereff. Inst. Meersforsch. Bremerhaven, Supplement II. p. 289-292.

MUUS, K.
1973. Setting, growth and mortality of young bivalves in the Oresund. Ophelia 12:79-116.

NICOLL, W.
1906a. Notes on trematode parasites of the cockle (Cardium edule) and mussel (Mytilus edulis). Ann. Mag. nat. Hist. 17:148-155.

NICOLL, W.
1906b. Some new and little-known trematodes. Ann. Mag. nat. Hist. 17:513-527.

NIELSON, C.
1975. Observations on Buccinium undatum attacking bivalves and on prey responses, with a short review on attack methods of other prosobranchs. Ophelia 13:87-108.

NYSTROM, R.A.
1976. Spontaneous activity of clam intestinal muscle. Comp. Biochem. Physiol. 21:601-610.

OGREN, L. and J. CHESS.
1969. A marine kill on New Jersey wrecks. Underwater Nat. 6:4-12.

OGREN, L.
1969. New Jersey fish/crustacean mortality. Smithsonian Inst. Center for Short-lived Phenomenon. Event No. 38-69.

OLSEN, S.B.
1970. Some aspects of the ecology of Spisula solidissima solidissima (Dillwyn). M.S. Thesis. Univ. Rhode Island. 77 p.

O'CONNOR, J.S.
1976. Contaminant effects on biota of the New York Bight. In: J.B. Higman (ed.) Proc. 28th Ann. Gulf and Carib. Fish. Inst. p. 50-631.

PARKER, P.S.
1971. History and development of surf clam harvesting gear. U.S. Dept. Comm., NOAA Tech. Rept. NMFS Circ. 364, 15p.

PATTON, J.S. and J.G. QUINN.
1973. Studies on the digestive lipase of the surf clam, Spisula solidissima. Mar. Biol. 2/(Berl.): 59-69.

PAYNE, W.L., T.A. GERDING, J.W. BIER, and G.J. JACKSON.
1977. Recent incidence of an anisakine nematode and its hyperparasitic protozoa in commercial surf clams from the coastal waters of Mid Atlantic states. Prog. and Absts., 52nd Ann. Meeting, Amer. Soc. Parasit., 14-19 Aug., Las Vegas, p. 54. (Abstract).

PEARCE, J.B.
1972. The effects of solid waste disposal on benthic communities in the New York Bight. In: M. Ruivo (ed.) Marine Pollution and Sea Life. Fishing News (Books) Ltd., London. pp. 404-411.

PEARCE, J.B., J.V. CARACCIOLO, M.B. HALSEY and L.H. ROGERS.
1976. Temporal and spatial distribution of benthic macroinvertebrates in the New York Bight. In: Gross, M. G. (ed). Middle Atlantic Continental Shelf and the New York Bight. Amer. Soc. Limnol. Oceanogr., Spec. Symp. 2:394-403.

PEARCE, J.B.
1979. Marine sand and gravel production in areas off the Northeast Coast of the United States. Mar. Pollut. Bull. 10:14-18.

PERKINS, F.O., D.E. ZWERNER and R.K. DIAS.
1975. The hyperparasite, Urosporidium spisuli sp. n. (Haplosporea), and its effects on the surf clam industry. J. Parasitol. 61:944-949.

PERKINS, F.O., P.A. MADDEN and T.K. SAWYER.
1977. Ultrastructural study of the spore surface of the Haplosporidium Urosporidium spisuli. Trans. Amer. Micros. Soc. 96:376-382.

PORTER, H.J. and A.F. CHESTNUT.
1962. The offshore clam fishery of North Carolina. Proc. Natl. Shellfish. Assoc. (1960) 51:67-73.

PORTER, H.J. and D.A. WOLFE.
1971. Mollusca from the North Carolina commercial fishing grounds for the calico scallop, Argopecten gibbus (Linne), J. Conchol. 109:91-109.

PORTER, H.J.
1972. Mollusks coincident with North Carolina's calico scallop fishery. Bull. Amer. Malacol. Union, Inc. for 1971. p. 32-33.

PORTER, H.J.
1974. The North Carolina marine and estuarine Mollusca - an atlas of occurrence. Univ. N.C., Inst. Mar. Sci. 351p.

PRAKASH, A., J.C. MEDCOF, A.D. TENNANT.
1971. Paralytic shellfish poisoning in eastern Canada. Fish. Res. Board Can. Bull. 177, 79p.

PRATT, D.M.
1974. Attraction to prey and stimulus to attack in the predatory gastropod Urosalpinx cinerea. Mar. Biol. (Berl.) 27:37-45.

PRIOR, D.
1972a. Electrophysiological analysis of peripheral neurons and their possible role in the local reflexes of a mollusc. J. Exp. Biol. 57:133-145.

PRIOR, D.
1972b. A neural correlate of behavioral stimulus intensity discrimination in a mollusc. J. Exp. Biol. 57:147-160.

PRIOR, D.J.
1974. Role of the incurrent siphonal valve in the surf clam, Spisula solidissima (Mactridae). Nautilus 88:115-117.

PRIOR, D.J. and B.H. LIPTON.
1977. An ultrastructural study of peripheral neurons and associated non-neural structures in the bivalve mollusc, Spisula solidissima. Tissue and Cell 9:223-240.

PRIOR, D.J., A.M. SCHNEIDERMAN, and S.I. GREENE.
1979. Size dependent variation in the evasive behavior of the bivalve mollusc, Spisula solidissima. J. Exp. Biol. 78:59-76.

REBHUN, L.L.
1959. Studies of early-clevage in the surf clam, Spisula solidissima, using methylene blue and toluidine blue as vital stains. Biol. Bull. (Woods Hole) 117:518-545.

REYNOLDS, B.H.
1979. Trace metals monitoring at two ocean disposal sites. U.S. Environ. Protec. Agency. EPA-600/3-79-037 64 p.

RHODES, E.W. and R. GOLDBERG.
1978. The use of pumped raceway systems for the intermediate grow-out of hatchery reared bivalves. Proc. Natl. Shellfish. Assoc. 68:85 (Abstract).

RHODES, E.W., A. CALABRESE, W.D. CABLE, and W.S. LANDERS.
1975. The development of methods for rearing the coot clam, *Mulinea lateralis*, and three species of coastal bivalves in the laboratory. *In*: W.L. Smith and M.H. Chanley (eds.). Culture of Marine Invertebrate Animals. Plenum Press, N.Y. Part II. p. 273-282.

RITCHIE, T.P.
1977. A comprehensive review of the commercial clam industries in the United States. U.S. Dept. Comm., NOAA, NMFS. 106p.

ROPES, J.W. and A.S. MERRILL.
1966. The burrowing activities of the surf clam. Underwater Nat. 3:11-17.

ROPES, J.W. and A.S. MERRILL.
1967. *Malacobdella grossa* in *Pitar morrhuana* and *Mercenaria campechiensis*. Nautilus 81:37-40.

ROPES, J.W.
1968a. Hermaphroditism in the surf clam, *Spisula solidissima*. Proc. Natl. Shellfish. Assoc. 58:63-65.

ROPES, J.W.
1968b. Reproductive cycle of the surf clam, *Spisula solidissima*, in offshore New Jersey. Biol. Bull. (Woods Hole) 135:349-365.

ROPES, J.W., J.L. CHAMBERLIN, and A.S. MERRILL.
1969. Surf Clam Fishery. *In*: F.E. Firth (ed). The Encyclopedia of Marine Resources. Van Nostrand Reinhold, Co., N.Y. 740p.

ROPES, J.W. and A.S. MERRILL.
1971. Data on samples for surf clams and ocean quahogs. NOAA, Natl. Mar. Fish. Serv., Data Rept. 57, 43p.

ROPES, J.W.
1971. Surf clams and ocean quahogs. *In*: Merrill, A.S. (covener). Symposium on Commercial Marine Mollusks of the United States. Amer. Malacol. Union, 36th Ann. Meeting. p.22.

ROPES, J.W.
1972a. Chromosome number of the surf clam, *Spisula solidissima*. Nautilus 85:93-95.

ROPES, J.W.
1972b. The Atlantic coast surf clam fishery 1965-69. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 34(7-8):20-29.

ROPES, J.W. and A.M. BARKER.
1972. The Atlantic surf clam fishery - 1970. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 34(9-10): 36-44.

ROPES, J.W., A.M. BARKER and G.E. WARD, JR.
1972. The Atlantic coast surf clam fishery - 1971. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 34(11-12):48-54.

ROPES, J.W. and A.S. MERRILL.
1973. To what extend do surf clams move? Nautilus 87:19-21.

ROPES, J.W., A.M. BARKER and G.E. WARD, JR.
1975. The Atlantic coast surf clam fishery - 1972 U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 37(8):22-27.

ROPES, J.W., A.S. MERRILL and G.E. WARD, JR.
1975. The Atlantic coast surf clam fishery - 1973. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 37(12):31-34.

ROPES, J.W. and A.S. MERRILL.
1976. Historical cruise data on surf clams and ocean quahogs. NOAA, Natl. Mar. Fish. Serv., Data Rept. ERL MESA - 17, 108p.

ROPES, J.W. and G.E. WARD, JR.
1977. The Atlantic coast surf clam fishery - 1974. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 39(5):18-23.

ROPES, J.W.
1979a. Biology and distribution of surf clams (*Spisula solidissima*) and ocean quahogs (*Arctica islandica*) off the Northeast coast of the United States. *In:* Proceedings of Northeast Clam Industries: Management for the Future. Exten. Sea Grant Prog., Univ. Mass. and Mass. Inst. Tech. SP-112:47-66.

ROPES, J.W.
1979b. Shell length at sexual maturity of surf clams, *Spisula solidissima*, from an inshore habitat. Proc. Natl. Shellfish. Assoc. 69:85-91.

ROPES, J.W. and L. O'BRIEN.
1979c. A unique method of ageing surf clams. Int. Coun. Explor. Sea., Shellfish and Crustacea Comm., C.M. 1979/K:28, 4p.

ROPES, J.W., A.S. MERRILL, S.A. MURAWSKI, S. CHANG, and C.L. MACKENZIE, JR.
(in prep.) Chapter XI. Impact on clams and scallops associated with anoxic bottom water in the Middle Atlantic Bight during the summer of 1976. Part 1. Field Survey Assessments. In: R.L. Swanson and D.J. Sindermann. (eds.) Oxygen depletion and associated mass mortalities in the New York Bight. 1976. NOAA, ERL-MESA Spc. Publ.

ROPES, J.W.
(in prep.) The speed of burrowing by surf clams, *Spisula solidissima*.

ROPES, J.W.
(in prep.) The Atlantic coast surf clam fishery 1965-1974. U.S. Natl. Mar. Fish. Serv. Mar. Fish. Rev.

SAILA, S.B. and S.D. PRATT.
1973. Mid-Atlantic Bight Fisheries. In: Saila, S.B. (coordinator). Coastal and Offshore Environmental Inventory, Cape Hatteras to Nantucket Shoals. Mar. Exp. Sta., Grad. School Oceanogr., Univ. Rhode Island, Kingston, R.I., Mar. Publ. Ser. No. 2, p. 6-1 to 6-125.

SANDINE, P.H., V.J. MCDERMOTT and J.H. CHAMBLIN, JR.
1973. Zooplankton. In: Thomas, D.L. and C.B. Milstein. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic generating station, New Jersey. Prog. Rep. for the period January - December 1972. Part 1. Ichthyological Assoc., Inc. p. 151-164.

SAVAGE, N.B.
1976. Burrowing activity in *Mercenaria mercenaria* (L.) and *Spisula solidissima* (Dillwyn) as a function of temperature and dissolved oxygen. Mar. Behav. Physiol. 3:221-234.

SCHECTER, V.
1941. Experimental studies upon the egg cells of the clam, *Mactra solidissima*, with special reference to longevity. J. Exp. Zool. 86:461-478.

SCHECTER, V.
1956. The effect of water upon gametes, upon maturation and upon fertilization and cleavage. Exp. Cell. Res. 10:619-630.

SCHLEE, J.
1968. Sand and gravel on the continental shelf off the northeastern United States. Geol. Sur. Circ. 602, 9p.

SCHLIEPER, C., H. FLUGEL and H. THEEDE.
1967. Experimental investigation of the cellular resistance ranges of marine temperate and tropical bivalves of the Indian Ocean Expedition of the German Research Association. Physiol. Zool. 40:345-360.

SERCHUK, F.M., S.A. MURAWSKI, E.M. HENDERSON, and B.E. BROWN.
1979. The population dynamics basis for management of offshore surf clam populations in the Middle Atlantic. In: Proceedings of Northeast Clam Industries: Management for the Future. Exten. Sea Grant Prog., Univ. Mass. and Mass. Inst. Tech. SP-112:83-101.

SHALLENBERGER, R.S., C. SEARLES, and B.A. LEWIS.
1974. Laminaranase activity in the crystalline style of the surf clam (Spisula solidissima). Experientia (Basel) 30:597-598.

SHALLENBERGER, R.S., S.M. HERBERT and B.A. LEWIS.
1975. Nature's immobilized enzyme. 3p. N.Y. Food Life Sci. Q.

SIELING, F.W.
1960. Mass. mortality of the starfish, Asterias forbesi, on the Atlantic coast of Maryland. Chesapeake Sci. 1:73-74.

SINDERMANN, C.J. and A. ROSENFIELD.
1967. Principal diseases of commercially important marine bivalve Mollusca and Crustacea. U.S. Fish. Wildl. Serv. Fish. Bull. 66:335-385.

SINDERMANN, C.J.
1970. Principal Diseases of Marine Fish and Shellfish. Academic Press, N.Y. 369p.

SMITHSONIAN INSTITUTION.
1979. Newport clam eruption. Ann. Rep. 1969, Center for Short-lived Phenomenon. Event 81-69, p. 121-122.

SMUCKER, L. and R.A. NYSTROM.
1970. Control of gut movements by an intrinsic neural plexus in the clam, Spisula solidissima (Dillwyn, 1817). Fed. Am. Soc. Experim. Biol. 29:89 (Abstract).

SMUCKER, L.A. and R.A. NYSTROM.
1972. Control of gut motility by an intrinsic neural plexus in the pelecypod Spisula. Comp. Biochem. Physiól.41(4A):731-748.

STEPHENS, G.C. and R.A. SCHINSKE.
1961. Uptake of amino acids by marine invertebrates. Limnol. Oceanogr. 6:175-181.

STICKNEY, A.P.
1963. Histology of the reproductive system of the soft-shell clam (Mya arenaria). Biol. Bull. (Woods Hole) 125:344-351.

STEIMLE, F.W., JR. and R.B. STONE.
1973. Abundance and distribution of inshore benthic fauna off Southwestern Long Island, N.Y. NOAA Tech. Rept. NMFS SSRF-673, 50 p.

STEIMLE, F.W. and C.J. SINDERMANN.
1978. Review of oxygen depletion and associated mass mortalities of shellfish in the Middle Atlantic Bight in 1976. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 40(12): 17-25.

STOUT, W.E.
1970-71. Some associates of Tresus nuttallii (Conrad, 1837). Veliger 13:67-70.

SULLIVAN, C.M.
1948. Bivalve larvae of Malpeque Bay, P.E.I. Fish. Res. Board Can. Bull. 77. 36p.

SWANSON, R.L.
1976. Evaluation of proposed sewage sludge dumpsite areas in the New York Bight. U.S. Dept. Comm., NOAA, Tech. Mem. ERL-MESA-11, 212p.

TAGATZ, M.E.
1968. Biology of the blue crab, Callinectes sapidus Rathbun, in the St. Johns River, Florida. U.S. Fish. Wild. Ser. Fish. Bull. 67:17-33.

TAKAHURA, U.
1897. On a new species of Malacobdella (M. japonica). Annot. Zool. Jpn. 1:105-112.

THEEDE, H., A. PONAT, K. HIROKI, and C. SCHLIEPER.
1969. Studies on the resistance of marine bottom invertebrates to oxygen-deficiency and hydrogen sulfide. Mar. Biol. (Berl.) 2:325-337.

THEEDE, H.
1965. Verleichende experimentelle Untersuchungen uber die zellulare Gefrierrestenz mariner Muschelin. (Comparative experimental investigations of the cellular freezing resistance of marine bivalves). Kiel. Meeresforsch. 2:153-166.

THORSON, G.
1950. Reproductive and larval ecology of marine bottom invertebrates. Biol. Rev. 25:1-45.

THORSON, G.
1966. Some factors influencing the recruitment and establishment of marine benthic communities. Neth. J. Sea Res. 3:267-293.

THURBERG, F.P., W.D. CABLE, M.A. DAWSON, J.R. MACINNES and D.R. WENZLOFF.
1975. Respiratory response of larval, juvenile, and adult surf clams, Spisula solidissima, to silver. In: J.J. Cech, Jr., D.W. Bridges, and D.B. Horton (eds.) Respiration of Marine Organisms. Proc. Mar. Sci., First Maine Biomed. Sci. Symp., Mar. 14-15, 1975, Augusta, ME. 211p.

VARGA, S. and W.A. HIRTLE.
1975. Incidence of Vibrio parahaemolyticus in fish, shellfish, mud, water, and fish products in the Canadian Maritime region. J. Fish. Res. Board Can. 32:541-544.

VERBER, J.L.
1976. Safe shellfish from the sea. In: Gross, M.G. (ed.) Middle Atlantic Continental Shelf and the New York Bight. Am. Soc. Limnol. Oceanogr. Spec. Symp. 2:433-441.

WADA, S.K.
1957. Chap. 11. Mollusca. In: Kume, M. and K. Dan (eds). Invertebrate Embryology. Bai Fu Kan Press, Tokyo, Japan. (From translation by J.C. Dan, printed in Yugloslavia by Prosveta, Belgrade, Dure Dakoviia 21). p. 485-525.

WELCH, W.R.
1963. Personal communication.

WELLS, H.W., M.J. WELLS and I.E. GRAY.
1961. Food of the sea-star Astropecten articulatus. Biol. Bull. (Woods Hole) 120:265-271.

WENZLOFF, D.R., R.A. GREIG, A.S. MERRILL, and J.W. ROPES.
1979. A survey of heavy metals in the surf clam, Spisula solidissima, and the ocean quahog, Arctica islandica, of the Mid-Atlantic coast of the United States. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 77:280-285.

WESTMAN, J.R. and M.H. BIDWELL.
1946. The surf clam. Economics and biology of New York marine resources. Typewritten ms on file at U.S. Dept. Comm., NOAA, NMFS, Northeast Fisheries Laboratory, Oxford, MD.

WHITEAVES, J.F.
1901. Catalogue of the marine invertebrata of eastern Canada. Geol. Sur. Can. Publ. No. 772. 271p.

WIGLEY, R.L. and K.O. EMERY.
1968. Submarine photos of commercial shellfish off Northwestern United States. Commer. Fish. Rev. 30(3):43-49.

WIGLEY, R.L. and R.B. THEROUX.
1970. Sea-bottom photographs and macrobenthos collections from the continental shelf off Massachusetts. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. No. 613, 12p.

WILBUR, K.M.
1964. Chap. 8. Shell Formation and Regeneration. In: K.M. Wilber and C.M. Yonge (eds.) Physiology of Mollusca. Academic Press, Inc., N.Y. p. 243-282.

WILLIAMS, A.B. and H.J. PORTER.
1971. A ten-year study of meroplankton in North Carolina estuaries: occurrence of postmetamorphal bivalves. Chesapeake Sci. 12: 26-32.

YANCEY, R.M.
1968. The 1967 Atlantic coast surf clam fishery. Commer. Fish. Rev. 30(11):50-53.

YANCEY, R.M. and W.R. WELCH.
1968. The Atlantic coast surf clam - with a partial bibliography. U.S. Dept. Interior, Fish and Wildl. Serv., Circular 288, 13p.

YANCEY, R.M.
1970. The Atlantic surf clam fishery (1968). Commer. Fish. Rev. 32(8-9):40-46.

YONGE, C.M.
1962. On the primitive significance of the byssus in the Bivalvia and its effect in evolution. J. mar. Biol. Assoc. U.K. 42:113-125.

YOUNG, R.
1961. Sedentary fisheries and the Convention on the Continental Shelf. Am. J. Internat. Law. 55:359-373.

YOUNG, J.S.
1973. A marine kill in New Jersey coastal waters. Mar. Pollut. Bull. 4:70.

ZOELLNER, D.R.
1977. Water quality and molluscan shellfish: An overview of the problems and the nature of appropriate laws. U.S. Dept. Comm., NOAA, NMFS. 106p and 115p Appendices.

NORTHEAST FISHERIES CENTER
SANDY HOOK LABORATORY
TECHNICAL SERIES REPORTS

NUMBER	TITLE AND AUTHOR	DATE & NTIS NO.
1	Proceedings of a workshop on egg, larval and juvenile stages of fish in Atlantic coast estuaries, by Anthony L. Pacheco (editor)	July 1973 COM75-10017/AS
2*	Diagnosis and control of mariculture disease in the United States, by Carl J. Sindermann (editor)	December 1974 PB263410/AS
3*	Oxygen depletion and associated environmental disturbances in the Middle Atlantic Bight in 1976 (composite authorship)	February 1977 PB287956/AS
4*	Biological and fisheries data on striped bass, Morone saxatilis (Walbaum), by W. G. Smith and A. Wells	May 1977 PB283900
5*	Biological and fisheries data on tilefish, Lopholatilus chamaeleonticeps Goode and Bean, by Bruce L. Freeman and Stephen C. Turner	May 1977 PB283901
6*	Biological and fisheries data on butterfish, Peprilus triacanthus (Peck), by Steven A. Murawski, Donald G. Frank, and Sukwoo Chang	March 1978 PB283902
7*	Biological and fisheries data on black sea bass, Centropristis striata (Linnaeus), by Arthur W. Kendall	May 1977 PB283903
8*	Biological and fisheries data on king mackerel, Scomberomorus cavalla (Cuvier), by Peter Berrien and Doris Finan	November 1977 PB283904
9*	Biological and fisheries data on Spanish mackerel, Scomberomorus maculatus (Mitchill), by Peter Berrien and Doris Finan	November 1977 PB283905
10*	Biological and fisheries data on Atlantic sturgeon, Acipenser oxyrhynchus (Mitchill), by Steven A. Murawski and Anthony L. Pacheco	August 1977 PB283906
11*	Biological and fisheries data on bluefish, Pomatomus saltatrix (Linnaeus), by Stuart J. Wilk	August 1977 PB283907
12*	Biological and fisheries data on scup, Stenotomus chrysops (Linnaeus), by Wallace W. Morse	January 1978 PB283908

NUMBER	TITLE AND AUTHOR	DATE & NTIS NO.
13*	Biological and fisheries data on northern searobin, *Prionotus carolinus* (Linnaeus), by Susan C. Roberts	June 1978 PB288648/AS
14*	A guide for the recognition of some disease conditions and abnormalities in marine fish, by Carl J. Sindermann, John J. Ziskowski, and Valentine T. Anderson	March 1978 PB284021/AS
15	Ichthyoplankton from the R/V *Dolphin* survey of continental shelf waters between Martha's Vineyard, Massachusetts and Cape Lookout, North Carolina, 1965-66, by P. L. Berrien, M. P. Fahay, A. W. Kendall, Jr., and W. G. Smith	March 1978 PB283865/AS
16	The seasonal maxima of *Ceratium tripos* with particular reference to a major New York Bight bloom, by John B. Mahoney	June 1978 PB2B7914/AS
17*	Biological and fisheries data on American eel, *Anguilla rostrata* (LeSueur), by Michael P. Fahay	August 1978 PB297067/AS
18	New York Bight ichthyoplankton survey - procedures and temperature and salinity observations, by Myron J. Silverman and Arthur W. Kendall, Jr.	August 1978
19*	Biological and fisheries data on sea scallop, *Placopecten magellanicus* (Gmelin), by Clyde L. MacKenzie, Jr.	February 1979 PB297415/AS
20	Dissolved oxygen levels in New York Bight waters during 1977, by Frank Steimle	September 1978 PB80127491
21	Biological and fisheries data on weakfish, *Cynoscion regalis* (Bloch and Schneider), by Stuart J. Wilk	February 1979 PB297015/AS
22	Biological and fisheries data on black drum, *Pogonias cromis* (Linnaeus), by Myron J. Silverman	October 1979 PB80124738

NUMBER	TITLE AND AUTHOR	DATE & NTIS NO.
23	Status of northwest Atlantic herring stocks of concern to the United States, by Carl J. Sindermann	December 1979
24	Biological and fisheries data on the Atlantic surf clam, *Spisula solidissima* (Dillwyn), by John W. Ropes	February 1980

* Out of Print. Copies may be ordered by NTIS number from:

U. S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

U.S. GOVERNMENT PRINTING OFFICE: 1980-617-577