THE ATLANTIC COAST SURF CLAM - with a partial bibliography

UNITED STATES DEPARTMENT OF THE INTERIOR
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BUREAU OF COMMERCIAL FISHERIES

Circular 288

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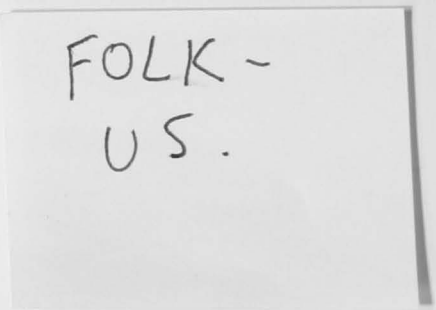
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THE ATLANTIC COAST SURF CLAM - with a partial bibliography

By

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ABSTRACT

The surf clam, Spisula solidissima solidissima (Dillwyn), supports an important commercial fishery along the coasts of the Middle Atlantic States. The major portion of the catch has been taken off New Jersey since 1949. Surf clam fishing vessels, equipped with hydraulic jet dredges, take the clams from depths of 100 feet or less and land them the same day. Most of the catch is processed for use as food; a minor portion is used as bait for fish. The total catch in 1965 was 44.1 million pounds of meat.

Surf clams are found in waters of oceanic salinity and sand or gravel bottoms from the low-tide line to depths of 480 feet. They range from the Gulf of Saint Lawrence to Cape Hatteras, N.C. The sexes are separate. Spawning usually occurs twice a year. Eggs, under experimental conditions, failed to develop in salinities below 23 parts per thousand. Young clams may reach a length of 1 3/4 inches in 1 year. Mature clams are commonly 6 to 7 inches long. Surf clams are very abundant in some areas. Populations of 1 to 2 million juvenile clams per mile of beach have been found at Wallops Island, Va., and Sandy Hook, N.J. As many as 5 million mature clams per mile of beach have been washed up on Long Island, N.Y., by a storm.

INTRODUCTION

The surf clam, Spisula solidissima solidissima (Dillwyn), is an important shellfish resource in the United States. In recent years (1949-65) the commercial fishery for surf clams has grown rapidly. The adoption of advanced technology in fishing and processing has enabled the fishery to harvest increasingly greater amounts each year--reaching 44.1 million pounds of clam meats in 1965.

A basic life history study of the surf clams was made in New England by Belding (1910). Many subsequent reports have been concerned with faunal surveys and aspects of physiology and taxonomy where the surf clam was of secondary importance.

Truly intensive studies of biology and population dynamics were first established in New Jersey where most of the catch since 1949 has been taken by highly efficient gear. Questions of sustained yield, growth, and recruitment to the fishery must be answered to provide information for the management of the fishery.

This report summarizes existing information about the surf clam fishery and its history as well as information about the distribution, abundance, and biology of the species. A partial bibliography is included.

HISTORY OF THE FISHERY

The history of the fishery for surf clams is divided into three periods: the early period, when the fishery was small; the developmental period, when it was growing rapidly; and the recent period, when it is well-developed.

Early Period -- 1870's to 1942

Large quantities of surf clams, thrown up on the beaches by storms, were gathered and eaten by the Indians in precolonial days. Early settlers on our Atlantic coast from Cape Cod, Mass., to New Jersey occasionally used the clams for food in times of hardship, but more often used them for fertilizer or food for swine and poultry.

The first organized fishery began on Cape Cod during the 1870's. Clams were raked or tonged up by hand, shucked, and salted down in barrels to be used as bait in the handline fishery for cod. In a good year (1877), 3,000 barrels, worth about $18,000, were produced (Ingersoll, 1887). Although early catch statistics are scanty, it appears that the fishery continued at a level below that of 1877 until 1929, when power dredging with scrape-type dredges began at Long Island, N.Y. Dredging began at Sheepshead Bay and spread to areas of Rockaway Inlet and Jones Inlet and southern New Jersey. The development and use of scrape-type dredges facilitated the taking of larger quantities of clams and the use of beds in deeper waters, although tongs continued to be used.

The fisheries in New York and New Jersey developed equally from 1929 to 1942, and irregular landings were made in Massachusetts and Rhode Island. The peak year for this early period was 1938, when 1.6 million pounds of meats were landed.

Developmental Period -- 1943-49[1]

Before 1943 many attempts were made by private industry to promote surf clams for food. All attempts failed, mainly because of inability to rid the clam meats of sand. In 1943, wartime demands for protein foods brought about a renewed interest in the surf clam resource. The F. H. Snow Canning Company of Pine Point, Maine, using clams landed at Freeport, Long Island, N.Y., solved the problem of sand removal with a drum washer and soon increased use of surf clams from small experimental quantities to 1,500 bushels per day. By the end of 1943 other processors had become interested and were preparing for 1944 production (fig. 1).

The resulting increase in landings for food occurred mainly in New York. By late summer of 1945, the area between East Rockaway Inlet and Fire Island Inlet was being dredged for surf clams and continued to be the most important area through 1949. Freeport and West Sayville, Long Island, N.Y., were ports where clams were landed. New Jersey clams were used mainly for bait, and the landings there dropped sharply owing to wartime restrictions on party boat (sport) fishing. In the Long Island, N.Y., area, the increased demand for more clams of better quality made the industry realize that fishing gear and methods needed improving. Late in 1945, when the forerunner of the modern hydraulic jet dredge was developed by the industry, catch per unit of effort and quality of clams increased markedly. Landings increased fourfold in 1945 because (1) the fleet increased to 50 boats by the end of the year, (2) the new hydraulic jet dredge doubled the efficiency of gear, and (3) boats could successfully dredge areas formerly considered to have too few clams. New York landings had reached nearly 5.0 million pounds of clam meats by 1949, but those of Massachusetts, Rhode Island, and New Jersey were far less.

[1] Westman, James R., and Milton H. Bidwell, 1946. The surf clam. Economics and biology of a New York marine resource. Unpublished manuscript. In files of Bureau of Commercial Fisheries Biological Laboratory, Oxford, Md. 21654.

Recent Period -- 1950-65

Industry found that the yield of meats per bushel of clams was 12 pounds in New York and 17 pounds in New Jersey. Because this greater yield and the increased demand for surf clam meats for food, the industry began exploring for clams in 1949 off the coasts of New Jersey, Delaware, and Maryland in 90 to 100 feet of water. Beds of clams were found. These beds were much more extensive than the Long Island beds, and the clams yielded more meat per bushel. In this middle Atlantic area a fishery subsequently developed for surf clams to be used as food. New Jersey landings increased from 0.4 million pounds of clam meats in 1949 to 6.9 million pounds in 1953, and Maryland landings reached 2.5 million pounds by 1953 (June and Reintjes, 1957; Reintjes and Roithmayr, 1960). The fishery in

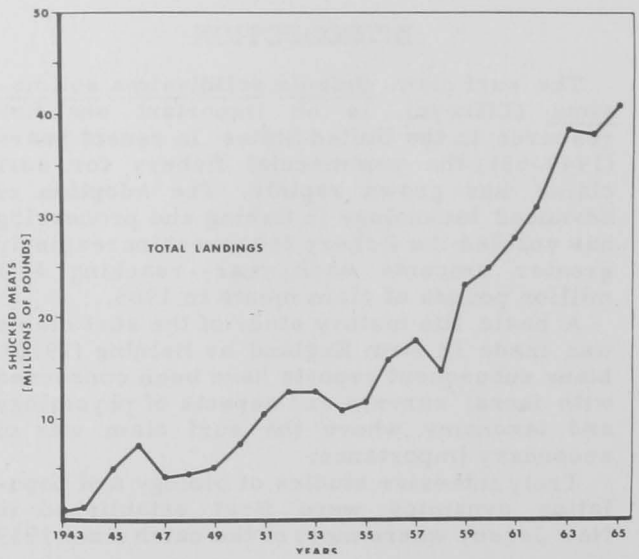

Figure 1.--Surf clam landings 1943-65. The important growth of the fishery came after 1943.

Maryland was short-lived, however, as the New Jersey grounds proved to be more productive. By 1957, most of the Maryland clam dredging fleet had moved to New Jersey. Since 1958, nearly all the Atlantic coast clam landings used for food have been taken off New Jersey. The total landings rose from 16.0 million pounds of clam meats in 1956 to 44.1 million pounds in 1965. New Jersey contributed 96 percent of the total landings in 1965. The major part of the New Jersey landings has come from the area between Point Pleasant and Beach Haven; some clams are taken off Cape May and landed there. The New York fishery has been unable to meet the competition of the New Jersey fleet which dredges densely populated beds; New York landings dropped from 2.4 million pounds of clam meats in 1956 to 1.5 million pounds in 1965.

The hydraulic jet dredge and accessory equipment were continuously evaluated and improved during this period of increase. The gear now is so efficient that the boats of the fleet generally work a 5-day week and are often on daily quotas that are met within a 12- to 14-hour workday (including sailing time). Daily quotas frequently have been imposed because the capacity of the processing plants is limited.

About 100 boats were dredging in 1957, and most of them were privately owned and operated; now the fleet has about 60 boats, of which nearly all are company-owned and operated. The present boats are generally larger than those in use 10 years ago.

HANDLING, PROCESSING, AND MARKETING

The clams are handled and processed by various methods. As the clams are dumped on deck from the dredge (fig. 2), they are separated from sand and dead shell by hand picking or are shoveled directly into a 1-bushel measure if the haul is clean. When full, the measure is dumped into a burlap bag, and the filled bags are stacked on deck. One company fills 30-bushel wire cages (fig. 3) rather than 1-bushel bags and stores them on deck. Clams are landed the same day they are taken. A dock hoist unloads six bags or one cage at a time. Most clams are then trucked to nearby shucking plants, but some are hauled as far as Delaware or Maine. Clams are usually unloaded in the afternoon, wetted down, and stored overnight in refrigerated rooms, or trucked overnight to Maine in refrigerated trucks. Next morning the clams, still in bags or cages,

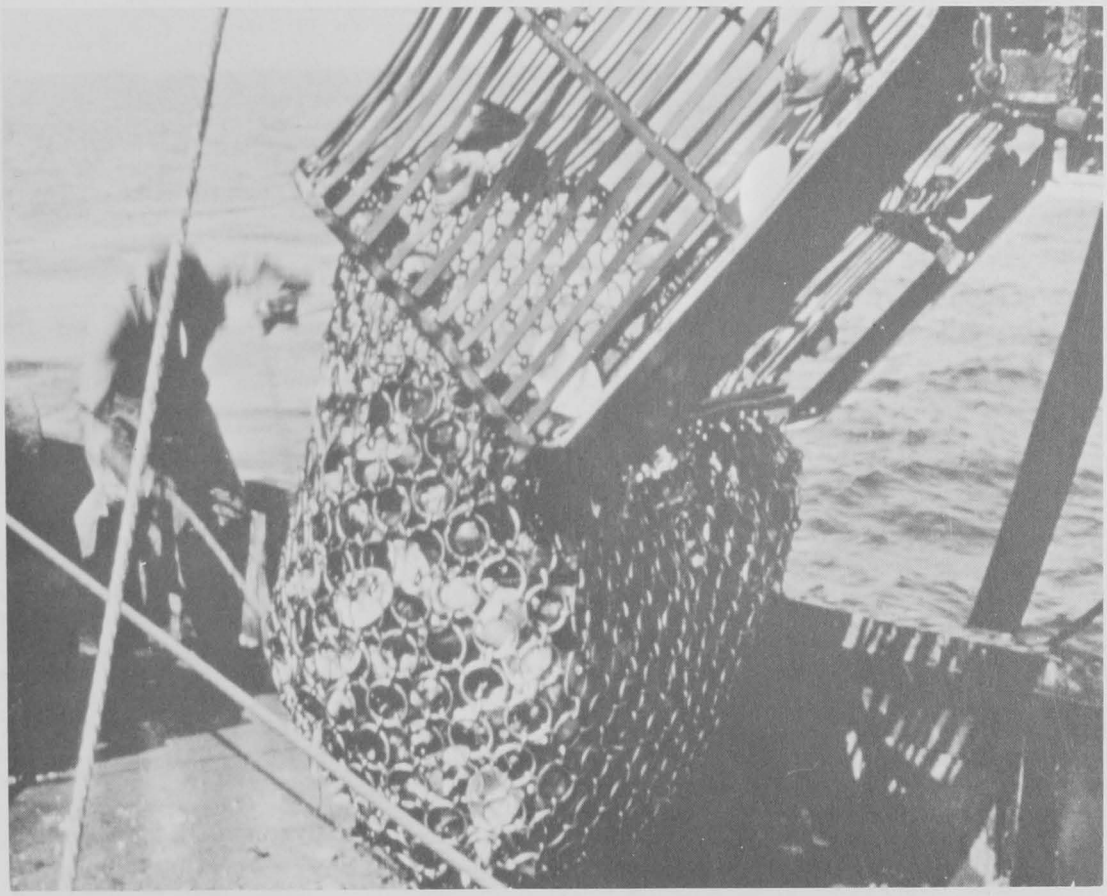

Figure 2.--A dredge load of clams about to be dumped on deck.

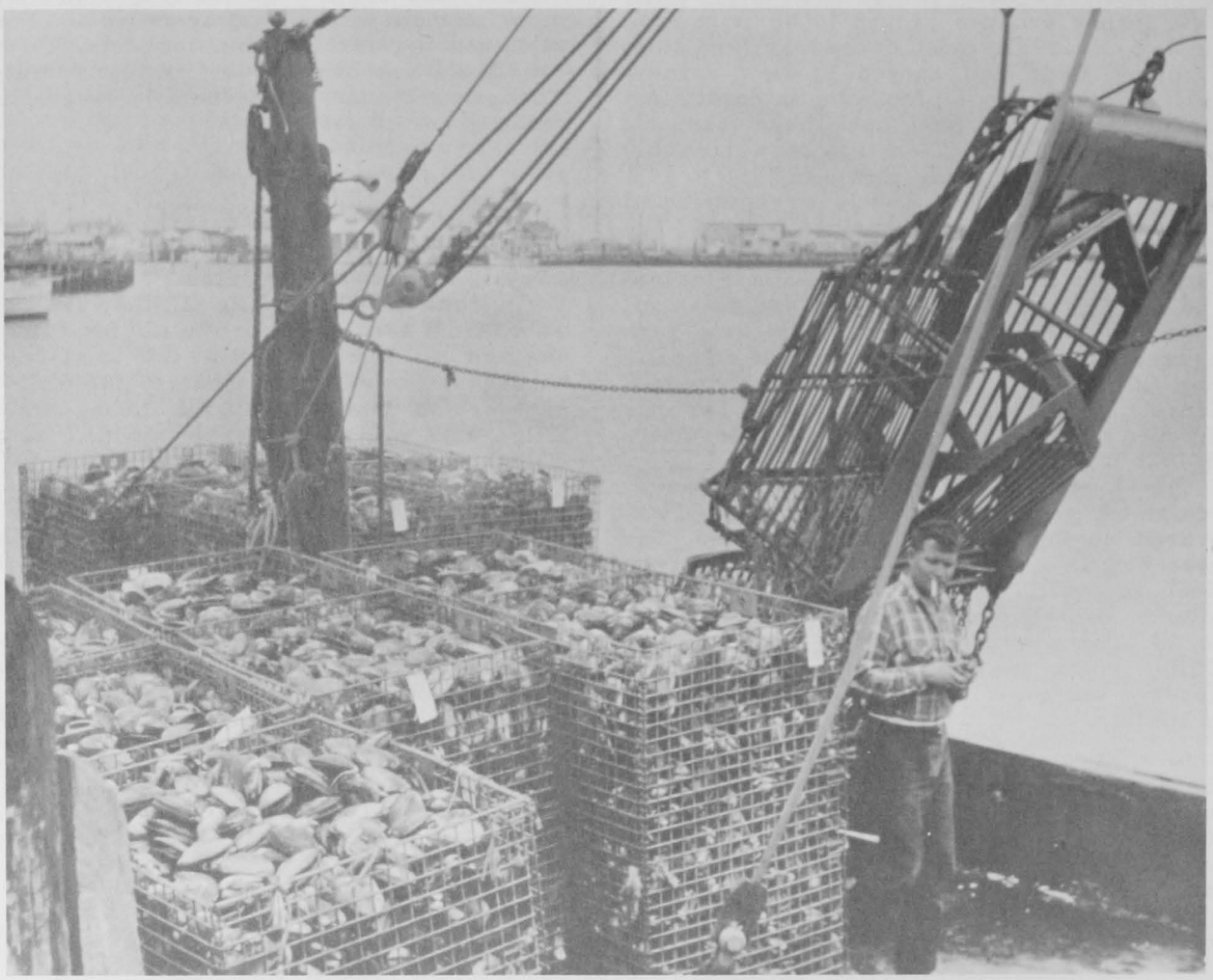

Figure 3.--Thirty-bushel cages of surf clams awaiting delivery to the shucking plant.

are dipped in hot fresh water (150° F.) for 30 or 40 seconds to open the shells slightly so the meats will be easier to shuck, and then cooled in fresh water to prepare them for the shuckers. Meats are shucked by hand (fig. 4) and placed in a washer to remove sand and pieces of shell.

Washed clam meats are packed in 130-gallon stainless steel tanks, lightly iced, and taken to the processing plant. The gonad and the visceral mass are squeezed out by hand (fig. 5), leaving the mantle strap, siphons, foot, and adductor muscles. The clam meats are washed again, and pieces of shell and the black edge of the mantle are stripped off. At this point the meat may be minced (1/4-inch pieces), chopped (1/2-inch pieces), or sliced into strips, depending upon what product is desired. The juices and wash water from this operation are sometimes saved, concentrated, clarified, salted, and packed as clam juice. Meats may be canned, made into chowder or clam cakes, refrigerated, or frozen and shipped to other processors of specialty products.

Surf clam meats compete with other clam meats because they are cheaper and make an acceptable product when processed. None are sold as food on the fresh market. The landed value of surf clams used for food is low and stable at about 7 cents per pound of meat. The wholesale value of the processed meats is about five times the landed value. Industry must operate at peak efficiency and depends on the continued availability of clams in heavily populated, easily accessible beds.

The surf clam fishery for bait has a limited market among sport and commercial fishermen. The landed value per pound of bait clams is higher than that of clams for food because of the demand for a special product. The landings in New York (practically all bait clams) in 1961-64 had an average value of $0.09 per pound of meats.

BIOLOGY

Knowledge of the biology of the surf clam has previously been based mostly on the work

of Belding (1910) and Verrill (1873) in Massachusetts. The questions of growth, distribution, and reproductive patterns in the area of greatest abundance in the Middle Atlantic Bight need to be answered by further research. Personnel at the B.C.F. (Bureau of Commercial Fisheries) Biological Laboratory, Oxford, Md., are now studying surf clam biology and population dynamics, with the ultimate goal of providing information to industry. The B.C.F. Exploratory Fishing and Gear Research Base, Gloucester, Mass., is surveying the distribution of the species.

Classification and Range

The surf clam belongs to the family Mactridae, which includes over 200 species found in most of the world's shallow seas. It is separated into two subspecies: Spisula solidissima solidissima (Dillwyn, 1817), the large commercial form which is found along our Atlantic coast from the Gulf of Saint Lawrence to Cape Hatteras, N.C., and Spisula solidissima raveneli (Conrad, 1831), a diminutive form found from Cape Hatteras, N.C., south to northern Mexico (Merrill and Webster, 1964). North of Cape Cod, Spisula polynyma (Stimpson, 1860), may be confused with S. solidissima, but no problem should arise along the Middle Atlantic Bight where S. polynyma is represented by only one record of a juvenile found between Cape Cod and the Hudson River Canyon (Chamberlin and Stearns, 1963). Common names that have been applied to the surf clam are sea clam, bar clam, hen clam, skimmer, dipper, beach clam, and giant clam. The commercially important S. s. solidissima is the only species reported on here.

Morphological Variation

The form of surf clams dredged from 40 to 200 feet of water between Montauk Point, Long Island, N.Y., and Cape Hatteras, N.C., appears to vary slightly from place to place. Some clams have an oblong or elliptical outline and a swollen or compressed thickness. All intermediate conditions occur. Verrill (1873) found similar differences in form for Massachusetts clams. Valves of clams from inshore waters, less than 40 feet deep, often have prominent check marks which are probably the result of environmental disturbances. Clams from one sample usually are of uniform shape and length.

Habitat

The surf clam inhabits the Continental Shelf from the lower edge of the intertidal zone to a depth of about 480 feet. South of Chesapeake Bay clams are not common in the shallower

Figure 4.--Workers shucking surf clams.

Figure 5.--Women eviscerating shucked clams.

waters; but in more northern waters of the Gulf of Saint Lawrence, the Bay of Fundy, Maine, and Massachusetts Bay, they live immediately below the low-tide line. Clams have been found at depths of 480 feet along the Middle Atlantic Bight, and at a depth of 250 feet off Digby Gut, Nova Scotia.

Surf clams require waters of near oceanic salinity. They are usually found on open beaches and open ocean bottom, and are generally absent from enclosed bays and estuaries. We have found surf clams at Chincoteague Inlet, Va. (1.5 miles from the open ocean at Chincoteague Point), where records show a minimum salinity of 29 p.p.t. (parts per thousand) (McGary and Sieling, 1953). Preliminary experiments with adults held at 50° F. indicate that salinities as low as 15 p.p.t. are lethal.

Surf clams live in sand or gravel bottoms. Shells, shell fragments, and fine sediments may be mixed with the basic bottom types. Clams are most common in a bottom of coarse sand and gravel.

Animals commonly associated with surf clams in dredge samples taken between Long Island, N.Y., and Cape Hatteras, N.C., at depths to 180 feet are: crabs (Cancer, Ovalipes, Ocellatus, and Libinia); moonsnails (Polinices heros and Lunatia duplicata); razor clams (Ensis directus); mahogany quahogs (Arctica islandica); southern quahog (Mercenaria campechiensis); and various echinoderms of the classes Holuthuroidea, Asteroidea, Echinoidea, and Ophiuroidea.

Reproduction

Reproduction of surf clams is poorly known (studies are in progress). The sexes of surf clams are separate--only one hermaphrodite has been found in 2,000 clams (John W. Ropes, personal communication[2]). Some Massachusetts clams have been reported to be sexually mature when 1.9 inches long and to spawn

[2] John W. Ropes, B.C.F. Biological Laboratory, Oxford, Md. 21654.

at 2.0 inches (Belding, 1910). The gametes are extruded into the water, where fertilization takes place. Clams spawn during June and July in Massachusetts; essentially the same period was reported for Long Island, N.Y. (see footnote 1). Our preliminary studies of the reproductive cycle show that New Jersey clams usually spawn from mid-July through mid-August; then they rapidly redevelop gametes and spawn again from mid-October through early December (John W. Ropes, personal communication (see footnote 2)). The clams again begin gametogenesis in February, followed by rapid development of mature gametes in March and April. Westman and Bidwell (see footnote 1) reported that Long Island, N.Y., populations of clams begin to spawn at 59° F. Fecundity of the clams is unknown.

Experiments on the rearing of larvae were performed at the B.C.F. Biological Laboratory, Boothbay Harbor, Maine. Eggs failed to develop normally at salinities below 23 p.p.t. at any temperature used (Alden P. Stickney, personal communications[3]). At 32 p.p.t. the optimum temperature range for development was 57° to 68° F.--mortality increased at higher and lower temperatures. Some larvae, reared on the unicellular alga Dicrateria inornata, survived and grew at salinities as low as 16 p.p.t., and could survive brief exposure (24 hours) to salinities as low as 8 p.p.t., if temperatures were sufficiently low (46° F.). At 32 p.p.t. growth was optimum at 68° F. but was somewhat inhibited at higher and lower temperatures. The larvae metamorphosed 18 to 30 days after fertilization when held at 68° F.

Growth

Studies of growth of surf clams are essential for practical resource management. The time required for clams to reach commercial length (5 inches) must be known to estimate rate of replacement of clams taken by the fishery. Figure 6 compares the information available from two published sources (Kerswill, 1944; Belding, 1910), one unpublished report (Westman and Bidwell, see footnote 1), and data obtained at the B.C.F. Biological Laboratory, Boothbay Harbor, Maine. Clams propagated during the summer at Boothbay Harbor averaged 0.04 inch (maximum 0.4 inch) long by late fall. Studies at the B.C.F. Biological Laboratory at Oxford, Md., showed that clams in a natural environment can reach a length of 1 inch by the end of their first 6 months and 1 3/4 inches by the end of their first year.

Relative Abundance

Surf clams are extremely abundant in some areas. From Maine to Maryland, tremendous quantities of clams have been reported washed ashore by wave action of winter storms (fig. 7). Jacot (1920) gave an estimate of 5 million clams washed ashore per mile of beach at Rockaway Beach, Long Island, N.Y., in the winter of 1919-20. Sampling for young clams at Wallops Island, Chincoteague, Va., in 1965 by the B.C.F. Biological Laboratory, Oxford, Md., indicated a density of 1 to 2 million live clams per mile between low- and high-tide marks; densities were similar in that year at Sandy Hook, N.J. (fig. 7).

The relative abundance of surf clams from Montauk Point, Long Island, N.Y., to Cape Hatteras, N.C., in depths from 40 to 480 feet has been determined from recent surveys with a jet dredge and a grab. The area of greatest abundance extends from Barnegat, N.J., to Cape May, N.J. Abundance is moderate in a narrow strip along the south shore of Long Island at depths to 100 feet and an offshore strip 70 to 90 feet deep off Chincoteague, Va. The present middle Atlantic fishery is dependent upon the continued availability of extensive and densely populated beds off New York, New Jersey, Delaware, and Maryland.

Mortality and Pathology

Small surf clams are subject to many types of predation. Bottom-feeding fish, diving ducks, and gulls feed on the clams. Moon snails of the genera Lunatia and Polinices bore holes through the shells and eat the meats. About one-half of the empty paired shells taken from a beach windrow at Wallops Island, Va., had been bored. As previously mentioned, storms often wash enormous numbers of surf clams ashore, where most die. The impact of predation and storms on surf clam populations is unknown.

No diseases of the surf clam are known, and records list only one parasite, Proboscidosaccus enigmaticus (of uncertain taxonomic position), in the related Spisula solida (L)--Gallien (1949). Gonads of some New Jersey surf clams taken in 1962-65 have been infested with an unidentified trematode. The effect of this parasite on the clam is not known.

[3] Alden P. Stickney, B.C.F. Biological Laboratory, West Boothbay Harbor, Maine 04575.

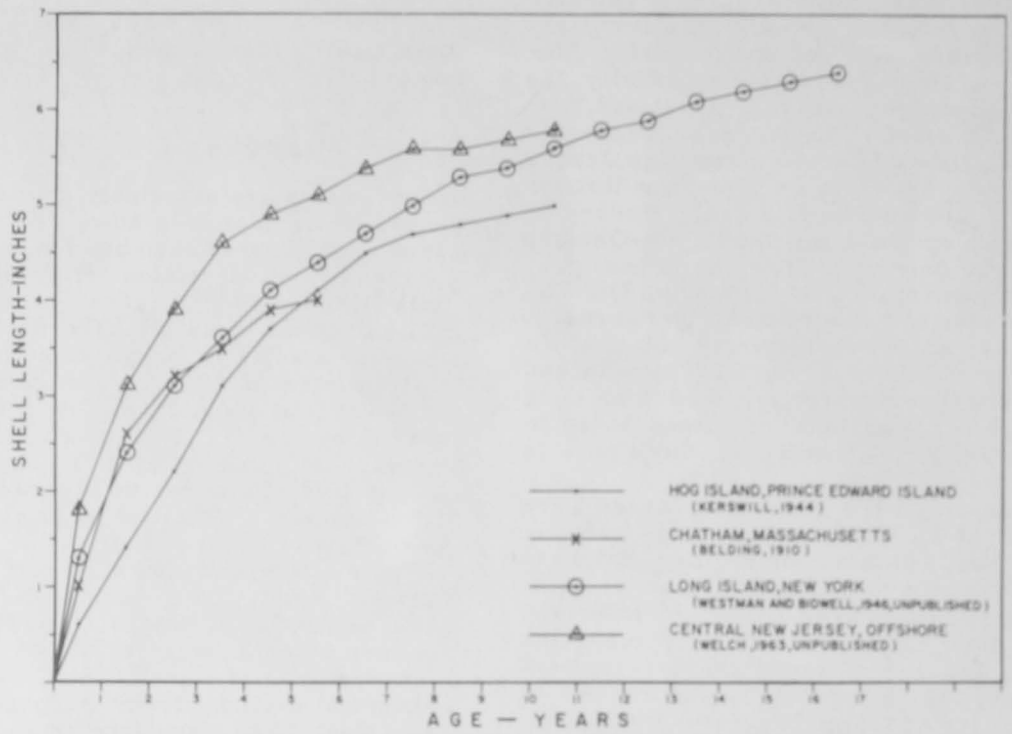

Figure 6.--Growth of surf clams, estimates from four sources.

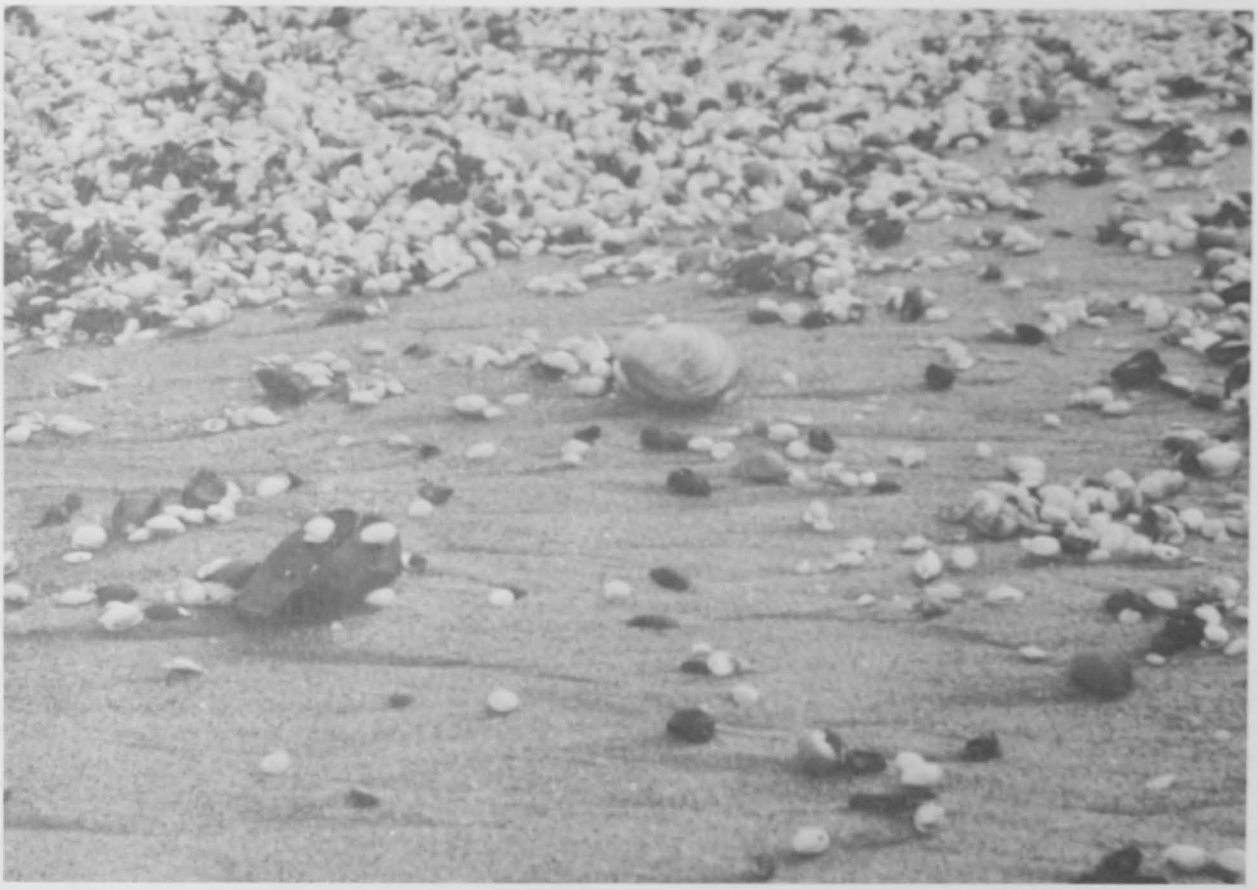

Figure 7.--Surf clams washed upon the beach by a winter storm. Lighter objects are surf clams.

PARTIAL BIBLIOGRAPHY OF THE SURF CLAM

(Asterisks indicate citations in text)

ADAMS, HENRY, and ARTHUR ADAMS.
1858. The genera of recent Mollusca. 2: 374-388. John Van Voorst, London.

ALLEN, ROBERT DAY.
1951a. Antimitotic substances secreted from eggs. [Abstract.] Biol. Bull. (Woods Hole) 101: 214.
1951b. The role of the nucleolus in spindle formation. [Abstract.] Biol. Bull. (Woods Hole) 101: 214.
1951c. The use of Spisula solidissima eggs in cell research. J. Cell. Compar. Physiol. 37: 504-505.
1952a. A visible response to stimulation in Spisula eggs. [Abstract.] Biol. Bull. (Woods Hole) 103: 283.
1952b. The behavior of Spisula eggs with respect to potassium ions. [Abstract.] Biol. Bull. (Woods Hole) 103: 290-291.
1953a. Fertilization and artificial activation in the egg of the surf-clam, Spisula solidissima. Biol. Bull. (Woods Hole) 105: 213-239.
1953b. Fertilization and artificial activation in the egg of the surf-clam, Spisula solidissima. Unpublished Ph.D. Thesis, Univ. Pennsylvania, 43 pp.

ANONYMOUS.
1955. Bar clam resources. Trade News 8(3): 8-10.
1959. Canada's shellfish resources. Trade News 11(9): 5-7, 9.

ASHTON, FRANCIS T.
1960. Germinal vesicle breakdown in the eggs of Spisula and Hydroides. Unpublished Ph.D. Thesis, Univ. Pennsylvania, 38 pp.

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

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

BOND, R. M., and J. C. MEDCOF.
1958. Epidemic shellfish poisoning in New Brunswick, 1957. Can. Med. Ass. J. 79: 19-24.

BOUSFIELD, E. L., and A. H. LEIM.
1958. The fauna of Minas Basin and Minas Channel. Nat. Mus. Can., Bull. 166, 30 pp.

BURCH, HELEN B., and PHILIPP STRITTMATTER.
1963. Enzyme patterns in eggs, developing embryos and adult tissues of Spisula solidissima. [Abstract.] Biol. Bull. (Woods Hole) 125: 373.

CARPENTER, HORACE F.
1887. The shell-bearing Mollusca of Rhode Island. Conchologists' Exchange 2: 78-79.

CARSON, RACHEL L.
1945. Fish and shellfish of the Middle Atlantic coast. [U.S.] Fish Wildl. Serv., Cons. Bull. 38, iv + 32 pp.

CHADWICK, GEORGE H.
1906. Shells of Prince Edward Island. Nautilus 19: 103-104.

CHAMBERLIN, JOSEPH LOCKWOOD.
1954. Studies in the Mactrinae. Unpublished Ph.D. Thesis, Harvard Univ., 132 pp.

CHAMBERLIN, JOSEPH LOCKWOOD, JAMES B. ENGLE, CARL. N. SHUSTER, JR., and WALTER R. WELCH.
1962. Report on the surf clam. Minutes 20th Annu. Meeting, Atl. States Mar. Fish. Comm. (1961). Appendix MA 2, 3 pp. [Mimeo.]

*CHAMBERLIN, JOSEPH LOCKWOOD, and FRANKLIN STEARNS.
1963. A geographic study of the clam, Spisula polynyma (Stimpson). Amer. Geograph. Soc. N.Y., Ser. Atlas Mar. Environ. 3, 12 pp.

CONRAD, T. A.
1868. Catalogue of the family Mactridae. Amer. J. Conchol. 3: 30-47.

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

FISCHER, PAUL.
1887. Manuel de conchyliologie. Pp. 1114-1120. Librarie F. Savy, Paris.

FORD, E.
1925. On the growth of some lamellibranchs in relation to the food-supply of fishes. J. Mar. Biol. Ass. U.K. 13: 531-559.

FORD, JOHN.
1889. List of shells of the New Jersey coast south of Brigantine Island. Nautilus 3: 27-28.

FOX, WILLIAM J.
1891. List of Mollusca of Gloucester Co., N.J. Nautilus 4: 113-115.

FROMMHAGEN, LAURENCE H., MARVIN J. FAHRENBACH, JOHN A. BROCKMAN, JR., and E. L. R. STOKSTAD.
1953. Heparin-like anticoagulants from Mollusca. Proc. Soc. Exp. Biol. Med. 82: 280-283.

*GALLIEN, L.
1949. Proboscidosaccus enigmaticus nov.g., nov.sp., parasite de Mactra solida L. (Note preliminaire.) Bull. Soc. Zool. France 74: 280-283.

GLANCY, JOSEPH B.
1945. Utilization of the surf clam, Mactra solidissima. Trans. 10th N. Amer. Wildl. Conf.: 294-297.
GONSE, PIERRE H.
1959. Respiration and motility in Spisula spermatozoa. [Abstract.] Biol. Bull. (Woods Hole) 117:433-434.
GOULD, AUGUSTUS A.
1870. Report on the Invertebrata of Massachusetts. 2d ed. Wright and Potter, Boston, 524 pp. + 22 plates.
GRAND, C. G.
1938. Intracellular pH studies on the ova of Mactra solidissima. [Abstract.] Biol. Bull. (Woods Hole) 75: 369.
HAGERMAN, DWAIN D., FREDERICA M. WELLINGTON, and CLAUDE A. VILLEE.
1957. Estrogens in marine invertebrates. Biol. Bull. (Woods Hole) 112: 180-183.
HARDING, CLIFFORD V.
1958. The osmotic behavior of marine oocyte nuclei. [Abstract] Biol. Bull. (Woods Hole) 115: 371-372.
HAYASHI, TERU, RAJA ROSENBLUTH, and HAYES C. LAMONT.
1959. Studies of fibers of acto- and paramyosin from lamellibranch muscle. [Abstract.] Biol. Bull. (Woods Hole) 117: 396.
HAYES, F. R., and D. PELLUET.
1940. Inorganic constituents in molluscan blood and muscle. Rep. Woods Hole Inst. Oceanogr. 1939: 1920. (Coll. Reprints WHOI 1940.)
HEILBRUNN, L. V., and W. L. WILSON.
1958. A physical study of the ground substance of the Spisula egg. [Abstract.] Biol. Bull. (Woods Hole) 115: 328.
HENDERSON, JEAN T.
1929. Lethal temperatures of Lamellibranchiata. Contrib. Can. Biol. Fish., n.s. 4: 399-411.
HOPKINS, HOYT S.
1934. Catalase and oxidative processes in animal tissues as possible factors in adaptation. Biol. Bull. (Woods Hole) 67: 115-125.
HUNTER, W. RUSSELL, and DAVID 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.
*INGERSOLL, ERNEST.
1887. Distribution, methods of gathering, and uses of sea-clams. In George Brown Goode, The fisheries and fishery industries of the United States, sect. 5, 2: 608-611. U.S. Government Printing Office, Washington, D.C.
INGERSOLL, ERNEST, and JOHN A. RYDER.
1884. The bivalves--Lamellibranchiata. In George Brown Goode, The fisheries
INGERSOLL, ERNEST, and JOHN A. RYDER--Con.
and fishery industries of the United States, sect. 1: 703-710. U.S. Government Printing Office, Washington, D.C.
ITO, SUSUMU, and CECILIE LEUCHTENBERGER.
1955. The possible role of the DNA content of spermatozoa for the activation process of the egg of the clam Spisula solidissima. Chromosoma 7: 328-339.
JACOBSON, MORRIS K.
1944. Variations of Spisula solidissima Dillwyn. Nautilus 57: 100-104.
JACOT, ARTHUR.
1919. Some marine Mollusca about New York City. Nautilus 32: 90-94.
*1920. Notes on some Mollusca about New York City. Nautilus 34: 59-60.
JOHNSON, CHARLES W.
1890. Annotated list of the shells of St. Augustine, Fla. Nautilus 4: 4-6.
1934. List of marine Mollusca of the Atlantic coast from Labrador to Texas. Proc. Boston Soc. Nat. Hist. 40: 1-204.
*JUNE, FRED C., and JOHN W. REINTJES.
1957. Survey of the ocean fisheries off Delaware Bay. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 222, iv + 55 pp.
KEITH, M. L., G. M. ANDERSON, and R. EICHLER.
1964. Carbon and oxygen isotopic composition of mollusk shells from marine and fresh-water environments. Geochim. Cosmochim. Acta 28: 1757-1786.
KELLY, JOHN W.
1954. Metachromasy in the eggs of fifteen lower animals. Protoplasma 43: 329-346.
KENNEDY, DONALD.
1958. Neural photosensitivity in Mactra. [Abstract.] Biol. Bull. (Woods Hole) 115: 338.
1960. Neural photoreception in a lamellibranch mollusc. J. Gen. Physiol. 44: 277-299.
*KERSWILL, C. J.
1944. The growth rate of bar clams. Fish. Res. Bd. Can., Prog. Rep. Atl. Coast Sta. 35: 18-20.
KIVY-ROSENBERG, EVELYN, and FRANCES RAY.
1961. Krebs and pentose cycle dehydrogenase systems in the eggs of Spisula as measured with a tetrazolium salt. [Abstract.] Biol. Bull. (Woods Hole) 121: 394.
KIVY-ROSENBERG, EVELYN, JOSEPH CASCARANO, and G. MERSON.
1959. Examination of some D.P.N.- and T.P.N.-dependent dehydrogenase activity before and after relatively high doses of x-irradiation of Spisula eggs. [Abstract.] Biol. Bull. (Woods Hole) 117: 415-416.

KIVY-ROSENBERG, EVELYN, KAREN STEEL KAGEY, and JOSEPH CASCARANO.
1958. Dehydrogenase activity in developmental stages of Spisula as measured with a tetrazolium salt. [Abstract.] Biol. Bull. (Woods Hole) 115: 354-355.

KRANE, STEPHEN M., and ROBERT K. CRANE.
1960. Effect of nicotinamide on pyridine nucleotide levels and cleavage rate of eggs of Spisula solidissima. [Abstract.] Biol. Bull. (Woods Hole) 119: 324.

KRANE, STEPHEN M., and LEONARD LASTER.
1962. The incorporation of nicotinamide-7-C^{14} into pyridine nucleotides of intact eggs and embryos of Spisula solidissima. [Abstract.] Biol. Bull. (Woods Hole) 123: 501-502.

LASTER, LEONARD, and ROBERT K. CRANE.
1962. Triphosphopyridine nucleotide formation and disappearance in the presence of extracts of eggs, embryos and adult liver of Spisula solidissima. [Abstract.] Biol. Bull. (Woods Hole) 123: 502.

LEIDY, J.
1878. Remarks on Mactra. Proc. Acad. Nat. Sci. Philadelphia 30: 332-333.

LOOSANOFF, VICTOR L.
1943. Soft and hard clams of the Atlantic coast of the United States. U.S. Fish Wildl. Serv., Fish. Leafl. 13, 11 pp.
1946. Commercial clams of the Atlantic coast of the United States. U.S. Fish Wildl. Serv., Fish. Leafl. 13(Rev.), 14 pp.
1954. New advances in the study of bivalve larvae. Amer. Sci. 42: 607-624.

LOOSANOFF, VICTOR L., and H. C. DAVIS.
1963. Rearing of bivalve mollusks. Adv. Mar. Biol. 1: 1-136.

LOVE, ROBERT, and LAURENCE H. FROMMHAGEN.
1953. Histochemical studies on the clam Mactra solidissima. Proc. Soc. Exp. Biol. Med. 83: 838-844.

*McGARY, JAMES W., and FRED W. SIELING.
1953. Chemical and physical data, Chincoteague Bay area, July 1943 to June 1953. Chesapeake Bay Institute, Johns Hopkins Univ., Data Rep. 15, Ref. 53-10, 49 pp. [Mimeo.]

MEDCOF, J. C.
1958. Stock-taking of molluscan shellfish resources and prospects for improvement. Fish. Res. Bd. Can., Prog. Rep. Atl. Coast Sta. 71: 21-25.

MEDCOF, J. C., A. H. LEIM, ALFREDA B. NEEDLER, A. W. NEEDLER, J. GIBBARD, and J. NAUBERT.
1947. Paralytic shellfish poisoning on the Canadian Atlantic coast. Fish. Res. Bd. Can., Bull. 75, 32 pp.

MEDCOF, J. C., and J. S. MacPHAIL.
1955. Survey of bar clam resources of the Maritime Provinces. Fish. Res. Bd. Can., Bull. 102, vi + 6 pp.

*MERRILL, ARTHUR S., and JOHN R. WEBSTER.
1964. Progress in surf clam biological research. In C. J. Sindermann (editor), The Bureau of Commercial Fisheries Biological Laboratory, Oxford, Maryland: Programs and perspectives, pp. 38-47. U.S. Fish Wildl. Serv., Circ. 200.

METZ, CHARLES B., and JOANNE E. DONOVAN.
1949. Fertilizin from the eggs of the clam, Mactra solidissima. [Abstract.] Biol. Bull. (Woods Hole) 97: 257.

MITCHILL, SAMUEL.
1826. Facts and observations intended to illustrate the natural and economical history of the eatable clam of New York and its vicinity. Amer. J. Sci. Arts. 10: 287-293.

MORSE, EDWARD S.
1919. Observations on living lamellibranchs of New England. Proc. Boston Soc. Nat. Hist. 35: 193-196.

NAGABHUSHANAM, R.
1962. The histology of the neurosecretory system of the clam, Spisula solidissima. [Abstract] Amer. Zool. 2: 543.
1963. Observations on the neurosecretory cells in the lamellibranch, Spisula solidissima (Dillwyn). Nucleus 6: 99-102.

NATIONAL FISHERMAN combined with MAINE COAST FISHERMAN (newspaper).
1961. Big stern dredge harvesting sea clams for Borden firm. National Fisherman 42(7): 14.

NOLAND, JERRE L.
1949. Determination of amino acids in invertebrates. [Abstract.] Biol. Bull. (Woods Hole) 97: 263-264.

PACKARD, ALPHEUS S.
1865. Observations on the glacial phenomena of Labrador and Maine, with a view of the recent invertebrate fauna of Labrador. Mem. Boston Soc. Nat. Hist. 1: 210-303.

RAPPORT, MAURICE M.
1961. The α, β-unsaturated ether (plasmalogen) content of the tissues of several mollusks. [Abstract.] Biol. Bull. (Woods Hole) 121: 376-377.

REHBUN, LIONEL I.
1956a. Electron microscopy of basophilic structures of some invertebrate oocytes. I. Periodic lamellae and the nuclear envelope. J. Biophys. Biochem. Cytol. 2: 93-103.
1956b. Electron microscopy of basophilic structures of some invertebrate

REHBUN, LIONEL I.--Con.
oocytes. II. Fine structure of the yolk nuclei. J. Biophys. Biochem. Cytol. 2: 159-171.
1957. Vital staining of eggs of Spisula solidissima by methylene blue. [Abstract.] Biol. Bull. (Woods Hole) 113: 353.
1958. Behaviour of metachromatic granules during cleavage in Spisula. [Abstract.] Biol. Bull. (Woods Hole) 115: 325.
1959. Studies of early cleavage in the surf clam, Spisula solidissima, using methylene blue and toluidine blue as vital stains. Biol. Bull. (Woods Hole) 117: 518-545.
1961a. Application of freeze-substitution to electron microscope studies of invertebrate oocytes. J. Biophys. Biochem. Cytol. 9: 785-798.
1961b. Electron microscope studies of frozen-substituted invertebrate oocytes. [Abstract.] Anat. Rec. 139: 266.
1961c. Endoplasmic reticulum in the asters of invertebrate eggs. [Abstract.] Biol. Bull. (Woods Hole) 121: 367-368.
1963. Induced amoeboid movement in eggs of the surf clam Spisula solidissima. Exp. Cell Res. 29: 593-602.
*REINTJES, JOHN W., and CHARLES M. ROITHMAYR.
1960. Survey of the ocean fisheries off Delaware Bay. Supplement report, 1954-57. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 347, iv + 18 pp.
RUGGIERO, MICHAEL.
1961. Equipment note no. 9....The surf-clam fishery of New Jersey. Commer. Fish. Rev. 23(8): 11-13.
SCHECHTER, VICTOR.
1937. Calcium and magnesium in relation to longevity of Mactra, Nereis, and Hydroides egg cells. [Abstract.] Biol. Bull. (Woods Hole) 73: 392.
1941a. Experimental studies upon the egg cells of the clam, Mactra solidissima, with special reference to longevity. J. Exp. Zool. 86: 461-478.
1941b. Further studies on Mactra egg cells. [Abstract.] Biol. Bull. (Woods Hole) 81: 303.
1956. The effect of water upon gametes, upon maturation and upon fertilization and cleavage. Exp. Cell Res. 10: 619-630.
1958. Water relations of the Spisula egg. [Abstract.] Biol. Bull. (Woods Hole) 115: 362-363.
SCHUEL, HERBERT, and CHARLES B. METZ.
1960. Inhibition of fertilization of Asterias, Spisula and Chaetopterus eggs by Arbacia dermal secretion. [Abstract.] Biol. Bull. (Woods Hole) 119: 297-298.
SCLUFER, EVELYN.
1951. Respiration of Spisula eggs. [Abstract.] Biol. Bull. (Woods Hole) 101: 228-229.
1954. Respiration of the Spisula egg. Unpublished Ph.D. Thesis, Univ. Pennsylvania, 67 pp.
SCOTT, GEORGE T., and HUGH R. HAYWARD.
1950. The influence of the glycolytic inhibitor iodoacetic acid on aging and on the potassium and sodium content of the egg cells of Mactra solidissima. [Abstract.] Biol. Bull. (Woods Hole) 99: 363-364.
SIELING, FRED W.
1955. Surf clam industry at Ocean City expands. Maryland Tidewater News 11(10): 1, 2, 4.
1960. Mass mortality of the starfish, Asterias forbesi, on the Atlantic coast of Maryland. Chesapeake Sci. 1: 73-74.
STEPHENS, GROVER C., and ROBERT A. SCHINSKE.
1961. Uptake of amino acids by marine invertebrates. Limnol. Oceanogr. 6: 175-181.
STICKNEY, ALDEN P.
1963. Histology of the reproductive system of the soft-shell clam (Mya arenaria). Biol. Bull. (Woods Hole) 125: 344-351.
STRITTMATTER, CORNELIUS F., and PHILIPP STRITTMATTER.
1960. Separation and isolation of Spisula embryo cells. [Abstract.] Biol. Bull. (Woods Hole) 119: 340-341.
STRITTMATTER, CORNELIUS F., PHILIPP STRITTMATTER, and CAROLYN BURDICK.
1960. Electron transport in eggs, developing embryos and adult tissues of Spisula solidissima. [Abstract.] Biol. Bull. (Woods Hole) 119: 341.
STRITTMATTER, PHILIPP, and CORNELIUS F. STRITTMATTER.
1961. Electron transport in eggs, developing embryos and adult tissues of Spisula solidissima. J. Cell. Compar. Physiol. 57: 87-93.
SULLIVAN, CHARLOTTE M.
1948. Bivalve larvae of Malpeque Bay, P. E. I. Fish. Res. Bd. Can., Bull. 77, 36 pp.
SWIFT, HEWSON.
1956. The fine structure of annulate lamellae. J. Biophys. Biochem. Cytol. 2: 415-419.
THIELE, JOHANNES.
1935. Handbuch der systematischen Weichtierkunde, vol. 2. Gustav Fischer, Stuttgart. Reprinted by A. Asher & Co., Amsterdam, 1963. 375 pp.
THOMAS, LYELL JAY, JR.
1951. A blood anticoagulant from surf clams. [Abstract.] Biol. Bull. (Woods Hole) 101: 230-231.

THOMAS, LYELL JAY, JR.--Con.
1953. A heparin-like blood anticoagulant from surf clams. Unpublished Ph.D. Thesis, Univ. Pennsylvania, 42 pp.
1954. The localization of heparin-like blood anticoagulant substances in the tissues of Spisula solidissima. Biol. Bull. (Woods Hole) 106: 129-138.
TOBIAS, JULIAN M.
1952. Some observations on the structure of nerve in the clam, Mactra solidissima. J. Cell. Compar. Physiol. 39: 161-164.
TURNER, HARRY J., JR.
1949. Report on investigations of methods of improving the shellfish resources of Massachusetts. Mass. Dep. Cons., Div. Mar. Fish., 22 pp. (Contrib. 510, Woods Hole Oceanographic Institute Coll. Reprints, 1950.)
1953. A review of the biology of some commercial molluscs of the east coast of North America. Sixth Rep. Invest. Shellfisheries Mass. Mass. Dep. Nat. Res., Div. Mar. Fish., pp. 39-74.
TURNER, HARRY J., JR., and DAVID L. BELDING.
1957. The tidal migrations of Donax variabilis Say. Limnol. Oceanogr. 2: 120-124.
[U.S.] FISH AND WILDLIFE SERVICE.
1949. Surf-clam fishery. Commer. Fish. Rev. 11(4): 33.
1955. Surf-clam industry at Ocean City expands. Commer. Fish Rev. 17(5): 31-32.
U.S. FISH AND WILDLIFE SERVICE.
1958a. Commercial fishery landings at Ocean City, 1957. Commer. Fish. Rev. 20(9): 44-45.
1958b. Hard-shell and surf clam exploration by M/V "Sunapee". Commer. Fish. Rev. 20(9): 45-46.
U.S. FISH AND WILDLIFE SERVICE.--Con.
1958c. Hard-shell and surf clam exploration continued (M/V "Sunapee"). Commer. Fish. Rev. 20(9): 46.
1958d. Surf-clam exploration in Nantucket Sound area by M/V "Sunapee". Commer. Fish. Rev. 20(11): 41-43.
*VERRILL, A. E.
1873. Report upon the invertebrate animals of Vineyard Sound and adjacent waters, with an account of the physical characters of the region. In U.S. Comm. Fish Fish., pt. 1, Rep. Comm. 1871-1872: 295-778.
WELSH, JOHN H., and MERILYN MOORHEAD.
1960. The quantitative distribution of 5-hydroxytryptamine in the invertebrates, especially in their nervous systems. J. Neurochem. 6: 146-169.
WENTWORTH, E. P.
1895. Marine shells on the coast of Maine. Nautilus 9: 34.
WESTMAN, JAMES R.
1946. Surf clam industry has rapid growth. Atl. Fisherman 27(7): 21, 30.
WIERCINSKI, FLOYD J., and JAMES K. TAYLOR.
1960. Experiments with Ca^{45} in marine egg cells. [Abstract.] Biol. Bull. (Woods Hole) 119: 299.
WINCKLEY, HENRY.
1891. Edible mollusks of Maine. Nautilus 4: 112-113.
1896. Note on Mactra. Nautilus 10: 47.
WOOD, ALBERT ELMER, and HORACE ELMER WOOD, 2ND.
1927. A quantitative study of the marine mollusks of Cape May County, New Jersey. Nautilus 41: 8-17.
WOODWARD, A. A.
1950. Proteolytic enzymes in the eggs of the clam, Mactra solidissima. [Abstract.] Biol. Bull. (Woods Hole) 99: 367.

Table 1.--Surf clam catch for the Atlantic coast of the United States, in pounds of meats, and value in dollars
(Absence of catch data may mean lack of either catch or data)[1/]

	Massachusetts		Rhode Island		New York		New Jersey		Delaware		Maryland		Total		Average price per pound
Year	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Dollars
1901	-	-	-	-	-	-	13,336	500	-	-	-	-	13,336	500	0.077
1904	-	-	-	-	92,080	6,720	67,200	6,000	-	-	-	-	159,280	12,720	0.082
1921	-	-	-	-	48,160	11,300	-	-	-	-	-	-	48,160	11,300	0.229
1926	-	-	-	-	59,112	15,436	-	-	-	-	-	-	59,112	15,436	0.254
1929	-	-	-	-	204,616	28,281	44,000	7,075	-	-	-	-	248,616	35,356	0.141
1930	38,275	3,750	-	-	291,270	34,639	131,670	15,281	-	-	-	-	461,215	53,670	0.117
1931	69,700	5,150	-	-	315,984	17,878	181,250	10,100	-	-	-	-	566,934	33,128	0.058
1932	55,390	3,525	-	-	352,656	18,440	136,250	6,175	-	-	-	-	544,296	28,140	0.051
1933	59,240	3,575	-	-	379,500	18,380	146,313	5,732	-	-	-	-	585,053	27,687	0.048
1935	800	50	-	-	523,300	22,825	313,900	13,829	-	-	-	-	838,000	36,704	0.044
1937	1,700	100	8,000	670	971,800	60,114	613,900	18,984	-	-	-	-	1,595,400	79,868	0.050
1938	1,300	76	-	-	808,800	51,537	804,900	20,301	-	-	-	-	1,615,000	71,914	0.045
1939	-	-	-	-	307,600	14,235	833,200	25,563	-	-	-	-	1,140,800	39,798	0.035
1940	-	-	-	-	660,000	30,370	573,400	24,801	-	-	-	-	1,233,400	55,171	0.045
1942	-	-	-	-	340,000	29,000	413,200	18,169	-	-	-	-	753,200	47,169	0.062
1943	249,800	64,170	-	-	475,200	50,200	170,100	10,514	-	-	-	-	895,100	124,884	0.140
1944	270,200	68,794	7,200	1,417	912,300	116,030	14,700	2,267	-	-	-	-	1,204,400	188,508	0.157
1945	263,800	80,935	7,900	1,986	3,982,200	499,670	526,500	47,000	-	-	-	-	4,780,400	629,591	0.132
2/1946	162,600	45,029	3,900	975	6,482,500	770,069	-	-	-	-	-	-	6,649,000	816,073	0.123
1947	209,800	57,060	4,300	1,083	3,314,700	345,470	169,300	20,973	-	-	-	-	3,698,100	424,586	0.115
1948	13,100	4,052	-	-	3,520,900	366,000	177,000	23,110	-	-	-	-	3,711,000	393,162	0.106
1949	10,600	2,617	7,300	1,824	4,903,700	470,433	407,700	39,219	-	-	-	-	5,329,300	514,093	0.096
1950	21,600	5,800	6,000	1,500	3,285,600	330,975	4,298,700	415,600	-	-	130,000	10,400	7,741,900	764,275	0.099
1951	21,800	5,950	-	-	4,046,100	421,474	6,419,400	622,033	-	-	-	-	10,487,300	1,049,457	0.100
1952	3,300	750	-	-	4,138,100	431,565	6,418,300	802,288	-	-	2,088,000	174,000	12,647,700	1,408,603	0.111
1953	-	-	-	-	3,345,000	418,000	6,878,000	790,000	-	-	2,454,000	204,000	12,677,000	1,412,000	0.111
3/1954	49,000	11,000	183,000	15,000	3,360,000	420,000	6,877,000	844,000	-	-	1,346,000	168,000	11,815,000	1,458,000	0.123
4/1955	23,000	4,000	157,000	18,000	2,026,000	253,000	8,278,000	967,000	-	-	1,695,000	141,000	12,179,000	1,383,000	0.114
1956	77,000	11,000	96,000	15,000	2,368,000	306,000	11,583,000	1,277,000	2,000	5/	1,850,000	173,000	15,976,000	1,782,000	0.112
1957	-	-	4,000	1,000	1,599,000	220,000	15,224,000	1,867,000	192,000	18,000	934,000	134,000	17,953,000	2,240,000	0.125
1958	1,000	5/	-	-	429,000	69,000	12,462,000	1,317,000	780,000	93,000	792,000	93,000	14,464,000	1,572,000	0.109
1959	2,000	1,000	-	-	514,000	61,000	20,164,000	1,622,000	1,750,000	170,000	850,000	70,000	23,280,000	1,924,000	0.083
1960	3,000	5/	-	-	722,000	85,000	23,448,000	1,546,000	478,000	48,000	420,000	34,000	25,071,000	1,713,000	0.068
1961	12,000	2,000	-	-	722,000	65,000	26,697,000	1,693,000	-	-	70,900	5,779	27,501,900	1,765,779	0.064
5/1962	10,000	2,000	-	-	840,000	76,000	29,830,000	1,917,000	99,000	9,000	75,000	6,000	30,854,000	2,010,000	0.065
5/1963	-	-	-	-	974,000	91,000	37,548,000	2,580,000	-	-	64,000	5,000	38,586,000	2,676,000	0.069
5/1964	13,000	3,000	-	-	1,218,000	109,000	36,875,000	2,504,000	-	-	38,000	3,000	38,144,000	2,619,000	0.069
6/1965	-	-	-	-	1,505,200	126,783	7/42,306,700	7/3,047,857	-	-	7/274,800	7/21,549	44,086,700	3,196,189	0.072

1/ Data for 1901-61 from personal communication, Walter R. Welch, BCF Biological Laboratory, Boothbay Harbor, Maine.
2/ No survey in New Jersey, Delaware, or Maryland in 1946.
3/ Ocean quahogs and surf clams combined and listed as surf clams in Rhode Island in 1954.
4/ Ocean quahogs and surf clams combined and listed as ocean quahogs in Rhode Island in 1955.
5/ Less than 500 pounds or 500 dollars.
6/ Data from U. S. Fish and Wildlife Service Statistical Digest Nos. 57, 58, and 59.
7/ Data from Current Fishery Statistics publications for the respective states.

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