A STUDY OF THE ARCTIC WEDGE CLAMS, MESODESMA DEAURATUM (TURTON) AND MESODESMA ARCTATUM (CONRAD) OF THE NORTHWESTERN ATLANTIC

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A STUDY OF THE ARCTIC WEDGE CLAMS, 
MESODESMA DEAURATUM (TURTON) AND MESODESMA ARCTATUM (CONRAD) 
OF THE NORTHEASTERN ATLANTIC 

BY 

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INTRODUCTION

The genus *Mesodesma*, world-wide in distribution, is represented in the Northwestern Atlantic by two species, *Mesodesma arctatum* (Conrad) and *Mesodesma deauratum* (Turton). *Mesodesma deauratum* was originally described as *Mactra deaurata* by Turton in 1822. The original description is quoted below:

MACTRA testa oblonga depressa inaequilaterali, latere producto rotundato altero subtruncato, umbonibus incurvis. (deaurata).

Shell oblong flattish inaequilateral, rounded at the elongated side and somewhat truncate at the other, with the beaks incurved.

Tab. nost. 5, g. 8.

Mus. nost. Dredged up in the offing of Exmouth.

   Shell five-eights of an inch long [high], and an inch and a quarter broad [long], opaque and strong; one side elongated, sloping from the beaks, and rounded; the other shorter and somewhat angular, where it is a little open: color dull greyish-white, covered with a shining bronzed skin reflecting metallic lustres; coarsely and irregularly striate transversely, with a few coarser ridges towards the hinge: inside glossy greyish white, with the margin plain: beaks rather prominent and pointed, a little inclining to the longer side.

   Of this very beautiful shell we know neither description nor figure. In the outline it something resembles the *Mactra deal-bata* described in the eighth vol. of the Linnean Transactions, p. 68, tab. 1, fig. 10, and the Dorset Catalogue, tab. 7, fig. 7. But that shell is represented as thin and transparent, and somewhat angular at the longer side: the teeth also appear to be different.

*Mesodesma arctatum* was described (also as a mactrid) by Conrad in 1831. The description is quoted below:

1
1. *M. arctata*. Plate XI, fig. 1. Shell subovate, solid, compressed, anterior side short, truncated and somewhat angular; posterior side produced, with the end margin rounded; cartilage pit triangular and profound; posterior lateral tooth elongated, and crossed by regular elevated striae.

Inhabits Massachusetts.

Cab. Academy, No. 840. I. Lea, D. B. Smith.

This shell somewhat resembles in shape the *M. donacia*, Lam. The specimens in the Academy's collection were obtained on the coast of Massachusetts, by Dr. C. Pickering.

Note that Conrad confused the ends of the animal. It is the posterior end of the shell that is truncate. The anterior is extended. Fig. 1, shows a collection of valves of both species.

Very little has been recorded concerning these two species of mollusks collectively called arctic wedge clams. For several reasons these bivalves are not well-known. They are easily confused with several other species. *Donax fossor* Say (or *D. variabilis* Say), *Thracia septentrionalis* Jeffreys, and *Mesodesma* all exhibit a truncate posterior edge. Also, the shells of *Mesodesma* are relatively small, seldom longer than 55 millimeters, and only occasionally do the living animals invade the intertidal zone. Furthermore, the distribution of *Mesodesma* is discontinuous. In New England waters they usually reside in sandy areas and shun rocky or muddy coastlines, probably requiring a relatively coarse, loose sand. Along the St. Lawrence Estuary a reversal occurs, and they usually reside in rocky or muddy shores.
Figure 1. Selected left valves of *Mesodesma arctatum* and *Mesodesma deauratum*. A: Plum Island, Massachusetts; B: Cape Cod, Massachusetts; C: St. Ulric, Quebec; D: Petite Matane, Quebec. A, B,—*M. arctatum*; C, D,—*M. deauratum*. 1/2x.
Not only are these two members of the genus often confused with other bivalves by those not well-acquainted with the identifying characteristics, but even among competent workers there has been disagreement as to whether one or two species of *Mesodesma* live in the waters adjacent to the northeast coast of the United States and Canada. It is hoped that this study will initiate work toward a solution of this problem. To this end the present status of the taxonomic problem is presented. The bulk of the work, however, consists of presenting the information available on distribution, anatomy, ecology, and growth rates derived from populations studied at selected sites.
TAXONOMY

The genus *Mesodesma* was established in 1831, by Deshayes in the second volume of the *Encyclopédie Méthodique Histoire Naturelle des Vers*. Although dated 1832, the portion containing the description of *Mesodesma* was issued in 1831, according to both Neave (1939) and Sherborn (1922).

Deshayes presented the generic characters and described seven species, but unfortunately did not designate a type. MacPherson and Gabriel (1962) accept *Mactra donacia* (*Mesodesma donacia* in Deshayes' work) as the type. Other authors have done the same, reasoning that in the absence of a subsequent type designation the first-described species becomes the type. Therefore, MacPherson and Gabriel (1962) have suggested that *Mesodesma* is an absolute synonym for *Donacilla* Blainville 1819, and thus *Donacilla* may replace *Mesodesma*.

Nine years before the genus *Mesodesma* was established, Turton (1822) described *Mactra deaurata* as a new species of bivalve mollusk dredged up in the "offing" of Exmouth, England. There was no indication whether the animal was taken alive or represented by empty valves, but description of the metallic luster of the periostracum by Turton indicates the specimen was not an old eroded shell. Only the right valve was figured indicating a less truncate
shape than exhibited by *Mesodesma* as now found along New England shores and also less truncate than many specimens from Canadian waters.

In 1831, Conrad described *Mactra arctata*, a bivalve more truncate than Turton's species, from the coast of Massachusetts. The shells were deposited in the collection of the Academy of Natural Sciences in Philadelphia. These shells have not been found, and it will probably be necessary to designate a lectotype and a type locality.

In the same year (1831) in his *American Marine Conchology*, Conrad commented on the *Mactra deaurata* of Turton and pronounced *Mactra arctata* Conrad and *Mactra deaurata* Turton to be synonyms. Other conchologists have had similar suspicions.

In 1834, De Joannis described *Mesodesma Jauresii* from the St. Lawrence Estuary. His figure resembles closely the shells found there today. De Joannis correctly noted the posterior portion as being the more truncate.

Several authors referred to these new descriptions. Gould (1833) and Jay (1836) mentioned *Mactra arctata* while Richardson (1836) referred to *Mactra deaurata* as common to both the Atlantic coasts of North America and of Europe. Müller (1836) mentioned *Mesodesma Jauresii* from the St. Lawrence, but Gould (1838) included it in the fauna of Massachusetts. Anton (1839) also mentioned *Mesodesma Jauresii*. Jay accepted Conrad's suggested synonymy by equating *Mactra deaurata* with *Mactra arctata*. 
Gould (1841) suggested that Mactra arctica Conrad, Mactra deaurata Conrad (should be Turton), and Mactra subtriangulata Wood were synonyms. (Mactra subtriangulata was introduced by Wood in 1828, from a shell in the British Museum. He did not indicate where it originally came from.) Gould decided that the mollusk was not a member of the Mactridae but of Deshayes' new genus, Mesodesma. On this basis he chose Mesodesma arctica as its name. Actually, he was in error, because, if he accepted Mactra deaurata Turton 1822, (not Conrad 1831) and Mactra arctica Conrad 1831 as synonyms, then his choice for a correct name should have been Mesodesma deauratum (Turton) 1822. Mesodesma is originally from the Greek meaning "middle ligament". It is neuter so all related specific names must end in "-um". Mactra is also Greek, meaning "kneading trough". It is feminine so related specific names end in "-a". However, all names cited from the literature in this thesis are written as given by the original author, whether correct or not.

Confusing the issue further, Gould accepted the continued existence of Mesodesma Jauresii as a separate species from Georges and Grand Banks. Reeve (1841) and DeKay (1843) accepted Gould's equating of Mesodesma arctica, Mactra arctica, and Mactra subtriangulata. Reeve, however, omitted Mactra deaurata from the synonymy and did not mention Mesodesma Jauresii. Catlow and Reeve (1845) equated Mactra arctica and Mesodesma arctica and also retained Mactra deaurata as a synonym of Mesodesma deauratum. They also

Stimpson (1851) agreed that *Mesodesma arctatum* and *Mactra arctica* were synonyms but kept *Mactra deaurata* separate and indicated that it was a synonym of *Mesodesma deauratum* and *Mesodesma Jauresii*. The suggestion of any relation between *Mesodesma deauratum* and *M. Jauresii* was interesting because two years later Forbes and Hanley (1853) proposed (quoted below) the same relationship.

Under the name of *Mactra deaurata*, Dr. Turton has introduced into our Fauna a species of the genus *Mesodesma*, stating that it was dredged up in the offing of Exmouth. One of our most assiduous and scientific collectors, Mr. Clark of Bath, whose researches in that neighbourhood extended over a period of twenty years, during that long space of time never once procured a single specimen, a strong, although negative, proof of the individual shell described by the doctor being of foreign importation, and not of native origin. The species is an inhabitant of the Gulf of St. Lawrence, Newfoundland, and does not range to the European seas. Inquiries instituted on the Devonshire coast have enabled us to solve the mystery of the discovery of this and other transatlantic shells in spots so utterly at variance with their known habitats. We find that during many years several vessels from those parts were engaged in prosecuting the Newfoundland fisheries; so that the accidental appearance of a few specimens of northern shells may readily be accounted for, as they frequently are mingled with the ballast of ships. A comparison of the original type with its delineation in the Conchylia Dithyra, compels the remark, that it is represented as more narrow and elongated than nature has shaped it, and enables us to declare its perfect identity with examples of the *Mesodesma Jauresii*, received by us from North America.

In 1853, Gray divided the *Mesodesma*-like pelecypods, or "Paphiadae" as he called them, into two groups based on the absence or presence of a pallial sinus. The forms with a "siphonal inflection" included *Mesodesma*, *Taria*, *Donacilla*, *Paphia*, and *Ceronia*. The genera not exhibiting a sinus were *Anapa* and *Davila*. The *Mesodesma*-like forms of
the Northwestern Atlantic were placed in the genus *Geronia* because of their striated lateral teeth. According to Gray, the lateral teeth of "true" *Mesodesma* were smooth.

In his monograph of *Mesodesma* (1854) Reeve continued to list *Mesodesma arctata* with synonyms, *Mactra arctata*, *Mactra deaurata* and *Mactra subtriangulata* but kept *Mesodesma Jauresii* as a separate species in spite of Forbes and Hanley's discussion. A. and H. Adams (1858) accepted Gray's genus *Geronia* indicating the lateral teeth were "curiously grooved" while those of *Mesodesma* were smooth. They recognized four species; *G. arctata* Conrad, *G. donacia* Lam., *G. Jauresii* Joannis (sic), and *G. lanceolata* Desh. but erred in attributing all four to California.

Subsequent papers continued to recognize the validity of Gray's genus, *Geronia*. Using Gray's suggestions as a basis, Carpenter (1861), Chenu (1862), Tryon (1868, 1873, and 1882), Gould (1870), and Verrill and Smith (1874) proposed various new arrangements for the *Mesodesma*-like forms up to the family level.

In 1870, Gould's work (completed by W. G. Binney) added more confusion. He listed two species, *G. arctata* from Plum Island, Nahant, Cape Cod, Nantucket, Sable Island and along the banks of the St. Lawrence, and *G. deaurata* from Nova Scotia, Georges Bank, and the Grand Bank. He suggested several morphological features separating the two but then placed *G. deaurata* in synonymy with *Mactra deaurata* Turton (Dithyra Brit. 1822) and placed *G. arctata* in synon-

Conrad was referring to *Mactra deaurata* Turton 1822, in his Am. Jour. Conch. of 1831, and was not creating a new species as Gould mistakenly implied.

In 1898, Dall presented an excellent discussion of the family Mesodesmatidae. Among other things he concluded that *Ceronia* and *Mesodesma* were synonyms. Subsequently, usage of the term *Ceronia* declined.

Despite the several attempts at synonymy the concept of two separate species continued to survive. Yet continued doubts were expressed. As early as 1869, J. F. Whiteaves suggested *Ceronia arctata* was only the immature form of *Ceronia deaurata*. Later (1901), Whiteaves commented further:

The writer has long been under the impression that there is only one species of *Mesodesma* in Canadian waters, and that the distinction between *M. arctatum* and *M. deauratum* can scarcely be satisfactorily maintained. Young or not quite adult specimens, with the valves covered with a yellowish and sometimes slightly iridescent epidermis agree in that respect with the description of *M. arctatum*; whereas adult and aged specimens, with only a narrow strip of pale ashen gray epidermis around the ventral margin, correspond better with that of *M. deauratum*. Judging by the figures in the second edition of Dr. Gould's Invertebrata of Massachusetts, the principal difference between these two forms would seem to be that in *M. arctatum* the short posterior end is so abruptly subtruncate that the beaks are almost terminal; whereas in *M. deauratum* the same part of the shell is somewhat produced. In this particular, all the Canadian specimens that the writer has seen, agree better with the figure of *M. arctatum* than with that of *M. deauratum*.

Whiteaves final conclusion in the above quotation is certainly different from many others familiar with the area. From my own experience I would say the opposite is true. Most of the shells from Canadian waters that I have collected...
or seen in museum collections more closely resemble the shape of *M. deauratum*. Whiteaves also quoted a letter from Dall indicating that Stimpson had even suggested three forms of *Mesodesma* in the Northwestern Atlantic, *M. arctatum*, *M. deauratum*, and *M. cinerea*. Dall indicated this idea came from one of Stimpson's manuscripts, but Stimpson probably did not feel strongly on the matter because I have not been able to find any other reference to it in the literature. However, several lots of shells in museums have turned up labeled *M. cinerea*. Another similarly encountered name is *M. arctica*. Both names have no validity as far as I know.

Similarly, the name *Ceromya*, used by Provancher (1890), is a misspelling of *Ceronia* and not a different genus.

The question of two species or one has come down to the present. Johnson (1915, 1934) and LaRocque (1953) recognized two species of *Mesodesma*. Miner (1950), on the other hand, mentioned only *M. deauratum* and described its range as from the Gulf of St. Lawrence to Georges Bank. Morris (1951) mentioned only *M. arctica*, found from the Gulf of St. Lawrence to New Jersey. Abbott (1954) listed *M. arctatum* extending from Greenland to Chesapeake Bay. Bousfield (1960) included *M. arctatum* and mentioned that the name *M. deauratum* had been applied to less truncate forms.
GEOGRAPHICAL DISTRIBUTION

The Distribution of Recent Forms

Abbott's (1954) version of the range of *Mesodesma arctatum* was given in the previous section. La Rocque (1953) indicated that *M. arctatum* has a range from the Gulf of St. Lawrence to New Jersey and stated that *M. deauratum* is found from the Gulf of St. Lawrence to Georges Bank. Numerous other papers taken collectively indicate the general lack of knowledge concerning the number of species occurring on the Atlantic coast of North America and the equal lack of solidly based information on their distribution.

Appendix I gives a summary of records of the distribution of *Mesodesma* based on museum specimens and my collections. Definition of the museum lot symbols used in this discussion can be found in the explanatory note of Appendix I. The detailed designation of each collection is from the records and labels of the museum. Fig. 2 and 3, in map form, show the origin of museum samples and personal collections of the author. A check between Appendix I and the maps will reveal that those museum lots without specific geographical designation are excluded from the maps.

Arctic regions. Abbott determined the range of *Mesodesma* for his 1954 publication by examination of the shells in the U. S. National Museum (stated in personal communication). This can be confirmed by a check of the
Figure 2. Distribution of *Hesodesma* in eastern Canadian waters. Based on museum samples and personal collections of the author.
Figure 3. Distribution of Mesodesma in eastern U.S. waters. Based on museum samples and author’s collections.
U. S. National Museum shells listed in Appendix I. The northernmost sample, USNM14169 (see Appendix I for explanation of symbols), designated only as Ceronia and containing only one valve, was dredged off Hare Island on the west coast of Greenland. The valve was of medium size (L. = 26.0 mm, H. = 17.3 mm) but badly eroded. It was obviously not from a recently deceased specimen.

Southward, the next samples were collected at Forteau Bay, Labrador, on the Strait of Belle Isle, June 24 and 25, 1949. They were part of the biological material collected by the research vessel "Blue Dolphin" which, under the direction of Captain David C. Nutt, conducted oceanographic and biological studies along the Labrador Coast in 1949, 1950, 1951, and 1952 (see Nutt 1952, and Nutt and Coachman 1956). Mesodesma was not encountered north of Forteau Bay. Richard H. Backus, biologist for the 1949 expedition, stated (personal communication) that a number of animals collected at Forteau Bay were not encountered at more northerly points.

Packard (1891) mentioned Mesodesma Jauresii De Joannis from the Strait of Belle Isle and also recorded it from Caribou Island, south of the Strait of Belle Isle (1863). He stated, "It is thrown up very abundantly on beaches, of a very large size". Later (1867) he noted that in Labrador Mesodesma Jauresii "...is of a very large size and thrown up very abundantly on beaches". No site was mentioned, but the similarity of the quotes suggests reference to the earlier site and publication. Bush (1883) also
published a list of shells from Labrador based, in part, on the collections made by Packard.

Collections of the Arctic Unit of the Fisheries Research Board of Canada, extending poleward from the northern tip of Labrador, contain no specimens of Mesodesma.

Packard's work, the "Blue Dolphin" collections, and the Fisheries Research Board collections all suggest that the Strait of Belle Isle represents the northern limit of Mesodesma. The Hare Island specimen (Greenland) is probably adventitious and does not represent the Arctic limit of the range.

Newfoundland and adjacent waters. No specimens of Mesodesma from intertidal or sub-tidal areas of Newfoundland were found in the museums. Dredging operations on the Grand Banks have yielded some valves from medium to large size (10-46 mm long). C. W. Johnson (1926) noted that Mesodesma arcuratum (sic) was collected by Owen Bryant in St. Pierre Harbor (a French possession near the south coast of Newfoundland) on October 1, 1908. This single valve, less than 8 mm long and extensively eroded, is in the collection of the Museum of Comparative Zoology. Verkruzen (1881) mentioned collecting Ceronia deaurata on the Grand Banks and Ceronia arctata at Avalon and Notre Dame Bai in southeastern Newfoundland, but he did not indicate whether the two latter sites were intertidal.

Quebec. Bousfield (1955) discussed the subdivisions of the St. Lawrence Estuary and the Gulf of St. Lawrence.
Using water temperature, summer salinity and faunal and floral composition, he divided the region into four areas. The upper St. Lawrence Estuary extending east to St. Joachim on the north and to Montmagny on the south shore was essentially a freshwater region with summer water temperatures exceeding 20°C. The second zone extended eastward to Baie St. Paul and Rivière du Loup on the north and south shores respectively. Its waters exhibited summer temperatures above 15°C and salinities under 20°/oo. The third area was composed of the remaining estuary and probably most of the gulf and had summer water temperatures of 7-14°C and surface salinities between 20 and 31°/oo. The fourth area, enclosed by the eastern coast of New Brunswick, the northern coast of Cape Breton Island and the Magdalen Islands had summer salinities of 20 to 30°/oo and summer water temperatures from 15 to 20°C.

The subarctic or Syrtensian fauna, of which Mesodesma is a member, is largely excluded from the first and second zones but is extensive in the third zone. It is there that Mesodesma is abundant. On the north shore it has been found as far west as Tadoussac (Bousfield 1960) and on the south shore to Trois Pistoles and Green Island (Bell 1859).

Prefontaine and Brunel (1962) summarized the 145 collections made by the Station Biologique du Saint-Laurent at Trois Pistoles from 1929 to 1934. Eleven of these collections yielded specimens of Mesodesma. Two of these samples,
22 and 71, are now in the Grande Rivière collection and are included in Appendix I. The eleven stations were divided between two areas: six stations located between Trois Pistoles (south shore) and Les Escoumains (north shore), and five stations from five to eight miles off the north coast between Ste Anne de Portneuf and Cape Colombier.

Many years ago Bell (1859) found live specimens intertidally at Bic, but in July 1962, when I made a survey trip along the south shore of the estuary from Rivière du Loup to Petite Matane, stops at the Trois Pistoles ferry dock and at the mouth of the Metis River produced neither live specimens nor beach shells. Fresh and worn beach shells were found for the first time on the beach below the sea wall at Les Boules, northeast of Metis Beach.

Note that only three samples of Mesodesma have been recorded between Petite Matane and Cape Gaspé. In part, at least, this may result from a lack of study in this area rather than any lack of abundance.

Mesodesma has never been reported from the shores of Anticosti Island—even in Schmitt's work of 1904—but it was found at Magpie Village on the mainland, thirty miles from the western end of the island (Whiteaves 1871).

The lower gulf. The southwest portion of the gulf, especially Northumberland Strait, is occupied by a Virginian fauna similar to that found south of Cape Cod. Bain (1885) did not find Mesodesma on the shores of Prince Edward Island. Other early efforts give little indication that Mesodesma
could be found in this region. Among the first records were the discovery of shells by H. G. Richards at Souris, P. E. I., by J. R. Miller on Orphan Bank about 30 nautical miles east of Miscou Island, New Brunswick, and also by J. R. Miller on Bradelle Bank south of Orphan Bank. Both offshore samples consisted of small shells. Strangely enough, Ganong (1837) published two lists of shells, collected from these banks by Whiteaves, and Mesodesma was not mentioned.

Recent work by Pierre Brunei (Station de Biologie Marine at Grande Rivière, P. Q.) has confirmed the existance of Mesodesma from Cape Bon Ami to the Baie des Chaleurs. The samples from the Grande Rivière collection were from below mean low water (1-2 feet at Port Daniel, P. Q.) to 55-56 fathoms at the mouth of Gaspe Bay. The Grande Rivière collection also contained an interesting sample collected near the high tide line at Harve-aux-Basques, Magdalen Islands. It contained eleven empty valves and seven reasonably complete because the soft parts had undergone some dessication and decay before preservation. The animals were probably not taken alive. Perhaps they had been dropped at the high tide line by gulls feeding on them. Bousfield (personal communication) has found beach shells, but no living specimens, on the north and east coasts of Prince Edward Island and also on the Magdalen Islands. He has also found shells in the Tracadie region of northeastern New Brunswick. According to Bousfield, the records are currently in preparation for publication.
In July 1962, I visited the shore at Caraquet and Tracadie Beach, New Brunswick. Neither live Mesodesma nor beach shells were found. Lack of intertidal specimens in most of the transitional and true Virginian faunal areas suggests that summer warming is limiting, while dredgings indicate successful survival in deeper, colder waters.

**Nova Scotia, Bay of Fundy, Maine and New Hampshire.** Bousfield (1958) recorded Mesodesma shells from the southwest coast of Nova Scotia. Specimens had been collected previously from the area and deposited in museums, but no distributional records had been published.

Offshore samples were known much earlier. Jones (1877) listed both Ceronia arctica and C. deaurata from Sable Island, and T. R. Willis (1862) listed the species as residents of Nova Scotia but indicated no localities.

In his 1958 publication, Bousfield noted Mesodesma as a beach shell at Round Bay, Port Mouton South, and Summerville Beach. He did not find it at Cape Sable Island. During July 1962, I found dead valves of the species on the outer beach of Cape Sable Island, at the mouth of Round Bay near Roseway Beach, and at Summerville Beach. Bousfield (personal communication) found additional shells of Mesodesma in eastern Nova Scotia in the summer of 1962.

There are no records of this bivalve from the Fundy coasts of New Brunswick and Nova Scotia. It is rare on the Maine coast. Ganong (1887), in his survey of the marine mollusca of New Brunswick, included a list of shells reported
from Eastport, Maine, but not from New Brunswick. This list mentioned *Ceronia arctata* as rare, but the record is questionable as there have been no subsequent reports of the bivalve from the area. Bullock (1961) listed one valve of "*Mesodesma arctatum form deauratum*" from Kent Island but later informed me that this valve was actually *Thracia septentronics* Jeffreys. Lemond (1909) and Kingsley (1901) stated that *Mesodesma arctatum* could be found in the vicinity of Portland, but no more specific information was given.

South of Portland, Maine, the character of the coast changes. Rocky headlands are replaced by sand beaches, and the environment appears to become more favorable for *Mesodesma*. The shells in lot MCZ33509 were probably collected at the mouth of the Goose Fair Brook near Old Orchard Beach, a site mentioned by Winkley (1896). Michels (1843) found shells on "Saco Beach" possibly in the same area, located at the southern end of Old Orchard Beach. A visit to this general area in April 1962, uncovered no evidence of *Mesodesma*.

I have found dead valves at the mouth of the Webhannet River in Wells (10/8/61) and at the mouth of a tidal river at Ogunquit (9/10/61). Several subsequent attempts to find shells or specimens at Ogunquit have failed, leading me to suspect that valves recovered were driven ashore from a subtidal location by an ocean storm. I have also searched, without success, for *Mesodesma* shells on beaches at Reid State Park, Popham, Pine Point, the mouth of the Saco River, Drakes Island (Wells) and York.
Both empty valves and living animals are found at the mouth of the Hampton River and in the harbor at Hampton Beach and Seabrook, New Hampshire. Valves are occasionally found along most of the length of the beach in Seabrook, New Hampshire.

Massachusetts, Rhode Island, and Connecticut. The extensive knowledge of the Massachusetts coast results in large part from the fine work carried on for many years by the Boston Society of Natural History and the Essex County Natural History Society. See, for example, Prescott (1842), Russell (1839, 1852a, and 1852b), True (1858), and Tufts (1856).

Basically, the distribution of *Mesodesma* in Massachusetts is in two areas, the North Shore (from Salisbury Beach to Boston Harbor) and the Outer Cape Shore (Provincetown to Monomoy and Nantucket Islands).

As noted earlier, when Conrad described *Mesodesma arctatum* (as *Mactra arctata*) in 1831, he stated the specimens were collected from the coast of Massachusetts. Although there is no proof, there is a good chance that these first specimens came from the shores of Plum Island, a six-mile long combination of barrier beach and sand dunes near Newburyport, Massachusetts. Here, where much of my ecological work and growth studies have been conducted, *Mesodesma* occurs abundantly.

Shells have also been found at Castle Neck Beach opposite the south end of Plum Island. I have never found
live specimens at Castle Neck and suspect that any shells
found there probably came from offshore areas or from the
Plum Island side of the bay.

This bivalve is found at a number of beaches in the
Cape Ann—Marblehead area. One excellent example is Good
Harbor Beach near Gloucester. Adjacent to the beach and
separated from it by the mouth of a small stream is a prom-
ontory called Bass Rocks. The samples labeled "Bass Rocks"
in Appendix I (USNM203171, 74339, and ANSP102169) are prob-
ably from the same location as those collected by Clarke
(1954) and Dexter (1962) at Good Harbor Beach.

A few samples have been taken south of Boston, and
Warren (1917) reported live specimens from Castle Island in
Boston Harbor.

Mesodesma does not appear abundantly on the inside of
the Cape but is a common beach shell on the outer shore.
Winkley (1907) described this area as the "home" of Ceronia
arctata. During the summer of 1962, I collected dead valves
at Highland Beach near Cape Cod Light, Ballston Beach near
the head of the Pamet River in Truro, Nauset Beach in East-
ham and Orleans, and Chatham Beach directly below the Coast
Guard Station. The shells became noticeably more abundant as
one approached the mouth of Nauset Harbor from either north
or south, and only in the vicinity of the harbor mouth was I
able to collect live specimens intertidally. There is little
information on the occurrence of Mesodesma on the outer beach
at Chatham, Morris Island, and Monomoy Island, but C. W.
Johnson (1904) did mention *Mesodesma arcuatum* (sic) as being plentiful at Chatham.

Some specimens have been found on the beaches of Nantucket, but Summer, Osburn and Cole (1911), attributing their information to Gould, stated that it was rare on the island. One should remember that valves of *Mesodesma* have been found in the Pleistocene deposits at Sankaty Head on Nantucket, thus raising the possibility that fossil and subfossil shells could be confused at this site.

Specimens have been recovered from Muskeget Channel between Nantucket and Martha's Vineyard, but, as far as I know, none have ever been collected on the shores of Martha's Vineyard or at Woods Hole. A few shells have been found in Buzzards Bay.

Listed in Appendix I are two samples from the waters adjacent to Rhode Island. Strangely enough, H. F. Carpenter listed *Ceronia arctata* in his catalogue of mollusca of Rhode Island (1873) but stated in a later publication (1888) that he had never found the species in Rhode Island waters. If found at all, it must be very rare.

Linsley (1845) listed *Mesodesma arctata* in his catalogue of Connecticut shells but stated they were immatures found in the stomach of a codfish. Although Perkins (1870) later mentioned Linsley's record as *Ceronia arctata* from Stonington, the lack of definite information on the original location of the shells eliminates any real significance as part of the distributional record. I have not
encountered any subsequent records of this bivalve in Connecticut waters.

**Long Island and New Jersey shores.** Summer water temperatures in Long Island Sound probably exceed tolerable levels for *Mesodesma*. As a result, like the Connecticut shore, the north shore of Long Island has not produced any specimens of this pelecypod. Sanderson Smith (1860) dredged in Peconic and Gardiner's Bays, probably in 1858 and 1859. Although most of his work was conducted near Greenport, the few dredgings taken around Montauk Point produced specimens of *Mesodesma arctatum*. In June 1962, I visited six locations on the south shore of Long Island from Montauk Point westward. At Montauk Point no evidence of *Mesodesma* was found. Examination of the south beach opposite Fort Pond in the village of Montauk revealed a few dead valves. Possibly this marks the first approach of the mollusk to shore in this area. Subsequent collections on the south shore at Hither Hills State Park, the end of Ocean Avenue near Hook Pond in East Hampton, near the breakwater at Georgica Pond, and on the east side of Shinnecock Inlet produced only dead valves. A week-long easterly storm in March 1962, extensively damaged and altered the Long Island shore. It probably had profound effects upon the distribution of marine life in the area.

Smith and Prime (1870) also reported this mollusk from East Hampton. Jacobson (1943) and Jacobson and Emerson (1961) noted the shell at Hither Hills and as far west as the outer beach opposite Patchogue. Jacot (1922) found shells at
Far Rockaway Beach and Long Beach (west of Jones Beach). Jacobson (personal communication) considers Jacot's record as from an adventitious animal. Possibly, the Fire Island sample is in the same category. It appears that *Mesodesma arctatum* may not normally occur intertidally on Long Island but that dead valves are washed ashore from deeper waters. Possibly, the warming of surface waters in the summer restricts intertidal distribution.

*Mesodesma* has never been considered a regular resident of New Jersey shores, but some specimens have been found there. Joseph Leidy (1888) found one dead specimen of *Ceronia deaurata* near Beach Haven on Long Beach Island. Apgar (1891) mentioned *Ceronia arctica* but said it was found from New York City northward. Richards (1938) listed *Mesodesma arctatum* and commented, "A northern species that is occasionally found on the New Jersey beaches from Seaside Park northward". In April 1962, I examined sections of the beach from Asbury Park north to Sea Bright but found no shells.

Very little has been written on the marine fauna of New Jersey. For more information, I wrote to shell collectors in New Jersey and New York City, inquiring about records of *Mesodesma*. I received no affirmative answers but did initiate interest. As a result, in June 1962, two collectors Charles Germer and Mrs. Paul Woodlock, found eight live specimens at Sandy Hook directly in front of the park administration office. These animals were all small (up to 12 mm). The identification was confirmed, and the specimens are now in the collection at the American Museum of Natural History.
(AMNH103228) New York City. Recently I received word of specimens found at Barnegat Light on Long Beach Island. This identification has not been confirmed.

The sample labeled USNM78351 taken southwest of Thomas Point Light in Chesapeake Bay was probably an adventitious specimen. Only one valve was involved. Evidence of considerable erosion and attack by boring organisms indicated this was not a recently deceased specimen.

Offshore areas from Georges Bank south. As indicated in Appendix I, samples have been taken from Georges Bank. Most have been small—less than 20 mm long. It is surprising that a sediment study of Georges Bank conducted by the U. S. Fish and Wildlife Service in 1957, and described by Wigley (1961) did not reveal any specimens of *Mesodesma* (Wigley, personal communication). However, I have found valves of this mollusk in a series of more recent dredgings of the Bank conducted by the Fish and Wildlife Service on the research vessel M/V Delaware in May 1962. These samples are still unsorted, and no additional information is yet available.

Dredging has revealed a considerable abundance of *Mesodesma* valves south of Cape Cod and Block Island. Many of these were either fragments or valves of considerable size but badly eroded.

In May 1960, the U. S. Fish and Wildlife Service conducted a series of dredgings on the continental shelf from Block Island to Cape Hatteras in an effort to confirm the existence of commercial quantities of the sea scallop, *Placo-
pecten magellanicus (Gmelin). Methods, equipment, and areas sampled are described by Merrill (1960). All material collected was sorted and preserved for later study.

Through the courtesy of Mr. Arthur S. Merrill of the U.S. Fish and Wildlife Service, I was able to examine the specimens of Mesodesma collected. As indicated by Fig. 3, most of these shells were taken far to the south of areas usually considered in the range of either M. arctatum or M. deauratum. All of the valves were empty and eroded. No living specimens were found. They do not at this time provide valid evidence for a southward extension of the range.

The Distribution of Pleistocene Forms

Both Mesodesma arctatum and Mesodesma deauratum occur in Pleistocene deposits of Eastern North America. Gardner (1943) designated Mesodesma spatha Gardner as a possible precursor of Recent and Pleistocene forms. I quote part of her description:

Dimensions of holotype: Height 6.4 millimeters, width [length] 10.3 millimeters, convexity 1.7 millimeters. Holotype, a right valve: U.S. Nat. Mus. 325591. Type locality: 1 mile northeast of Suffolk, Nansemond County, Va., Yorktown formation.

This single valve, the only one of the genus thus far reported from the east coast Miocene, has many characters in common with Mesodesma deauratum Turton of the Pleistocene faunas of the North Atlantic coast and may be the precursor of that species. The umbones are more posterior than in the majority of Recent individuals; the hinge plate is set in the plane of the dorsal margins rather than slightly oblique to it, as in the M. deauratum of Turton; and the ventral laminae of the laterals and the anterior arm of the cardinals are less elevated....

The Pleistocene in North America was composed of a number of subdivisions representing a chronological arrange-
ment of glacial and interglacial periods. Richards (1962) presented them as follows:

Recent Stage
Wisconsin Glacial Stage
Sangamon Interglacial Stage
Illinoian Glacial Stage
Yarmouth Interglacial Stage
Kansan Glacial Stage
Aftonian Interglacial Stage
Nebraskan Interglacial Stage

Frye and Willman (1960) set the Wisconsin Glacial at about 55,000 year B.P. (before the present) but possibly varying as much as 50,000 to 70,000 years B.P.

H. C. Richards (1962) depicted a number of basic aspects of the Wisconsinian Stage. First, the glaciation extended south to the area of New York City where the terminal moraine is located. Second, three basic activities were involved: (1) The accumulation of moisture in the ice sheet lowered the sea level as much as 300 to 450 feet. (2) The weight of the ice sheet tended to depress the land. As a result, when the glacier receded, the sea poured in over large areas of newly uncovered, but depressed land. (3) Slowly these areas recovered from the tremendous weight and a gradual emergence of land occurred. Thus, in many areas, the marine Pleistocene Sea was extended by the temporary sinking of the land.

South of the terminal moraine fluctuations in the
land level relative to the water level were primarily de-
pendent upon the ocean level itself, which in turn was con-
trolled by the amount of water locked in the ice sheet.

North of the terminal moraine the last invasion of
the land by the ocean was post-glacial at the end of the
Wisconsinian ice stage. Subsequent emergence extended into
the Recent period. The initial flooding of newly uncovered
land formed the Champlain Sea, extending up the St. Lawrence
and Ottawa Rivers, into Lake Champlain, and covering coastal
portions of Newfoundland, Labrador, Maine, New Hampshire,
and lowlands adjacent to Hudson Bay and James Bay.

South of the terminal moraine the most recent tran-
gression of water over the land was probably during the
Sangamon Interglacial Stage and extended up to 28 feet above
the present ocean level. Deposits of this warm, interglacial
sea are designated as the Pamlico or Cape May formation.

Richards (1962) gave an excellent distributional sur-
vey of marine Pleistocene mollusks of Eastern North America.
His records for Mesodesma follow:

Pleistocene distribution: Mesodesma arctatum

Maine: Portland, Cumberland County.
Freeport, Cumberland County.

Massachusetts: Sankaty Head, Nantucket County.

New York: Westhampton, Suffolk County. Well between
depths of 116 and 137 feet.

New Jersey: Cape May Canal, Cape May County. Excavations
from canal dug in 1942. Contains mixture of
warm and cold faunas. Probably Cape May
formation and Wisconsin.

Sediment core from Hudson Canyon, about 225

Virginia: ?

Pleistocene distribution: *Mesodesma deauratum*.

Quebec: Matane River.

Massachusetts: Sankaty Head, Nantucket County.

New Jersey: Cape May Canal, Cape May County--as cited above.

The Freeport, Maine, site is described by Bloom (1960) as follows: "13-57 Freeport, subquad 7; W. side of Dowdy gravel pit, on W. side of secondary road 0.5 mi S. of corner 171, 1.4 mi S.E. of Walnut Hill. Alt. 160-180 ft." This location, actually in the town of North Yarmouth, falls within the U. S. Geological Survey 15-minute topographic map entitled "Freeport", thus the general designation in Bloom's and Richards' works. I visited this site, about five miles from the present ocean shoreline, on September 1, 1962, and collected many valves of *Mesodesma arctatum*. None of the valves collected were as long as the large specimens found today on New England shores. I also found a few shells of *Hiatella arctica* L., *Macoma calcarea* Gmelin, *Mytilus edulis* L., and *Lunatia groenlandicus* Möller. Bloom also listed *Mya arenaria* L., *Mya truncata* L., *Serripes groenlandicus* Pruguiere, and *Spisula solidissima* Dillwyn from this same location.

While examining Recent shells of *Mesodesma* at the Academy of Natural Sciences in Philadelphia I encountered a
set from Kill Devil Hill, North Carolina, collected by H. G. Richards. These shells were quite dark and not unlike fossil specimens. Upon examination, both Tucker Abbott and H. G. Richards agreed that they were Pleistocene shells. This site is not mentioned in Richards' list.

Richards indicated to me (personal communication) that he suspects beach shells of *Mesodesma arctatum* found at Assateague, Virginia, are also probably Pleistocene.

Bell (1859) made the following reference to fossil *Mesodesma* along the St. Lawrence:

...In an ancient sea beach between Matis and the Trent, about 15 feet above the present sea level, these shells are found in heaps and mixed with sand and fragments of other shells, the same as along the present shore. Some imperfect valves were found at Matan [sic] in a bed of sand near the top of the 50 feet [sic] terrace occurring there.

These were probably Pleistocene deposits. I attempted to find and study these locations in July 1962, but was unsuccessful. Accumulations of *Mesodesma* shells along some parts of the present shoreline are sufficient to turn the area white and may represent mixtures of Recent and Pleistocene shells.

Packard (1866-1869) did not mention any fossil deposits of *Mesodesma* in his study of glacial phenomena of Labrador and Maine.

Richards (1962) also mentioned *Mesodesma concentrica* Holmes, 1860, collected at Simmons Bluff, on Yonges Island in Charleston County, South Carolina. Recent distribution is unknown according to Richards, and Abbott (1954) did not mention the species. In an earlier work, Richards (1936)
synonymized M. concentrica and Ervilia concentrica Gould 1862. Mazyck (1913) listed M. concentrica Holmes as rare (and presumably alive) from Sullivan's Island. This confusing situation should be clarified.

A recent article by Bousfield (1961) recounted the continued appearance over several years of shells and fragments of Noetia ponderosa Say 1922, Chione cancellata L. 1767, and Mulinia lateralis corbuloides Deshayes 1857, on the eastern end of the beach at Partridge Island, south of Parrsboro, Nova Scotia.

These three forms probably do not live in this area today. He stated that Noetia ponderosa extends today from Virginia to the Gulf of Mexico, Chione cancellata from North Carolina to Texas and the West Indies, and Mulinia lateralis corbuloides from North Carolina to Texas.

Bousfield concluded that these were subfossil remains of a post-Pleistocene warm period because water temperatures in the Fundy region today would not permit year-round survival of these mollusks. In a later paper (1962) he suggested that at the time of glacial recession, before the land had recovered from the weight of the ice, the lowered ocean level and elevated offshore banks impaired cold water flow into the Gulf of Maine sufficiently to create a warm water area with a fauna more typical of southern shores. Today, tidal currents are probably eroding the resting places of these shells and concentrating them on adjacent beaches.

The occurrence of shells in an area where they no
longer live is of considerable importance to those deter-
mining the range of Recent species. Possibly the range of
Mesodesma has been artificially extended in this manner.

I have seen Pleistocene Mesodesma shells from Kill
Devil Hill, North Carolina (previously mentioned), the Red
Crag in Sutton, England (USNM172822), and from Freeport,
Maine (also mentioned previously). The shells from Kill Devil
Hill and the Red Crag exhibit considerable coloration,
usually orange to red. The shells from the Freeport site
were colorless. I have also examined Mesodesma valves from
Sable Island, Nova Scotia, and from the south shore of Long
Island displaying similar coloration. All colored shells
were worn and had not been occupied recently. I have never
seen, from any location, a recently vacated valve of Meso-
desma (periostracum present, no sign of erosion) showing any
coloration suggestive of that described above. Possibly, the
coloration is picked up from the substratum after the death
of the animal. Fossil shells are certainly not always col-
ored as indicated by the Freeport shells.

Some of the dead valves of Mesodesma collected on the
cruise of the Delaware are also similarly colored. Signifi-
cantly, no live specimens or valves from recently living
specimens of Mesodesma were collected on that cruise. Al-
though it probably cannot be fully substantiated, the evi-
dence suggests that worn shells, occasionally colored, taken
intertidally or from deeper waters may be from recently un-
covered subfossil or even Pleistocene deposits.
In any case, the situation suggests careful consideration before initiating range extensions on the basis of dead valves like those found on the Delaware 60-7 Cruise, at Hare Island near Greenland, and in Chesapeake Bay.
MORPHOLOGY

Analysis of shell proportions. In spite of the confusion surrounding the taxonomy of *Mesodesma arctatum* and *Mesodesma deauratum*, the majority of authors have agreed that the distinction between species can most likely be detected in differences in the sharpness with which the posterior edge is terminated. The southern form, *M. arctatum*, is considered more truncate than the northern form, *M. deauratum*.

Gould (Binney 1870) probably tried harder than anyone to distinguish between these two forms. In reference to *M. deauratum* he stated:

The distinctive marks in comparison with *C. arctica* are its coarse, rough exterior, its longer and uncut posterior side; its very peculiar outline when viewed from above, on account of its breadth anteriorly; and its strong, curved, nearly smooth lateral teeth. Mr. Hanley has decided that the shell described by Turton under this name was not a British shell, but was introduced from America, and is identical with the shell since described as *C. Jauresii*.

Regarding the "coarse, rough exterior" of *M. deauratum*, I have examined thousands of shells from Labrador to Cape Hatteras and have noted no distinctive differences in shell surface. However, live specimens from the St. Lawrence usually possess less periostracum than those found in other areas.

Viewed from above, both northern and southern forms exhibit their greatest width about midway between the beaks and the anterior end.

Gould was in error when he stated that the lateral
teeth are nearly smooth in *M. deauratum*. The striations of
the lateral teeth are equally well-defined in specimens fit-
ting the description of one species or the other. Thus, the
one distinguishing characteristic remaining acceptable is
the shape of the posterior edge.

Nevertheless, the variation among geographical local-
ities has kept alive the question as to whether there are two
species or simply many geographical varieties of one. To
gain insight into this structural distinction, a statistical
study of shell dimensions was undertaken using samples from
four different locations.

All material was collected alive and preserved in
10% formalin. Each sample is described below:

(1) Two hundred fifty-nine specimens were taken by
hand from an area 1.6 by 6.6 meters approximately 200 meters
south of Nauset Inlet on Cape Cod, June 18, 1962. The area
searched was from approximately mean low water to one meter
above. The area was completely covered in a thorough search
over a two-hour period (5-7 PM). This collection was desig-
nated sample A. The specimens ranged in length from 9 to
48 mm with a mode at 27 mm including 31 specimens. (See
Appendix II-B for a size distribution of this sample.)
Another sample, designated as sample B, was taken by the
collecting rake in the same area and showed an identical mode.

(2) Five hundred specimens, designated as sample 5-11,
were taken from an area 15 to 25 meters south of the Coast
Guard pier at Plum Island, Newburyport, Massachusetts, on
May 11, 1962. The collection was by rake from mean low water to five meters below at about noon. (The method of collecting with the rake is described in the section on ecology.) See Appendix II-J and II-A, respectively, for a chart of the area and the size distribution of the sample. The specimens ranged from 9 to 36 mm long with two modes, one at 12 mm with 72 specimens and one at 26 mm with 33 specimens.

(3) Three hundred specimens (sample C-4) were collected from one square meter within a tide pool eight miles west of St. Ulric Cathedral, St. Ulric de Rivière Blanche, P.Q., on the south shore of the St. Lawrence Estuary, July 5, 1962. The tide pool was located near the high water line. Appendix II-K shows a sketch of the area. Collecting was at low water, between 10 AM and 1 PM. A definite bimodal distribution was observed with a peak at 18 mm (17 specimens) and one at 34 mm (44 specimens). The size distribution is shown in Appendix II-H.

(4) Two hundred forty-two specimens (sample C-2) were taken from one square meter about one meter below the high tide level near Petite Matane, P.Q., on July 4, 1962. See Appendix II-L for a map of the area. Collecting was at low tide, from 10 AM to 12 noon. This sample exhibited only one mode, 44 specimens at 30 mm, as shown in Appendix II-F.

For measuring, the left valve was removed from each animal and cleaned and dried. Then an imprint was made of the prepared valves by one of two methods. One approach was
Figure 4. Shell dimensions used in the comparative morphology study of *Mesodesma arctatum* and *Mesodesma deauratum*.
to ink each valve (concave side down) on a pad and press it against a sheet of paper producing an outline of the shell. The other method was a matter of placing the prepared valves (concave side down) on a transparent grid over positive photographic paper and exposing the paper to light. The developed paper exhibited a pattern of grid lines and "shadows" of the valves. These "shadows" or inked outlines were measured with calipers.

Fig. 4, indicates the nature of the measurements taken. Because the straight line of the dorsal edge is a dependable feature found on all valves, it was chosen as a standardizing device for all measurements. The shell profiles were so arranged that a perpendicular could be dropped from the straight dorsal edge through the beak. This permitted a standard measurement, designated as P, which was that portion of the total length projecting posterior to the perpendicular. The length (L) was the greatest length on a line parallel to the dorsal edge, and the height (H) was the greatest distance from the dorsal edge to the ventral edge on a line parallel to the perpendicular.

The statistical work was done on an IBM 1620 computer at the University of New Hampshire Computation Center. The relationships were determined according to the general regression equation, \( y = a + bx \), with the method of the least squares. Substitution of the appropriate symbols produced the equations \( H = a + bL \) for the length--height study and \( P = a + bL \) for the length--P-value study. Table 1 gives the
Figure 5. Comparison of length-height relationships in selected populations of *Mesodesma*. 
Figure 6. Comparison of length and P-value relationships in selected populations of *Mesodesma*. 
Figure 7. Comparison of length and W/2 relationships in selected populations of *Mesodesma.*
TABLE 1. Computed values (rounded off) for (a) and (b) used in the straight line regression analysis.

\[ H = a + bL \]

<table>
<thead>
<tr>
<th>Site</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plum Island</td>
<td>-0.13070</td>
<td>0.65258</td>
</tr>
<tr>
<td>Nauset Beach (So. Side)</td>
<td>0.15602</td>
<td>0.66110</td>
</tr>
<tr>
<td>Petite Matane</td>
<td>0.61107</td>
<td>0.62727</td>
</tr>
<tr>
<td>St. Ulric</td>
<td>0.72150</td>
<td>0.64768</td>
</tr>
</tbody>
</table>

\[ P = a + bL \]

<table>
<thead>
<tr>
<th>Site</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plum Island</td>
<td>0.59131</td>
<td>0.19256</td>
</tr>
<tr>
<td>Nauset Beach (So. Side)</td>
<td>0.84090</td>
<td>0.18744</td>
</tr>
<tr>
<td>Petite Matane</td>
<td>0.49821</td>
<td>0.25742</td>
</tr>
<tr>
<td>St. Ulric</td>
<td>-0.03891</td>
<td>0.26425</td>
</tr>
</tbody>
</table>

computed values for the constants \( a \) and \( b \) in each case.

Fig. 5, portrays the linear relationship between length (\( L \)) and height (\( H \)) for each of the four samples. There appears to be little difference among the \( H \times L \) relationships of the four samples. The unequal size-range of the samples to some extent limits the degree of comparison possible.

Fig. 6, depicts the relationship between length (\( L \)) and \( P \)-value for the four samples. Here, an interesting difference is revealed. The samples from Quebec have a higher \( P \)-value and are accordingly less truncate than their southern relatives.

Using the Nauset and Petite Matane samples described
above, an additional study of the relationship of length to width was conducted. Fig. 4, indicates how the measurements were taken. The length (L) was identical to that employed earlier. The width, designated as $W/2$, was the greatest width of one valve measured at the perpendicular dropped from the beak.

Fig. 7, represents the results of this study. As suspected, the specimens in the Petite Matane sample were wider than their southern counterparts at Nauset Beach. Calculations were identical with those described previously. Computed values were; Nauset, $a = -1.83360, b = 0.99795$; Petite Matane, $a = -2.45645, b = 1.22590$. As in Table 1 these values were rounded off to five figures to the right of the decimal point.

The above observations tentatively suggest that two species are being studied. One is the northern species *Mesodesma deauratum* with a less truncate posterior margin and with a greater width. The southern species, *M. arctatum*, is more truncate posteriorly and thinner.

*Morphology of the soft parts.* With few exceptions (Deshayes 1831, Tapperone-Canefri 1874, and Coscaron 1959, as examples) very little attention has been focused on the animal within the valves of any species of *Mesodesma*. Virtually no work has been done on the forms inhabiting the northwestern Atlantic.

Several hundred specimens have been examined in the samples collected at the four sites described with virtually
no variation detected in internal structure. Even relatively insignificant but noticeable characters peculiar to the genus show little variation from one location to another.

Because of the shortened posterior section, most of the animal is found anterior to the umbo. Only the siphons, posterior adductor muscle, heart, rectum and part of the foot retractor muscles lie posterior to the perpendicular dropped from the beaks. Fig. 9-13, show various aspects of the internal anatomy.

The entire animal is enclosed in the mantle with openings only through the siphons and the antero-ventral margins. This latter aperture provides egress for the active foot.

Removal of the mantle reveals the large foot pointing antero-ventrally and quite slender at its extremity. This burrowing device fills much of the mantle cavity. The two pairs of gills are suspended along the sides of the visceral mass. The outer pair is smaller and attached along a diagonal line separating the visceral mass from the pericardial cavity located ventral to the posterior lateral teeth. The inner pair of gills, similarly attached, is much larger extending anteriorly nearly to the palps.

The siphons, although eversible and separate, are much less prominent than in some pelecypods. The excurrent siphon is located beneath and partially anterior to the posterior adductor muscle. The digestive tract empties into the excurrent siphon chamber between the mantle margin and the
Figure 8. Sketches of siphons of *Hesodesma arctatum* by E. S. Morse. (a)(b)(c) Various degrees of extension by the excurrent siphon. (d) Diagrammatic representation of papillae on incurrent siphon. (e) Ventral view of relaxed animal.
lower edge of the posterior adductor muscle. The space or chamber into which the rectum opens extends up part of the anterior side of the posterior adductor muscle and forward to the posterior attachment of the gills where it is partially separated from the mantle cavity by a thin, membranous wall. This chamber, of course, draws water from the gill region and empties to the outside through the excurrent siphon.

The incurrent siphon is located directly below the excurrent. It opens internally into a small chamber which, in turn, connects with the mantle chamber. The incurrent siphon chamber is separated from the excurrent chamber by a thick wall. A ridge continues anteriorly on each side of the ventral mantle margins from the incurrent siphon chamber to the posterior limit of the opening for the foot in the mantle. This ridge is quite noticeable and constitutes one of the structural characters common to all specimens examined.

In the living animal the incurrent siphon of an undisturbed specimen can be sufficiently extended to display a ring of papillae of varying length. E. S. Morse (1919) described this in some detail for M. arctatum in the only prior instance where anyone has focused attention on the soft parts of either species. Fig. 8, is a reproduction of Morse's sketches of the pattern as he observed it.

This pattern was not detectable in preserved specimens. However, examination showed that the incurrent siphon of specimens from all locations usually exhibit twenty-four papillae, the same number Morse found. This feature probably is constant for all specimens.
Figure 9. Interior view of right and left valves of *Mesodesma arctatum.*
Figure 10. *Mesodesma arctatum* with left valve and portion of mantle removed.
Posterior to the anterior adductor muscle on the sides of the anterior part of the visceral mass are located two pairs of tapering, curled palps. These structures serve as ciliated guides to direct food particles to the mouth, recessed between the anterior adductor muscle and visceral mass.

The odd shape of the anterior adductor muscle, caused by an indentation slightly above the the midline of the muscle on the posterior side, was similar in specimens collected at all sites. It was even apparent on the muscle scar of the empty valve.

When the mantle is first removed from the side of the animal, a strand of tissue can be seen overlying the palp region. It is connected with the mantle at one end and with the visceral mass at the other. This structure has been found characteristic of all specimens of *Hesodesma* examined.

Dissection of the visceral mass readily reveals most of the digestive system. The thick-walled esophagus runs directly posterior from the mouth to the large vertical crystalline style sac, located just anterior to the posterior margin of the visceral mass. Within the esophagus numerous thick ridges project into the lumen. The enlarged space atop the style sac, commonly called the stomach, is surrounded by the many ramifications of the digestive diverticula, collectively called the liver. The diverticula also surround much of the esophagus and fill most of the central part of the visceral mass. Numerous muscle tracts pass laterally
Figure 11. *Mesodesma arctatum* with left valve, mantle, left gills, and part of siphons removed.
Figure 12. *Mesodesma arctatum* with left valve removed, other organs dissected to show digestive diverticula.
over the top of the esophagus and stomach between clusters of diverticula.

Branches of the gonads pass through much of the periphery of the diverticular region. The reproductive tracts with outpocketings are found near the perimeter of the dorsal of the visceral mass as well as in the more ventral section, but they are more abundant in the region immediately surrounding the ventral part of the crystalline style sac. See Fig. 18, for sections of mature gonads.

This sac contains the style, an important aid in carbohydrate digestion. From the upper anterior side of the style sac the intestine emerges and undergoes several convolutions in the mid-section of the visceral mass. Here, the digestive tract is surrounded by clusters of diverticula, since few gonadal structures penetrate this region. After leaving the stomach the intestine exhibits the typical typhlosole structure described by Morton (1958) and others. This specialized structure is apparent only in that portion of the intestine located anterior to the style sac.

From the "liver" region the intestine passes by or beneath the style sac and ascends to the upper posterior margin of the visceral mass, subsequently passing through the pericardium into the pericardial cavity located directly beneath the cartilage, cardinal tooth, and posterior lateral tooth. This terminal portion of the digestive tract then passes directly through the ventricle of the heart.

Upon emerging from the heart the intestine is still
Figure 13. *Mesodesma arctatum* with left valve removed, digestive and nervous systems shown.
enclosed in the aorta, from which the bulbus arteriosus is suspended above the posterior adductor muscle. The digestive tract passes dorsal to this and plunges between the two cylindrical foot retractor muscles and around the posterior side of the posterior adductor muscle. It then curves forward beneath the muscle emptying into the excurrent siphon chamber.

The three paired ganglia typical of the pelecypod mollusk are easily identified by their light orange color. The so-called cerebral ganglia lie above and slightly anterior to the mouth. From them two lateral trunks pass ventrally (one on each side of the esophagus) to the pedal ganglia embedded in the anterior part of the foot slightly below the level of the palps. Twin trunks also pass laterally and posteriorly from the cerebral ganglia and enter the pericardial cavity just below the digestive tract. At this point each trunk bends downward and traverses the outer side of each foot retractor muscle. Beneath the muscles the two trunks fuse to form the visceral ganglia.

In the region beneath the pericardial cavity the gradual transition from foot muscle to paired foot retractor muscles occurs. Enclosing the musculature of this region are the rather ill-defined paired masses of tissue representing the nephridia or kidneys. It is presumed that these organs, sometimes orange-brown in color, open into both the mantle chamber and the pericardial cavity, but this has not been determined.
Summary. In this study of the anatomy of the soft parts no distinguishing characteristics between northern and southern forms have been found. For example, the indentation of the anterior adductor muscle, the attachment of the mantle in the palp region, the ventral mantle ridge, the papillae of the incurrent siphon and the location of the ganglia show no variation among forms from separate geographical areas.

However, the study of shell proportions presents an interesting situation from which some tentative conclusions are suggested. It appears that the relationship of height and length probably does not differ significantly between forms from northern and southern localities. On the other hand, the southern form seems to exhibit a more truncate posterior edge than those specimens from the shores of the St. Lawrence Estuary. At the same time the Quebec specimens appear to be broader than the Cape Cod forms.

In spite of the lack of differences in the anatomy of soft parts the observations described above suggest a good possibility that two species of *Mesodesma* exist in the Northwestern Atlantic. The northern form, *M. deauratum*, is probably confined largely to the St. Lawrence Estuary and the north coast of the gulf. The southern form, *M. arctatum*, probably inhabits the remaining regions within the geographical distribution.
ECOLOGY

Plum Island

Occurrence and density. One of the better-known areas where M. arctatum can be found is Plum Island, near Newburyport, Massachusetts. This combination of sand dunes and barrier beach is separated from the mainland by the Plum Island and Merrimack Rivers and Plum Island Sound.

The island is a segment of relatively uniform, beach-lined coast stretching from south of Portland, Maine, to Cape Ann, Massachusetts. Johnson (1925) stated that much of this coastline experienced its formation by a combination of marine clays with the outwash of a glacial front during the late Wisconsin portion of the Pleistocene. This deposition combined with a coastline that runs roughly parallel to the ridges of the underlying rock formation to produce a seashore of uniform lines with few indentations. According to Johnson the overall appearance is one of a shoreline of emergence, consisting of an offshore bar backed by extensive salt marshes slowly rising into upland plain slopes. But appearances are deceiving, as he stated that actually the shoreline is gradually receding through combined erosion and submergence.

Plum Island is a six-mile section of this offshore bar. The island possesses some dunes of considerable height, probably formed by wind action, but now that much of the
island has become a wildlife refuge under the U. S. Department of the Interior, Fish and Wildlife Service, the land surface has been stabilized by the planting of erosion-inhibiting vegetation.

Many empty valves of *M. arctatum* were found along the entire seaward side of the island and on the ends until the sandy shores are replaced by muddy habitats of estuarine regions. Most of the collection work was conducted at the north end of the island outside the Parker River Refuge. The most frequently visited sites are indicated by letters A, B, C, and D in Appendix II-J. The work was concentrated in these areas because of easy access by auto and the greater abundance of the animals.

The mouth of the Merrimack River provided a unique and convenient situation for collection work and study. The volume and velocity of the water passing through this narrow region has cut comparatively steep shorelines on both sides. In many places the force of water has created sandy banks that drop as much as one meter per linear meter. The banks are especially steep below mean low water permitting sampling from fairly deep water close to shore.

Site A has been sampled on several occasions and found densely populated with *Mesodesma*. The sample used in the study of morphology was collected at this location. Site B probably has the highest population density in the area. Observation of the surface water suggests that an eddy effect lowers water velocity slightly, possibly making this a some-
what more desirable habitat. Although the sand is moved easily by the action of water, this region has maintained a fairly constant terrain. Site C has a much smaller density of individuals and is subjected to far greater water velocity. Possibly the effect is opposite to that at site B. Site D is on the exposed ocean beach and has exhibited a low population density. On one occasion, however, (October 19, 1961) I collected many small individuals at this location, but this abundance has never been detected again.

Collections were made with a drag fashioned from a wooden hayrake (Fig. 14). It was modified by removing every other "tooth" and attaching a net of wire hardware cloth behind the toothed region. The mesh of the netting permitted passage of the sand but retained specimens longer than 8 mm. Similar devices have been described in the literature (see Pearse, Humm and Wharton 1942, for example).

With 30 to 40 feet of rope attached, the rake was tossed from shallow water or the water's edge far enough to reach depths of 20 to 25 feet—under minimum current conditions. The other end of the rope was usually attached to a pail filled with wet sand preventing loss of the rake. This collecting technique was particularly successful in this area because considerable depths could be reached easily from shore. Specimens of M. arctatum usually do not live more than two or three inches beneath the surface of the sand. The collecting rake was so tilted that it penetrated to this depth, collected the clams, and allowed the sand to pass.
Figure 14. Collecting rake.
Comparative estimates of density are relatively easy to make, but reasonably accurate figures are more difficult at Plum Island, because nearly all of the collections were taken below the low water line. For this reason a rough method of estimation was devised. The collecting rake was approximately one meter wide. Considering the depth of the wire enclosure attached to the rake, it seemed reasonable to assume that about one linear meter might be traversed before the sand would have backed up sufficiently to prevent admittance of more sand. Thereafter, until emptied, the rake would tend to push sand ahead of it. This permitted the approximation that each "throw" of the rake probably sampled an area of about one square meter.

Variability in density is illustrated by the following. On May 10, 1962, four square meters (four hauls of the rake) at site B yielded a total of 1571 living specimens or about 390 per square meter. At the same location on August 9, 1962, two square meters (two rake hauls) yielded 414 animals or 207 specimens per square meter. On December 9, 1962, at site B, a half-hour's work produced only twenty live specimens. This was after the passage of an ocean storm severe enough to undermine several cottages on the ocean side of the island. The following month (January 15, 1963) a collecting attempt produced 306 specimens in ten hauls or about 30 per square meter.

The larger totals probably represent relatively dense
populations of this pelecypod. However, other sand-dwelling bivalves have been found in greater concentrations. Loesch (1957), for example, estimated the density of *Donax variabilis* and *D. tumida* as high as 32,000 per linear yard of beach on Mustang Island, Texas.

The disappearance and reappearance of *Mesodesma* is an interesting aspect that deserves more study. Edgren (1959) reported a somewhat similar series of events in a study of *Donax variabilis* at Clearwater Beach, Florida. Prior to his work, others (Pearse, Humm and Wharton 1942, Turner and Belding 1957) had indicated that *Donax* exhibited a tidal "migration" up and down the beach with the tide. Edgren did not detect this behavior at Clearwater. He did find, however, that a population established between the high and low tide levels disappeared after the passage of a storm. After a day or so of moving up and down the beach with the tide, the population slowly re-established itself in the old location. I have not detected any evidence of tidal migration by *M. arctatum*. However, it would be interesting to know more about how it becomes established again after storm erosion.

One might suspect that if population density is altered by storm erosion, the action of water might also exert a continuous limiting effect on the composition of the population. In other words, as the individuals grow older, the larger ones might be removed to another place thus producing a population with a seemingly static mode. The phenomenon might well be called "hydrographic sorting". Examination of
the size distributions of the growth study samples from site B indicates that from January 1962, to September 1962, the mode of the population moved from 11 mm to 21 mm. If hydrographic sorting did occur within that time period, it seems unlikely the population mode would change so markedly.

Yet the sampling subsequent to October 1962, posed the question of what happened to the specimens over 20 mm long. Their numbers were reduced. (See section on Growth.) Possibly under abnormal conditions of high water flow or heavy wave action, some selective hydrographic sorting may take place.

**Burrowing behavior.** A study of burrowing times by *M. arctatum* indicated the larger specimens might conceivably be at a disadvantage under the conditions described above. Table 2 gives some burrowing times for specimens observed in a basin filled with sand and water from the natural habitat. The sand was disturbed until a specimen was uncovered. Care was taken not to touch the specimen as it was found this would stop all activity for some time. Disturbing the adjacent sand did not inhibit behavior to any extent. As soon as the specimen was uncovered, the stopwatch was started and allowed to run until the clam was completely buried except for the siphons.

There was a definite sequence in burrowing. Initially, while the animal lay on either side, the pointed foot was extended and the substratum located. Then the anterior extremity of the foot penetrated the surface of the substra-
TABLE 2. Burrowing times correlated with size.
Conducted in cold room, 10/23/61, 4 PM. Animals collected from main beach at Plum Island, 10/19/61. Cold room temperature 12°C. Observations in order of occurrence.

<table>
<thead>
<tr>
<th>Size</th>
<th>Time</th>
<th>Size</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-15 mm</td>
<td>35 seconds</td>
<td>20-23 mm</td>
<td>50 seconds</td>
</tr>
<tr>
<td>20-23 mm</td>
<td>73 seconds</td>
<td>12-15 mm</td>
<td>32 seconds</td>
</tr>
<tr>
<td>12-15 mm</td>
<td>95 seconds</td>
<td>10-12 mm</td>
<td>54 seconds</td>
</tr>
<tr>
<td>12-15 mm</td>
<td>94 seconds</td>
<td>30-32 mm</td>
<td>105 seconds*</td>
</tr>
<tr>
<td>10-12 mm</td>
<td>20 seconds</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Ceased activity before completely buried.

Tum, presumably gaining sufficient anchorage to permit the animal to raise itself into a vertical position with the posterior end uppermost. This position achieved, a series of downward thrusts soon left only the siphons showing. There is a definite interval between each thrust, and it seems nearly constant for a given specimen. A correlation with size also exists. Larger specimens have a longer interval between downward thrusts. Thus, they cannot burrow as fast as their smaller companions.

There is no attempt to infer that the observations in Table 2 are definitive. Averages for the size groups may possibly give a better indication of the relation between size and burrowing speed. The averages are: 10-12 mm, 37 seconds; 12-15 mm, 64 seconds; 20-23 mm 62 seconds; the one specimen in the 30-32 mm group, 105 seconds. The differential is not as apparent from these figures as one might wish, but many observations in the field have repeatedly confirmed the view that larger specimens do have a burrowing handicap.
Although *M. arctatum* is a fairly speedy burrower, it is probably not the equal of extremely fast bivalves like *Ensia*, *Donax*, and *Siliqua*. On the other hand, Pearse, Humm and Wharton (1942) indicated that heavy bivalves like *Venus* (*Mercenaria*), *Cardium*, and *Macrocystis* require many pulls to become covered. *M. arctatum* usually requires no more than five to eight movements before it is covered even though it is not a slender clam. Standing in the surf at Plum Island, I have watched specimens dislodged by the rush of water and sand tossed back and forth in the waves with the foot extended, seemingly powerless to alter their fate. Then, in a moment of relatively calm water, they would insert the foot in the sand, stand erect, and with a few quick thrusts disappear into the sand.

Although I have not observed the action of the foot in the substratum, it is natural to speculate that it is not unlike that of *Solemya*. Owen (1961) detailed this behavior by *S. parkinsoni* Smith in New Zealand. The foot of *Solemya* is capable of enormous expansion at its extremity, thus acting as an anchor while the foot retractor muscles draw the rest of the animal downward. This type of terminal expansion has not been observed in *Mesodesma*, but the more distal part of the foot does produce ring-like expansions which, having originated at the tip, move rapidly back toward the main part of the foot. This action probably plays a major role in burrowing behavior. If the older and larger specimens are not able to cover themselves as quickly and find themselves
more at the mercy of currents and waves, the burrowing behavior may be a factor in hydrographic sorting, so-called.

At the other end of the size scale, specimens less than 12 mm long were more common in the sand adjacent to and beneath the Coast Guard pier than at sites A and B. Possibly, the pilings of the wharf decrease the movement of water sufficiently to provide some additional amount of protection for the smaller animals.

Observations in the field and laboratory confirm that *M. arctatum*, like many other pelecypods, assumes a vertical position in the sand with the siphon end upward. Under quiet conditions in a laboratory basin the animals will settle into a position where the incurrent siphons project to the surface of the sand. Thus, the animals usually will not penetrate below the top two or three inches of the bottom or beach. Under the more disturbing conditions of the natural environment the vertical position of the animal is more difficult to maintain.

**Salinity variation.** At Plum Island there is an interesting contrast in environments in relation to one ecological factor—salinity. The animals on the ocean side of the island are bathed in water with a nearly constant salinity of 31°/oo. On the ends of the island, at the mouth of the Merrimack River and the mouth of Plum Island Sound, there is a shading between estuarine and marine conditions. Because of the large volume of fresh water involved, the mouth of the Merrimack at the north end presents the more striking situation. Here the clams are subjected to marine conditions.
at high tide when salinities reach those of the open ocean (28-32°/oo). At low tide when the usual outflow of the tide is supplemented by the flow of fresh water, salinities are much lower. In the spring when the river is high I have recorded what is essentially fresh water at the Coast Guard pier. Unquestionably, bivalves are admirably equipped to cope with this situation. Their valves, in many cases, can remain closed for some time providing protection from the foreign environment outside (see Wells 1961).

As one might suspect, another tempering mechanism tends to help bivalves through this difficult twice-a-day period. The water held within the sand tends to be removed or diluted more slowly than the water above the sand. If the sand is above the low tide level, then the water will drain out at a slow rate keeping the sand moist until the tide returns. A relatively high level of salinity is also maintained in the sand. If the sand is below the low tide line, the water within the sand will tend to mix with the fresh water above the sand rather slowly, helping to maintain a more saline environment until the incoming tide returns.

Numbers 1-4, in Appendix II-J, indicate the locations for a study of this mechanism. On October 10, 1962, samples of water were taken from sites 1-4 at low tide (2:45 PM, EST) at the water's edge and from holes dug two to six feet back from the edge. The following day at high tide (10:30 AM, EST) the procedure was repeated at locations approxi-
TABLE 3. Comparison of water and sand salinities at the northern end of Plum Island.

H.W. = high water 10:30 AM, EST, 10/12/62. L.W. = low water 2:45 PM, EST, 10/11/62. Salinities in parts per thousand.

<table>
<thead>
<tr>
<th></th>
<th>Station (1)</th>
<th>Station (2)</th>
<th>Station (3)</th>
<th>Station (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In water</td>
<td>In water</td>
<td>In water</td>
<td>In water</td>
</tr>
<tr>
<td></td>
<td>sand</td>
<td>sand</td>
<td>sand</td>
<td>sand</td>
</tr>
<tr>
<td>L.W.</td>
<td>8.5 0.5</td>
<td>9.0 26.0</td>
<td>5.0 11.0</td>
<td>0.8 22.5</td>
</tr>
<tr>
<td>H.W.</td>
<td>30.0 29.8</td>
<td>29.8 30.0</td>
<td>30.0 30.0</td>
<td>30.0 30.0</td>
</tr>
</tbody>
</table>

mately in line with the previous day's sites. The salinity of the samples was determined by hydrometer using a kit produced by the G. M. Manufacturing Company, New York, N.Y.

The results are indicated in Table 3. At high tide there was little difference between the salinity of the open water and the water in the sand. This sand was probably dry at low tide. At low tide considerable variation was observed. The water salinities were all low, but the salinity at station 4, was lower than at station 1, which is upstream about 100 meters, because station 4, is nearer the main stream flow of the river. Station 1, is in an eddy where slightly more salt water may be retained at low tide.

The low salinity in the sand at station 1, may be caused at least partially by fresh water running out of the ground. A constant flow of water can be observed at this and other locations at low tide. Nevertheless, sand does tend to keep the salinity higher than the surrounding water at low tide. This could be a definite factor in helping a non-estaurine bivalve to survive in a semi-estaurine environment.
Predation. A short time collecting dead valves on the beaches at Plum Island will convince even the casual observer that *M. arctatum* is subjected to considerable predation by boring gastropods. Shells exhibiting the neat little tapered holes are everywhere on the shore. A brief search of the lower regions of these same beaches will reveal that its most common gastropod resident is the large Moon Shell snail, *Polinices heros* (Say). *P. triseriata* (Say) is also reported from this area.

As an attempt was made to estimate what per cent of total mortality might be attributed to predation by gastropods at various localities. All the dead valves of *M. arctatum* were collected from a given area and sorted into two lots, those valves that were bored and those that were not. The method of mortality estimation follows:

\[
\text{Total number of valves} = X \\
\text{Number of bored valves} = N \\
\text{Number of valves belonging to bored specimens} = 2N \\
\text{Number of specimens dying by other means} = X/2 - N \\
\text{Total number of specimens} = N + X/2 - N = X/2 \\
\text{Per cent of animals bored} = N/X/2 = (2N/X)(100).
\]

The samples are described and the results presented in Table 4.

The degree of significance that can be attached to
TABLE 4. Predation samples from New Hampshire and Massachusetts

<table>
<thead>
<tr>
<th>Site</th>
<th>Total valves</th>
<th>Number valves bored</th>
<th>Specimens present</th>
<th>% Mort. from gast. predate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coll. from 6 x 12 m rectangle at low water on northern tip of Plum I., Mass. 7/12/61.</td>
<td>210</td>
<td>43</td>
<td>105</td>
<td>41%</td>
</tr>
<tr>
<td>Coll. on entire bch. on no. side of Hampton R. mouth, east of bridge, Hampton Beach, N.H. 8/31/61.</td>
<td>100</td>
<td>33</td>
<td>50</td>
<td>67%</td>
</tr>
<tr>
<td>Coll. from 100 m part of bch. on both ocean and river sides of br'kw'r. No. side of mo. of Merrimack R., Salisbury Bch., Mass. 9/22/61.</td>
<td>228</td>
<td>53</td>
<td>114</td>
<td>46%</td>
</tr>
<tr>
<td>Coll. from south end of Good Harbor Beach, Gloucester, Mass. 5/5/62.</td>
<td>71</td>
<td>25</td>
<td>36</td>
<td>69%</td>
</tr>
</tbody>
</table>

these estimates is, of course, quite limited. Nevertheless, it appears that a significant part of the mortality results from predation by snails.

Cape Cod

Occurrence and density. During the summer of 1962, a week was spent studying the ecology of M. arctatum on Cape Cod, Massachusetts. As indicated previously, the clam is found only along the outer shore from Provincetown to Monomoy Island below Chatham. Occasional specimens have been recovered from Nantucket and surrounding waters.

Cape Cod is essentially a glacial formation. Woodworth and Wigglesworth (1934) indicated that most of the Cape is composed of glacial moraine deposits laid down during the maximum Pleistocene extension of the continental glacier. Subsequent changes have been brought about by the action of
wind, waves, and stream erosion. These instruments of change are still at work.

Work was conducted at five localities: Highland Light, Ballston Beach at the head of the Pamet River, Nauset Beach north of Nauset Inlet, Nauset Beach south of the inlet, and the shore below Chatham Light.

At three locations, Highland Light, Ballston Beach, and Chatham Light, no live specimens were located; and only small numbers of dead valves were found on the beach. In fact, at Chatham Light even dead valves were rare. It was observed after considerable collecting that the mollusks became more abundant as one neared Nauset Inlet from either north or south. At Cape Cod National Seashores Headquarters in Eastham very few shells were found. Adjacent to the public parking lot on Nauset Beach in Orleans there were also few shells. Then, as one walked toward Nauset Inlet from either of these points, there was a gradual increase in the number of empty valves. Upon arriving at the inlet entrance, on either side, valves of *Mesodesma arctatum* were more abundant than those of any other bivalve. Only in the vicinity of the harbor entrance was I able to locate living specimens intertidally.

Unlike many beaches, the outer shore of the Cape is characterized by a rather uneven appearance at low water. The beach at the water's edge takes on a scalloped look with low mounds of rocks and sand often appearing opposite the projections of the beach. These features obviously are not
visible at high tide.

In the area adjacent to Nauset Inlet, *Mesodesma arctatum* was abundant in the indentations between the offshore mounds and occasionally in the "channel" areas between the mounds and the shoreline. Appendix II-I indicates an example of this situation.

Time did not permit thorough examination of the sides of the inlet. The north side of the mouth was not examined at all, while the south side was dragged at the mouth, but no live specimens were collected. Nevertheless, there are probably extensive populations of *M. arctatum* in the channel and within the immediate harbor entrance.

As revealed by Appendix II-I, collections south of the inlet were at two locations about 10 meters apart. Sample A, used in the study of shell morphology, was collected by hand from a 1.6 by 6.6 meter area on the shore directly opposite an offshore mound. The mound was elliptical, being about 25 meters long and 15 meters wide at its maximum dimensions. It stood less than one meter above mean low water and was separated from the shore by a channel about five meters wide at low tide.

To check the accuracy of sample A, an area about 10 meters long on the northwest side of the offshore mound was dragged with the collecting rake on June 21, 1962. This collection, designated sample B, had a size distribution similar to that of sample A.

Sample C was collected, as shown in Appendix II-I, in
an indentation of the low water shoreline north of the harbor mouth. The floor of this "cove", covered by about a foot of water at mean low water, was nearly level and characterized by many ripple patterns. Six hundred thirty-three specimens were taken by hand from a 15 by 15 meter area in this place on June 22, 1962. The size distribution is shown in Appendix II-D. Note it is characterized by a large number of specimens over 35 mm long. This was one of the few times when such large specimens were recovered. Note also this was a clearly-defined bimodal population.

One interesting ecological aspect was noted. Many larger specimens (over 25 mm long) supported sizable growths of a green alga, probably Ulva, which were attached to the posterior ends of the animals. This had been previously noted on some specimens found in the Academy of Natural Sciences of Philadelphia and collected from Nauset Beach some years before. Attachment of the alga possibly indicates these specimens were subjected to some less turbulence and erosion. It also suggests that as the specimens get older and larger they tend to remain partially uncovered leaving the posterior edge sufficiently exposed to permit attachment by the alga.

On returning to this site on October 17, 1962, none of this population could be found. The topography of the area was unchanged, but the number of dead valves on the beach had decreased. This extensive change was probably caused by the passage of several severe storms in September.
and early October—excellent testimony that little is permanent in the area.

**Predation.** During the summer study each offshore mound was usually covered with gulls at low tide. Further study revealed that the gulls were predators on *M. arctatum*. During spring tides large tracts of these clams are either exposed or are in water so shallow that gulls can reach them. Many freshly-opened valve-pairs were found. Invariably, valves so found exhibited a chipped postero-ventral margin, an area where the valves are not as tightly closed.

In connection with this predation, many live specimens are carried to the high reaches of the beach, beyond the high water line. Assuming the gulls do not succeed in prying the valves open, the clams soon succumb from lack of natural environment, open their valves, and are quickly devoured. South of the inlet on the highest part of the beach, there were many shells showing evidence of gull predation. Here I found several cone-shaped depressions in the sand. At the bottom of each was a live specimen of *M. arctatum*. These animals were probably carried to this level by gulls and then driven into a pit as each gull tried to pick one open.

Evidence of predation by *Polinices* was also common. This is indicated by the valve samples described in Table 5. The same procedure was used as described in the discussion of Plum Island. The part played by gastropods, particularly *Polinices*, does not seem to be as large as in the Plum Island region. Possibly the more active role assumed by gulls has
TABLE 5. Predation samples from Cape Cod, Mass.

<table>
<thead>
<tr>
<th>Site</th>
<th>Total valves</th>
<th>Number valves bored</th>
<th>Species from gast. pres't predation</th>
<th>% Mort.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coll. from high water drift on 500 m of beach, 500 m north of Highland Light. 6/20/26.</td>
<td>127</td>
<td>11</td>
<td>64</td>
<td>17%</td>
</tr>
<tr>
<td>Coll. from one mile of Ballston Beach, near head of Pamet River. 6/21/62.</td>
<td>41</td>
<td>4</td>
<td>21</td>
<td>19%</td>
</tr>
<tr>
<td>Coll. from high water drift from Nat. Pk. Hqtrs. south to Nauset Inlet. 6/17/62.</td>
<td>187</td>
<td>26</td>
<td>94</td>
<td>27%</td>
</tr>
<tr>
<td>Coll. from beach above high water line at south side of Nauset Inlet. 6/18/62.</td>
<td>213</td>
<td>7</td>
<td>107</td>
<td>7%</td>
</tr>
</tbody>
</table>

Some bearing on this observation. This is certainly true of the collection from south of the inlet, which probably represented mostly gull predation.

Long Island

Occurrence and density. Examination of part of the south shore of Long Island in June 1962, did not produce any live specimens of Mesodesma. During this visit much of the beach from Montauk Point west to Shinnecock Inlet was covered. No shells were found near Montauk Point. Only after I reached the village of Montauk did valves appear. At the south shore of Hither Hills State Park valves of M. arctatum were abundant. Normally, M. arctatum is probably not an intertidal resident of the south beach of Long Island, but is confined to the adjacent offshore areas from which shells are cast up on the beach.

Predation. Using the procedures described, three samples of beach shells were analyzed for snail predation.
TABLE 6. Predation samples from Long Island, N.Y.

<table>
<thead>
<tr>
<th>Site</th>
<th>Total valves</th>
<th>Number valves bored</th>
<th>Specific mens from gast. predation</th>
<th>% Mort.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coll. from beach, sc. shore</td>
<td>198</td>
<td>17</td>
<td>99</td>
<td>17%</td>
</tr>
<tr>
<td>Hith. Hills St. Pk., area from bath house ½ mile west. 6/13/62.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coll. from high water drift near Georgica Pond Br'kw'r. East Hampton, L.I. 6/14/62.</td>
<td>121</td>
<td>14</td>
<td>61</td>
<td>23%</td>
</tr>
<tr>
<td>Coll. from eastern side of Shinnecock Inlet. 6/15/62.</td>
<td>67</td>
<td>9</td>
<td>34</td>
<td>26%</td>
</tr>
</tbody>
</table>

rates. The results are described in Table 6. These three samples show a surprising amount of uniformity considering the distance spanned. Nearly a quarter of the mortality of *Mesodesma* on Long Island shores may possibly result from predation by boring gastropods.

Nova Scotia

**Occurrence and density.** Several localities on the ocean side of southern Nova Scotia have yielded valves of *Mesodesma*. The clam is not common, however, and is probably more abundant on the offshore banks. In July 1962, several locations in Nova Scotia were visited to acquire additional ecological data. Areas studied were the outer beach on Cape Sable Island, Roseway Beach--Round Bay, Summerville Beach, and Crescent Beach, Lockport.

The outer coast is moderately indented with bays and harbors. Such areas often possess bayhead bars consisting of beaches of white sand at the inner reaches of these coastal indentations. Faribault (1914) described them as follows:
One of the remarkable features of the coast is the great number of beautiful white crescent-shaped sand beaches fringing the heads of coves and bays facing the broad Atlantic. The largest sand beaches are those of White Point, Summerville, Southwest Port Mouton, Little Joli Bay, Cadden Bay and Sandy Cove. They generally consist of sand bars enclosing salt water ponds and marshes, and on some of these the action of the wind has developed prominent sand dunes, those of Port Mouton being especially remarkable for their altitude and their glistening whiteness.

_Mesodesma arctatum_ has been collected from Port Mouton and Green Bay (see Appendix I), but it was not possible to visit these localities.

None of the sites visited produced live specimens. As a general rule, along Nova Scotian shores living specimens of _Mesodesma_ are probably confined to deeper waters offshore even though empty valves might be abundant on the beaches. _Mesodesma_ has never been reported from Crescent Beach, an area visited primarily to acquire additional sand samples.

The possibility of an offshore habitat was well-illustrated at Summerville Beach. At the northeast end of the beach dead valves of _Mesodesma arctatum_ were plentiful. A one meter quadrat yielded 516 valves. From past experience, the passage of a small river through the south end of the beach suggested an ideal habitat for this clam. However, a thorough search with the collecting rake at low tide turned up no living specimens. Apparently, the sand was too hard-packed to provide a satisfactory haven for a pelecypod possessing considerable burrowing ability. Unfortunately, no sand samples were taken at Summerville, but other similar beaches were sampled. One can possibly conclude that at some
place not too far offshore there is a suitable habitat for
the mollusk.

The valves collected were grayish-white, not unlike
the color of the intertidal section of the beach. Dead
valves from the outer shore of Cape Sable Island were whiter
although the two beaches looked very much alike.

The outer beach at Cape Sable Island showed the typ­
ical pattern of a barrier beach with low dunes backed by
marsh lands. In this instance the beach was segmented into
curving sections by frequent outcroppings of ledge and loose
rocks. Portions of the beach, at the half tide level and
lower, were covered with layers of marine peat.

Basically, the beach was similar to the hard-packed
one found at Summerville. However, below the mid-tide level
the fine, white sand was underlain with a much coarser grade
of sand. This material was searched extensively for Meso­
desma, but no specimens were found. Possibly, the coarse
lower layer indicated a Mesodesma habitat in deeper water
nearby, as only empty valves were found on the beach.

A few fragments of Mesodesma valves were recovered
in the Round Bay--Roseway Beach area. The beach was composed
of the same white sand found at Summerville and Cape Sable
Island.

Predation. Snail predation studies similar to those
at Plum Island and adjacent sites were undertaken on samples
from Summerville and Cape Sable Island. The results are
described in Table 7. The variability of these percentages
TABLE 7. Predation samples from Nova Scotia

<table>
<thead>
<tr>
<th>Site</th>
<th>Total valves</th>
<th>Number Specimens</th>
<th>% Holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coll. from 35 sq. m area above drift line near fish pk. plant on outer beach at Cape Sable Island. 7/12/62.</td>
<td>288</td>
<td>48</td>
<td>11/4</td>
</tr>
<tr>
<td>Coll. from 1/4 mile of high water drift near above sample. 7/12/62.</td>
<td>418</td>
<td>32</td>
<td>209</td>
</tr>
<tr>
<td>Coll. from one sq. meter in high water drift at Summersville Beach. 7/11/62.</td>
<td>516</td>
<td>15</td>
<td>258</td>
</tr>
</tbody>
</table>

suggest a comparatively low reliability (and also differences in the size of the predator populations at different sites). Nevertheless, gastropod predation probably plays a sizable role in the mortality of these clams.

Sand Particle-size Analysis

Although the ecological discussion of collecting areas is not complete and the consideration of the St. Lawrence Estuary will follow, a discussion of the study of particle-size analysis will be presented at this point, primarily because it is concerned with areas from Nova Scotia south. As will be seen later, the Quebec habitat is quite different.

After only brief association with the ecology of M. arctatum it was apparent that certain beaches met the ecological requirements of the animal; others did not. Usually, most areas (such as Plum Island) inhabited by this mollusk consisted of coarse sand which would not pack hard even when wet. When knowledge of the burrowing habits and behavior of the clam became available it seemed logical to
suspect that *Mesodesma* might tend to inhabit sandy bottoms sufficiently coarse to permit quick burrowing at all times. Areas such as Plum Island met this requirement very well.

A study was instituted which might indicate in a simple manner what substratum characteristics *Mesodesma* habitats had in common. A comparative particle-size analysis was considered the best approach. Basically, the method was to collect samples from various localities, wash and dry them, and then sift them into several particle-size classes for weighing. Each class could then be presented as a percentage of the total weight of the sample.

Sand samples were usually taken by means of a hard-rubber hand corer 30.5 cm long with an inside diameter of 2 cm. The volume of the coring tube was approximately 100 ml. One end of the tube was sharpened to reduce resistance, and the corer was fitted with a plunger. Samples were taken by slowly pushing the tube into the sand to its full length while withdrawing the plunger. The contents were quickly emptied into a container by pushing the plunger through the tube. Multiple samples from the same area were spaced at least 10 meters apart.

When returned to the laboratory, the samples were placed in aluminum trays and washed in running tap water to remove salt. When thoroughly dried they were run through five sorting screens of the Tyler Standard Screen Scale, U. S. Tyler Co., Cleveland, Ohio. Screens used were U. S. Series Equivalent No. 10, 1.981 mm mesh; U. S. Series Equivalent
No. 18, 1.0 mm mesh; U. S. Series Equivalent No. 35, 0.5 mm mesh; U. S. Series Equivalent No. 60, 0.246 mm mesh; and U. S. Series Equivalent No. 70, 0.210 mm mesh. This produced six particle-size classes (figures are approximate):

1. Larger than 2.0 mm
2. Between 2.0 mm and 1.0 mm
3. Between 1.0 mm and 0.5 mm
4. Between 0.5 mm and 0.25 mm
5. Between 0.25 mm and 0.21 mm
6. Smaller than 0.21 mm (pan).

The portion of each sample in each size-class was weighed, accurate to four decimal places, and then the percentages of total weight were computed for each sample.

The results are pictured on cumulative curves using the Wentworth scale. The principle of the Wentworth scale is essentially that each size-class shall be one-half the restrictive diameter of the previous class. This rule was followed except in the case of the last screen. Through an oversight a 0.210 mm screen was used instead of a 0.125 mm screen. Because most samples had relatively small amounts of fine material, there was little significant difference in the results. The 0.210 mm weight percentages were plotted although they are not indicated on the graphs.

Cumulative curves, well-suited to sedimentary work, are not unlike typical histograms except that each additional weight percentage is added to the previous portions of the sample and plotted immediately to the right of the preceding
portion. The method is particularly advantageous because it produces a continuous curve, allowing prediction of the percent weight of any particle-size, and because comparison of a substantial number of samples is permitted on one graph.

The curves in Fig. 15-17, represent averages of several samples. A list of the samples, under the title of the curve, can be found in Appendix III.

When the Wentworth scale is used, it is possible to define a well-sorted sample accurately. Ordinarily, a well-sorted sample is one in which most of the particles are within a narrow size range. By the Wentworth scale, it is customary to declare a sample (or beach) well-sorted if the curve traverses no more than one-half a Wentworth unit between the 25th and 75th percentile lines (the upper and lower dashed lines in the figures). A Wentworth unit is represented by the distance from the limit of one particle size-class to the limit of the next. Based on this criterion, Plum Island, Salisbury, and Rockport, Mass.; Shinnecock Inlet, L.I.; and Asbury Park, N.J. represent the only well-sorted beaches sampled.

Fig. 15, shows curves derived from samples taken at locations in Maine, New Hampshire, and northern Massachusetts. Living specimens of *M. arctatum* were found at all the sites named except Old Orchard, Maine.

Fig. 16, shows curves determined from samples taken on Cape Cod and Long Island. Living *M. arctatum* were collected only at south Nauset and north Nauset. Dead valves were found at Hither Hills and Shinnecock Inlet.
Figure 15. Comparison of sand samples from Maine, New Hampshire and No. Massachusetts.
Figure 16. Comparison of sand samples from Long Island and Cape Cod.
Figure 17. Comparison of sand samples from Nova Scotia, New Jersey and Massachusetts.
In Fig. 17, curves are shown representing locations where either little evidence or no evidence of Mesodesma was found. Dead valves were found on the beach only at Cape Sable Island. There are no records of this mollusk being found at the other locations on the graph.

Examination of these three graphs suggests a tentative conclusion: *Mesodesma arctatum* tends to be found, or at least is more abundant, in a substratum consisting of relatively well-sorted sand usually having a median particle diameter between 0.5 mm and 1.0 mm. The burrowing behavior of *M. arctatum*, previously described, is probably facilitated by such a substratum.

Quebec

Occurrence and density. For many years the St. Lawrence Estuary has been proclaimed the "home" of *Mesodesma deauratum* in the northwestern Atlantic. Although such statements are more poetic than accurate, there is little doubt that this bivalve is probably the most abundant pelecypod occupant in many parts of the area.

In July 1962, a series of locations were visited on the south shore of the estuary. Sites visited were Riviere Trois Pistoles (west side of the ferry slip), the east side of the mouth of the Métis River, below the seawall at Les Boules, the shoreline eight miles west of St. Ulric de Rivière Blanche, the beach just west of the town of Matane, and a portion of the shore at the western end of Petite
Matane. No evidence of *Mesodesma deauratum* was found at either Trois Pistoles or at the mouth of the Métis River even though the literature cites these as prominent locations for the mollusks. Possibly, the locations, being quite specific, were missed by only short distances.

Dead valves were found on the shore at Les Boules and also west of Matane. Only west of St. Ulric and at Petite Matane were living specimens found intertidally.

Within the area traversed, roughly from Riviere du Loup to Petite Matane, there were no beaches like those encountered on Plum Island, Cape Cod and Long Island. In fact, whenever the term "beach" was encountered in local terminology, it usually referred to a rock beach, consisting of a sloping shoreline of rocks occasionally as large as grapefruit. Under such conditions one would not expect to find intertidal populations of a clam thought to require a sandy environment. Nevertheless, at St. Ulric and Petite Matane dense populations of *Mesodesma deauratum* were found.

Appendix II-L and II-K present sketches of the two locations studied, indicating the collecting sites. These populations were found less than a meter below the high tide line in an area where the mean range of tides is 7.6 feet. Consequently, they were exposed much of the day and were covered with water perhaps for no more than four to six hours in a 24-hour period. Considering the possible icing conditions of winter and long days of summer, this represented quite a rigorous habitat. In addition, the substratum contained
little or no sand but was composed, instead, of a mixture of mud, rocks of all sizes, and dead valves of *Mesodesma* and *Mytilus*.

Only one sample of live specimens (C-4) was collected at the St. Ulric site. These animals were taken from a one square meter area within a tide pool less than a meter below the average high tide line. It was a dense population, the quadrat yielding 345 specimens. At Petite Matane three samples were taken, C-1 from an area approximately 1.6 by 6.6 meters and C-2 and C-3 from one square meter areas. Locations are indicated in Appendix II-L. Obviously, the density was extremely variable. C-1 produced 84 animals; C-2, 248; and C-3, 77.

At Petite Matane the mollusks were so plentiful that the high water drift consisted almost entirely of dead valves of *M. deauratum*. In an area below the drift line, where some live specimens were found, a one square foot area was dug to a depth of five centimeters for sorting and counting. The sample consisted of 402 whole valves and 503 fragments of *Mesodesma deauratum*. Areas of high density were often indicated by extensive accumulations of bleached dead valves on the upper part of the shore.

**Predation and other inter-species relationships.**

There was no evidence at any site of predation by boring gastropods. In its place the activity of another associated animal was clearly apparent—boring by the polychaete worm, *Polydora*. Fig. 18, shows evidence of this activity on shells
Figure 18. Left valves of *Mesodesma deauratum* from Quebec sites showing damage by *Polydora*. Left column from Petite Matane, right column from St. Ulric. 1/2x.
from Petite Matane and St. Ulric. Of the whole valves taken from the 30 by 30 cm area discussed above nearly one-half showed evidence of being subjected to Polydora activity.

Few animals probably succumb to this shell damage. For example, all the valves in Fig. 18, came from living specimens. Note that, as demonstrated in Fig. 18, the burrows usually start on the posterior end near the umbo and extend anteriorly. This probably is caused by the siphon end usually being uppermost and, therefore, more easily attacked. The worms primarily seem to be building burrows. As such, they usually penetrate lengthways within the valve and usually do not break into the mantle cavity. Occasionally one may blunder into the interior and then the mollusk may be in trouble from the increased chance that other predators or infectious agents can gain access to the soft parts.

No worms were found either on the valves or in the vicinity of the valves. However, Dr. Marian Pettibone, of the University of New Hampshire and the U. S. National Museum, examined some of the valves and believed that Polydora was the causative agent. It was not possible to determine the species involved.

Studies have indicated that different species of Polydora exhibit varying degrees of boring activity. Turner and Hanks (1959) noted the presence of "mud blisters" on the valves of Pecten irradians Lam. Hopkinson (1958) described the construction of mud tubes and the shallow burrowing in oyster valves by P. websteri Hartman in the Gulf of Mexico.
It would appear that the extent of burrowing in valves of *M. deauratum* may be more substantial than in the cases cited above.

**Habitat and speciation.** The fundamental question concerning the occurrence of different appearing animals in a different habitat resolves itself into a search for evidence as to whether the organisms are of a different species having different ecological requirements or whether they are of the same species with their differences largely attributable to the different environment. In any case, a pelecypod mollusk, either of the same species or of a closely related species, is found in dense aggregations in a mud-rock-shell substratum far above the mean low water line rather than in sandy areas below mean low water. Again the question is the same. Are *M. arctatum* and *M. deauratum* actually the same species or are there really two species involved?

Johnson (1925) stated that the shallow offshore areas from Bic to Matane were mostly covered with mud although there was a gradual changeover to sand as one approached Matane. Records indicate that *Mesodesma* occurs throughout this region. Are the littoral sites an extension of this muddy environment? Or are they a change from the sandy environment?

Shells in the National Museum of Canada collected near Forestville, P.Q., on the north side of the estuary also exhibit damage by *Polydora*. I have not visited the north shore; but, inasmuch as *Polydora* is a resident of muddy areas
and not sand beaches, possibly the north shore of the estuary also displays habitat conditions like those found at St. Ulric and Petite Matane.

Summary

In the discussion of shell morphology it was tentatively concluded that two species of Mesodesma exist in the northwestern Atlantic. That suggestion appears to be further substantiated by the detection of the different habitat in the St. Lawrence Estuary.

It is quite possible that the characteristic habitat of M. desuratum is a rock-mud-shell substratum extending from considerable depth into the high intertidal zone, and that the typical habitat of M. arctatum is a substratum of well-sorted sand having a median grain diameter between 0.5 mm and 1.0 mm reaching from deep water only into the low intertidal zone.
Methods of study. For the most part, efforts at determining the age of bivalve mollusks have involved the study of growth rings. Quayle (1952) noted that in those species exhibiting definite annual rings such an approach can be successful. Within species, the reliability of this method may vary from place to place. It is not known definitely whether this approach can be applied to Mesodesma or not. Both M. arctatum and M. deauratum usually possess several concentric ridges formed by interruptions or alterations in the growth rate, but similar-sized specimens frequently have different numbers of rings. For example, those specimens averaging 17 mm long may have one to five growth rings. While some of this may result from overlap among age classes, it seems most unlikely that this is the whole explanation. Thus, it is quite unlikely that each ring represents one year of growth.

Certain rings are often more prominent and could be age indicators, but only a thorough study of growth habits would determine the significance of the rings. The first step in such a study was to select a population which could be sampled frequently to determine the rate at which growth occurred. Site B on Plum Island was chosen as a desirable location.

The constant possibility of loss or depletion of the population by storm-caused erosion required that large numbers of individuals be used. Preliminary laboratory testing re-
revealed no available marking material suitable for numbering and lettering the shells that could withstand the abrasive action of the substratum. Subsequent fluctuation in the size of the population at the collection site emphasized the difficulties which would have been encountered had a marked population been used.

It was decided that it would be more desirable to maintain the natural population, sample it once a month, and return the sample to the habitat after taking measurements. Beginning in December 1961, and in the first part of nearly every month for the next 17 months, a sample was taken from the area with the collecting rake and measured on the measuring board shown in Fig. 19.

The specimen was passed down the measuring board until its maximum length prevented further movement. This was essentially the same length measurement used in the study of shell morphology. The animal's length was recorded to the nearest millimeter. For example, the interval representing 21 millimeters actually extended from approximately 20.50 to 21.49 mm.

Each sample was returned to the same place (site B) either immediately or on the following day (in the winter months measurements were taken in the laboratory). At no time did any specimens appear to have died before being returned to their natural habitat.

The size distributions are shown graphically in Fig. 20. Frequencies of each size class are expressed as percent-
Figure 19. Measuring board used in growth study.
ages of the total sample. Sample size varied from 20 individuals in December 1962, to 1381 animals in the sample of May 1962. The size of each sample is indicated on the graph. Because of severe winter conditions the February collection was omitted in both 1962 and 1963.

Observations. The first sample, taken in December 1961, was a small sample and showed no clear-cut mode. The next ten samples, however, were definitely unimodal. The first three, January, March, and April 1962, exhibited increases in modal length of one millimeter per month. This trend was interrupted in May 1962, by an influx of smaller specimens. This caused the mode to shift back two millimeters. In June 1962, a mode was apparent at 14 mm. This was an increase of two millimeters from the previous month but identical with the mode for April 1962. Between the June and July collections a five-millimeter increase in the mode occurred. At this time a wide band of periostracum, not apparent previously, appeared on many of the specimens, suggesting a period of intensive growth. August and September samples showed increases of only one millimeter.

The sample for October 1962, was taken after the passage of a severe ocean storm. Heavy rain had caused the Merrimack River to rise considerably. The appearance of the beach changed sufficiently to hinder location of the usual sampling site. Subsequent storms during the fall and early winter caused much fluctuation in sample size and prevented the detection of any definite growth sequence. The sample
for January 1963, with a mode of 15 mm, and the samples for March 1963, and April 1963, with two size classes of equal numbers, displayed little resemblance to the samples for the same months in 1962.

The population used in the growth study appeared to be unimodal. It may not have been, however, as a sizable year-class could exist below the minimum collecting limit of the rake—that is, a year-class with a mode at less than 8 mm. It is also possible that this population produced specimens larger than 34 mm, but these clams might be unable to maintain their position and were washed out to deeper and less disturbed waters.

Bimodal populations have been encountered at Plum Island (sample 5-11), Nauset (sample C and possibly sample B), and at St. Ulric (sample C-4). Among these samples the intermodal interval ranged from 13 to 17 mm. The Plum Island sample showed a 13 mm length difference between modes; the Nauset Beach sample C, 17; The Nauset Beach sample B, 13; and the St. Ulric sample C-4, 16. There is no geographical correlation among these interval differences. In fact, it is questionable if these are real differences. It is probable that ecological factors might slow or speed up the growth rate of a year-class sufficiently to produce variability of this magnitude.

Fifteen specimens were selected from the growth sample taken on July 18, 1962, for histological study of gonads. Fig. 21, shows some typical sections. Table 8 in-
TABLE 8. Sexual maturity and valve length in *Mesodesma arctatum*

<table>
<thead>
<tr>
<th>Sex</th>
<th>Length of valve</th>
<th>Gonad condition</th>
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<tbody>
<tr>
<td>Male</td>
<td>9 mm</td>
<td>sexually mature</td>
</tr>
<tr>
<td>Female</td>
<td>12 mm</td>
<td>&quot;</td>
</tr>
<tr>
<td>Female</td>
<td>13 mm</td>
<td>no mature eggs observed</td>
</tr>
<tr>
<td>Female</td>
<td>14 mm</td>
<td>sexually mature</td>
</tr>
<tr>
<td>Female</td>
<td>15 mm</td>
<td>&quot;</td>
</tr>
<tr>
<td>Male</td>
<td>17 mm</td>
<td>&quot;</td>
</tr>
<tr>
<td>Female</td>
<td>18 mm</td>
<td>&quot;</td>
</tr>
<tr>
<td>Female</td>
<td>19 mm</td>
<td>&quot;</td>
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<td>Male</td>
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<td>&quot;</td>
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<td>Male</td>
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<td>&quot;</td>
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<tr>
<td>Male</td>
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<td>Male</td>
<td>22 mm</td>
<td>&quot;</td>
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<tr>
<td>Female</td>
<td>28 mm</td>
<td>&quot;</td>
</tr>
<tr>
<td>Female</td>
<td>29 mm</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

dicates the length, sex, and gonadal condition of each specimen. With one exception, all appeared ready for breeding. Males were judged sexually mature when the gonad capsules contained well-developed sperm with their tails clustered in the center of the cavity. Females were judged mature when most of the ova were detached from the "follicle" wall and exhibited large nuclei, each containing a well-defined nucleolus, and with relatively little cytoplasm present.
Figure 21. Mature gonads of *Mesodesma arctatum*. 
Although no information has been found in the literature to substantiate these criteria for sexual maturity in the genus *Mesodesma*, several indirect sources of information have provided some support for the assumptions. First, I had observed voluntary discharge of eggs and sperm by *M. arctatum* from Plum Island in July 1961. Second, the eggs discharged at that time closely resembled those observed in the specimens used in this study. Third, although structurally quite different, ovaries and testes examined microscopically in sexually mature *Mytilus edulis* (they had been voluntarily discharging sperm and eggs) on several occasions closely resembled ovaries and testes found in *M. arctatum* in this study.

Fuji (1957) in a study of the growth and breeding season of the brackish-water bivalve, *Corbicula japonica*, noted that the greatest growth increment occurred in the few months prior to the breeding season. He attributed this to the rapidly rising water temperature and a corresponding increase in feeding rate and nutrition levels. *M. arctatum* at Plum Island also exhibited a large increase in growth rate in the month prior to the peak of the breeding season. Earlier in the season monthly increases in length averaged about one millimeter, but between mid-June and mid-July 1962, the increase (or movement of the mode) was by five millimeters. Possibly the same factors described by Fuji were at work at Plum Island.
SUMMARY

Description and taxonomy. Two species of Mesodesma occur in the northwestern Atlantic, *Mesodesma arctatum* (Conrad) and *Mesodesma deauratum* (Turton).

*M. arctatum*, considered the more southern form, is a bivalve mollusk possessing fairly thick, compressed valves. The anterior edge is extended, the posterior, sharply truncated making the beaks nearly terminal. The dorsal edge extends anteriorly in a nearly straight line. The ventral edge is rounded. Each valve possesses a large chondrophore. The left valve contains one slender cardinal tooth, and one posterior and one anterior lateral tooth. The right valve contains lateral grooves corresponding to the lateral teeth of the other valve, but no cardinal tooth. Both the lateral teeth of the left valve and the lateral grooves of the right valve have fine cross-striations. The recently-formed portion of the shell usually is covered externally with a golden-brown shining periostracum. Specimens seldom exceed 50 mm in length.

*M. deauratum*, probably confined to Canadian waters, differs from the southern form in that the posterior edge is less truncate, and the valves are less compressed. Less periostracum is usually found on valves of *M. deauratum*. Internal structure of the valves (dentition, etc.) is identical to that of *M. arctatum*.

*Mesodesma arctatum* was first described by Conrad in
1831, from shells collected in Massachusetts. *M. deauratum* was described by Turton in 1822, from valves found at Exmouth, England.

Initially included in the Mactridae by their discoverers, both species were soon moved to the newly-created genus *Mesodesma* (Deshayes 1831). In 1853, Forbes and Hanley announced that *Mactra deaurata*, originally described by Turton, was actually synonymous with *Mesodesma Jauresii* De Joannis 1834, found in the St. Lawrence Estuary. In fact, *Mesodesma* was not even a recent inhabitant of Britain. The shells found at Exmouth were probably carried from the New World in the ballast of fishing vessels.

Variation of shell truncation and compression has caused some authorities to doubt the validity of separating *Mesodesma arctatum* from *Mesodesma deauratum*.

**Distribution.** *Mesodesma arctatum* and *Mesodesma deauratum* are confined primarily to waters south of the Strait of Belle Isle. Along the St. Lawrence Estuary shells are found as far west as Tadoussac on the north side and Trois Pistoles on the south shore. Specimens also have been recovered from the Baie des Chaleurs, Magdalen Islands, the Cape Gaspé region and the New Brunswick banks. *Mesodesma* also inhabits the Grand Bank and the banks along the southeast coast of Nova Scotia, where inshore populations can also be found.

Few specimens are found on the Maine coast, but they are abundant along the New Hampshire and Massachusetts shores northeast of Boston. Some are found on the south shore and
in Massachusetts Bay, but they occur in greater abundance on the outer coast of Cape Cod. Offshore populations have been detected near Nantucket, Martha's Vineyard, and off the south shore of Long Island. Occasional specimens have also appeared on the beaches of New Jersey.

Recent dredgings along the edge of the Continental Shelf have revealed shells of *Mesodesma arctatum* as far south as Cape Hatteras. Some of these newly discovered valves and other valves previously collected on Long Island and Sable Island exhibit colors ranging from red to black, not unlike the coloration frequently found on shells in Pleistocene deposits. Possibly the colored valves from Long Island, Sable Island, and the Continental Shelf were from submerged Pleistocene deposits.

**Morphology.** The morphology of *M. arctatum* and *M. deauratum* was approached from two directions—comparative shell measurements and description of soft parts. For comparative shell measurements, samples were taken at four sites; St. Ulric, P.Q.; Petite Matane, P.Q.; Plum Island, Mass.; and Nauset Beach, Mass. Measurements indicated the length, height, width of valve and the portion of the length posterior to the umbo perpendicular (P-value). Comparison of length and height showed little difference between samples from Quebec and Massachusetts. Comparison of length and P-value and length and width showed considerable difference. The latter two comparisons serve as evidence for the existence of two species.
Study of soft-part anatomy of *M. arctatum* and *M. deauratum* revealed virtually no difference between northern and southern forms. Even minor characters such as the shape of the adductor muscles, the ventral mantle ridge, the number of incurrent siphon papillae, and the mantle attachment in the region of the palps showed little variety in specimens examined from each locality. I have been unable to distinguish between the species on the basis of internal structures.

**Ecology.** *M. arctatum* is typically found in sand at the low water line and sub-tidally. Plum Island, near Newburyport, Massachusetts, was studied as a typical habitat. Nearly 50 sand samples from many locations were analyzed to determine whether other sandy habitats containing specimens of *Mesodesma* showed similar particle composition. For this study samples from New Jersey to Nova Scotia were sorted into particle-size classes. Generally, substrata containing living *Mesodesma arctatum* were well-sorted and had a median particle diameter between 0.5 mm and 1.0 mm. This type of sand is usually sufficiently porous to facilitate burrowing behavior such as exhibited by *M. arctatum*.

Along the St. Lawrence a different habitat was discovered for *Mesodesma deauratum* consisting of mud, shells, and rocks. Dense populations were found some distance above mean low water. Possibly, this odd habitat may further substantiate the contention that two separate, valid species of *Mesodesma* are found in the northwestern Atlantic.

Studies of predation on *Mesodesma arctatum* by gastro-
pods, particularly *Polinices heros*, indicated six to sixty-eight per cent of total mortality may be caused by these snails. Shell damage on *Mesodesma deauratum* by the burrowing polychaete, *Polydora*, was detected in the St. Lawrence Estuary.

**Growth.** Although *M. arctatum* possesses several growth rings or ridges, the number varies in shells of the same size. Thus it appears unlikely that all rings represent annual growth increments. A study of a population at Plum Island for over a year indicated that growth increases often were about one millimeter per month except from mid-June to mid-July when the population mode moved up by five millimeters. Histological studies indicated that this is just prior to the breeding season.


117


Muller, T. 1836. Mesodesma Desh., p. 221. In Synopsis novorum generum, specierum et varietatum testaceorum viventium anno 1834 promulgatorum, etc. adjunctis iis quae diariis societatis zoologicae. Londinensis, Berolini.


Packard, A. S., Jr. 1863. A list of animals dredged near Caribou Island, Southern Labrador, during July and August, 1860. Canadian Nat. and Geol. (s. 1.)8:401-429.


---------- 1891. The Labrador Coast: A journal of two summer cruises to that region. N. D. C. Hodges, N. Y. 513 p.


------------- 1871. Report on a deep sea dredging expedition to the Gulf of St. Lawrence. Report to the Minister of Marine and Fisheries [Canada]:1-12.


APPENDIX I

THE DISTRIBUTION OF *Mesodesma* ON THE EAST COAST OF NORTH AMERICA, BASED ON MUSEUM COLLECTIONS AND FIELD WORK

BY THE AUTHOR

Latitude and longitude readings enclosed in parentheses represent the author's approximations. Others are from the original notations. Museum lots having no geographical location are listed separately. Lots having a designation of only the province or state concerned are placed at the end of the list for that province or state. Abbreviations: USNM=U.S. National Museum; MCZ=Museum of Comparative Zoology, Harvard University; ANSP=Academy of Natural Sciences of Philadelphia; AMNH=American Museum of Natural History, N.Y.C.; NMC=National Museum of Canada, Ottawa; GR=Station de Biologie Marine of Grande Riviere, P.Q.; PC=personal collection of the author; H.W.=high water; L.W.=low water; Int.=intertidal; M.=Mesodesma; C.=Coronia.

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<th>General Location</th>
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<th>Ident. No.</th>
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<th>Position</th>
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<td>Fortoau Bay</td>
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<td>USNM600999</td>
<td>6/25/48</td>
<td>51 23</td>
<td>D.C. Nutt</td>
<td>Tide pool on bedrock granite-Blue Dolphin Exp Dredge-sand, Blue Col.</td>
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<td>(Strait of Belle Isle)</td>
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<td></td>
<td>56 54</td>
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<td>Labrador</td>
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<td>MCZ- ------</td>
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<td></td>
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<td><em>C. arctica</em></td>
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<td>49 49 30</td>
<td>USFC Sta. 2440 Fine white sand USFC</td>
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<td>Quebec:</td>
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<td>Gulf of St. Lawrence</td>
<td><em>C. deaurata</em></td>
<td>USNM1728</td>
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<td>Whiteaves Jeff. Collection</td>
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<td>50 17</td>
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<td>Amory and Bourman</td>
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### APPENDIX I (cont.)

#### THE DISTRIBUTION OF *MESODESMA* ON THE EAST COAST OF NORTH AMERICA

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<th>Data Collected</th>
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<td>USNM405256</td>
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<tr>
<td>Baie-Comeau</td>
<td><em>M. arctata</em></td>
<td>GR-Sta. 01</td>
<td>5/11/52 (69 14 60 10)</td>
<td></td>
<td>Adolphe Roy</td>
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<td>Off Ste Anne de Portneuf, Sag. Co.</td>
<td><em>M. arctata</em></td>
<td>NMC11416</td>
<td>7/13/60 (69 03)</td>
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<td>A.H. Clarke, Jr.</td>
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<td>Seven Islands</td>
<td><em>M. arctata</em></td>
<td>MCGZ8965</td>
<td>5/23 (70 23)</td>
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<td>George</td>
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<td>Trois listoles</td>
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<td>Little Métis</td>
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<td>Métis</td>
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<td>MCGZ11330</td>
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<td>4/13/59 (65 44)</td>
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<td>St. Ulric, 8 mi SW of cathedral</td>
<td><em>M. deauratum</em></td>
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<td>7/5/62 (67 52)</td>
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<td>Matane, SW side</td>
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<td>7/2/62 (67 51)</td>
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<td>Petite Matane</td>
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<td>1/4/62 (64 28)</td>
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<td>Mont-Louis</td>
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<td>MCGZ12401</td>
<td>6/1931 (67 41)</td>
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<td>PC</td>
<td>8/12/58 (64 13)</td>
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<td>Mouth of Gaspe Bay (So. of Cape Gaspe)</td>
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<td>GR-Sta.</td>
<td>7/15/59 (64 11 33)</td>
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<td>8/14/56 (61 40)</td>
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*Note: Data Collected formats vary, indicating the year and position (latitude, longitude) of each collection point.*
### APPENDIX I (cont.)

THE DISTRIBUTION OF *MESODESMA* ON THE EAST COAST OF NORTH AMERICA

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<td>(46 20 62 16)</td>
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# APPENDIX I (cont.)

## THE DISTRIBUTION OF *MESODESMA* ON THE EAST COAST OF NORTH AMERICA

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<th>General Location</th>
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<th>Ident. No.</th>
<th>Date</th>
<th>Position</th>
<th>Collector</th>
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**Notes:**
- Acc. indicates accession number.
- Ex. indicates extraction number.
- Col. indicates collector.
- Other Information includes additional data such as location or collector's notes.
### APPENDIX I (cont.)

**THE DISTRIBUTION OF MESODESMA ON THE EAST COAST OF NORTH AMERICA**

<table>
<thead>
<tr>
<th>General Location</th>
<th>Name</th>
<th>Assign.</th>
<th>Ident.</th>
<th>No.</th>
<th>Date</th>
<th>Position</th>
<th>Collector</th>
<th>Other Information</th>
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*Note: The table continues with similar entries for other locations along the east coast of North America.*
## APPENDIX I (cont.)

**GENERAL LOCATION**

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<td>Cast on beach, near</td>
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<tr>
<td>Pleasant Bay, Chatham</td>
<td>C. arctata</td>
<td>USNM674381</td>
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<td>&quot;</td>
<td>D. V. Taylor</td>
<td>Moxes Pond</td>
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<td>M. arctatum</td>
<td>MCZ219887</td>
<td></td>
<td>(41 14)</td>
<td>D. V. Taylor</td>
<td>Post-Tert. Fossil?</td>
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<td>Sagatky Hh.</td>
<td>M. arctatum</td>
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<td>(41 17)</td>
<td>(41 58)</td>
<td>S. H. Scudder</td>
<td>Cisco, Cast on beach at</td>
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<tr>
<td>Island</td>
<td></td>
<td>MCZ219861</td>
<td>7/7/63</td>
<td>(41 40)</td>
<td>J. A. Cushin</td>
<td>Moxes Pond</td>
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<td>Muskeget Channel</td>
<td>M. arctatum</td>
<td>MCZ227735</td>
<td>8/2/65</td>
<td>(41 20)</td>
<td>J. A. Cushin</td>
<td>Bet. Nant. &amp; X. Vin. USFC Sta. 64/2</td>
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<td>Narragansett Bay</td>
<td>C. arctatum</td>
<td>ANSP65581</td>
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<td>(41 30)</td>
<td>Dr. Wilson</td>
<td>65581-581 also here.</td>
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<td>Newport</td>
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<td>(41 48)</td>
<td>J. R. Miller</td>
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<td>ANSP50931</td>
<td></td>
<td></td>
<td>Dr. Wilson</td>
<td></td>
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<td>USNM362393</td>
<td>6/13/62</td>
<td>(41 01)</td>
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<td>Dead valves</td>
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<td>Hith. Hills St. Pk.</td>
<td>H. arctatum</td>
<td>MCZ2113319</td>
<td>(41 00)</td>
<td>(71 02)</td>
<td>J. D. Davis</td>
<td>Ex. Peab. Mus. Salem</td>
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<td>M. arctatum</td>
<td>MCZ235109</td>
<td>6/11/62</td>
<td>(41 56)</td>
<td>Smith</td>
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<td>&quot;</td>
<td>H. arctatum</td>
<td>MCZ235109</td>
<td>6/15/62</td>
<td>(41 52)</td>
<td>J. D. Davis</td>
<td>D. valves, at Georgeia Pk.</td>
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<td>MCZ79008</td>
<td>7/3/60</td>
<td>(41 47)</td>
<td>P. H. Brown</td>
<td>E. side Shinn. Inlet</td>
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<td>Southhampton, L.I.</td>
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<td>Bate. W. Hampton &amp; Inqogue</td>
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### General Location

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<th>Coll'nr</th>
<th>Other Information</th>
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<td>(40 38)</td>
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<td>6/2/62</td>
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<td>74 00</td>
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<td>2/18/13</td>
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<td>66 50</td>
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**Note:** All locations are on the East Coast of North America.
## APPENDIX I (cont.)

### THE DISTRIBUTION OF MESODESMA ON THE EAST COAST OF NORTH AMERICA

<table>
<thead>
<tr>
<th>General Location</th>
<th>Name Asgn.</th>
<th>Ident. No.</th>
<th>Date</th>
<th>Position</th>
<th>Coll'r</th>
<th>Other Information</th>
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<tr>
<td>M. arctatum Sta.2 Tow 4</td>
<td></td>
<td></td>
<td>5/13/60</td>
<td>39 47.8 72 07.3</td>
<td>Merrill</td>
<td>60 fms mud, sand &amp; shell</td>
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<td>M. arctatum Sta.3-2 Alt.40</td>
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<td>5/20/60</td>
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<td>5/14/60</td>
<td>39 19.0 73 18.1</td>
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<td>30 fms sand &amp; shell</td>
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<td>M. arctatum Sta.3 Tow 3</td>
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<td>5/19/60</td>
<td>39 08.8 73 08.4</td>
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<td>40 fms mud &amp; sand</td>
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<td>M. arctatum Sta.3 Tow 5</td>
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<td>80 fms</td>
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<td>M. arctatum Sta.5 Tow 1</td>
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<td>37 50.6 74 51.1</td>
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<td>M. arctatum Sta.5 Tow 3</td>
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<td>5/16/60</td>
<td>37 24.3 74 38.5</td>
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<td>35 fms small shell</td>
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<td>M. arctatum Sta.5-6 Alt.4</td>
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<td>20 fms sand &amp; shell</td>
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<td>M. arctatum Sta.6-5 Alt.16,16A</td>
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<td>5/17/60</td>
<td>36 59.4 74 56.7</td>
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<td>24 fms coarse sand</td>
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<td>36 55.0 74 59.1</td>
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<td>20 fms sand &amp; shell</td>
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<td>36 50.7 75 04.9</td>
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<td>16 fms &quot;sm. stone &amp; sh.</td>
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<tr>
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<td>36 55.0 74 59.1</td>
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<td>36 50.7 75 04.9</td>
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<td>16 fms &quot;sm. stone &amp; sh.</td>
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<tr>
<td>M. arctatum Sta.6-7 Alt.10</td>
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<td>5/17/60</td>
<td>35 32.8 74 57.9</td>
<td></td>
<td>24 fms shell</td>
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</table>

*Note: M. arctatum refers to the species Mesodesma arctatum.*
APPENDIX I (cont.)

THE DISTRIBUTION OF MESODESMA
ON THE EAST COAST OF NORTH AMERICA

Samples Insufficiently Labeled to Include in the Distribution List


ANSP50932 (no name assigned) Swift Collection.


USNM44959 Ceronia arctica USFC Sta. 2259.

USNM27036 Mesodesma arctica (Con.) Totten.
APPENDIX II

A. Size distribution of sample 5-11, Plum Island, Mass.


APPENDIX II (cont.)

E. Size distribution of sample C-1, Petite Matane, P.Q..

F. Size distribution of sample C-2, Petite Matane, P.Q.
G. Size distribution of sample C-3, Petite Matane, P.Q..

H. Size distribution of sample C-4, St. Ulric, P.Q.
I. Sketch of collecting area, Nauset Bch. Cape Cod, Mass.
APPENDIX II (cont.)

J. Sketch of collecting area, Plum Island, Newburyport, Mass. Letters = Collecting sites, Numbers = Salinity study sites.
APPENDIX II (cont.)

8 Miles to St. Ulric Cathedral

Approximate Mean
High Water Line

Approximate Mean
Low Water Line

50 Feet
(Approx.)

ROUTE 6

Sample C-4

K. Sketch of collecting area, St. Ulric, P.Q.
APPENDIX II (cont.)

L. Sketch of collecting area, Petite Matane, P.Q.
APPENDIX III

SAND SAMPLES USED IN PARTICLE-SIZE ANALYSIS

Grouped Under Titles of Their Respective Curves in Fig. 15-17

Plum Island: Three samples. Ocean side of Plum Island, Mass., directly in front of parking lot in village, north side of jetty, in area six meters long, at low water, 3:30 PM, 10/19/61.
Three samples. Plum Island at river mouth, at site of growth study sampling, 12/29/61.

Three samples. Salisbury Beach State Park, ocean side of breakwater, at low water, near parking lot, 3/16/62.

Seabrook, N.H.: Four samples. Mouth of Hampton River, nearly beneath highway bridge, low water, 2/16/62.


Old Orchard, Maine: Three samples. Low water, north side of mouth of Goose Fair Brook, 4/21/62.

Montauk Pt., L.I.: Two samples. South side, corner of Air Force Reservation, low tide, 11:00 AM, 6/12/62.

APPENDIX III (cont.)

SAND SAMPLES USED IN PARTICLE-SIZE ANALYSIS

Shinnecock Inlet, L.I.: Two samples. Southampton, L. I., east side of inlet on outer shore, low tide, noon, 6/15/62.

South Nauset, Mass.: One sample. Nauset Beach, Orleans, Cape Cod, Mass., south of inlet mouth, low water, 8:00 AM, site of sample A, 6/18/62.

One sample. Nauset Beach, Orleans, inside of south side of inlet mouth, 6/18/62.

Two samples. Nauset Beach, Orleans, site of sample A as before, taken by hand—not by corer, 5:00 PM, 6/18/62.

North Nauset, Mass.: Three samples. Nauset Beach, Eastham, Cape Cod, Mass., outer beach north of inlet, site of sample C, 10:00 AM, low water, 6/22/62.

Monmouth Beach, N.J.: Two samples. Beach near Ocean Blvd. and Valentine St., mid-tide, 4/6/62.

Asbury Park, N.J.: Two samples. Beach at foot of 3rd Avenue, mid-tide, 4/6/62.


Rockport, Mass.: Two samples. Long Beach, Gloucester—Rockport, Mass., south end of beach, mid-tide, 2:00 PM, 5/5/62.

APPENDIX III (cont.)

SAND SAMPLES USED IN PARTICLE-SIZE ANALYSIS

Cape Sable I., N.S.: Three samples. Cape Sable Island, Nova Scotia, outer beach near fish packing plant, beyond Clark's Harbor, mid-tide level, noon, 7/14/62.

One sample. Same location as above, in area above high water level, noon, 7/14/62.