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DISTRIBUTION OF PELECYPODS AND GASTROPODS IN THE BAY OF FUNDY AND EASTERN GULF OF MAINE

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One hundred and thirteen molluscan species (63 pelecypods, 49 gastropods, and one scaphopod) have been identified from the Bay of Fundy and eastern Gulf of Maine at depths between 27 and 256 m. Ten faunal groupings of mappable areal extent (biotopes) are recognizable. The biotopes are related to substrate type (units described by Fader et al. 1977) and to depth. The total areal distribution, depth, and substrate preferences of the index species are noted. The biotopes of greatest areal extent have as their index species *Astarte undata* Gould, *Cerastoderma pinnulatum* (Conrad), *Astarte subaequilatera* Sowerby, and *Cyclocardia borealis* (Conrad) respectively. The index species *Nuculana pernula* (Müller), *Yoldia myalis* (Courthouy), and *Yoldiella inconspicua* Verrill and Bush are deposit feeders indicative of fine-grained substrates and generally quiet waters. The other index species are suspension feeders, a type normally associated with coarse sediments and stronger currents.

Introduction

In recent years, scientists from the Atlantic Geoscience Centre have conducted cruises to the Bay of Fundy and eastern Gulf of Maine. G.B. Fader and L.H. King, in 1971 and 1973, were interested in the physical setting of the area and used echogram profiles supplemented by bottom samples to identify and trace the extent of the various sedimentary units (Fader et al. 1977). Their Van Veen grab sample stations were located on the basis of echogram characteristics and/or where morphology of the sea floor suggested a change in sediment type. The sampling program of G. Vilks and F.J.E. Wagner in 1975 was confined to the immediate approaches of the Bay of Fundy and to the bay itself. One of the objectives of this cruise was a study of the distribution of foraminiferal and molluscan faunas in the area.

The purpose of this paper is to synthesize the molluscan species distribution data derived from the 1971, 1973, and 1975 cruises to the Bay of Fundy and the eastern part of the Gulf of Maine and to investigate the relationship of the faunal associations to water depth and substrate type in the 27 m to 256 m depth range. Ninety-eight species (52 pelecypods, 45 gastropods, and one scaphopod) were recognized previously and presence/absence data for these forms were analyzed using Q-mode cluster analysis (Wagner 1977). The data used in this analysis resulted in the definition of nine biotopes at the 0.2 level of similarity.

Marine Geology

Sedimentary units on the Scotian Shelf were informally named by King (1970). Subsequently, 5 of these units were traced into the Gulf of Maine and the Bay of Fundy (Fader et al. 1977) (Fig 1). Scotian Shelf drift was the name applied to material deposited by the Pleistocene glaciers. It consists of a poorly sorted mixture of clay- to sand-sized particles with angular pebbles, cobbles, and boulders. This unit, presenting a rough and undulating surface, forms a narrow zone bearing in a general southerly direction across the western part of the Bay of Fundy and the eastern part of the Gulf of Maine. The sediment surface has been modified by modern currents in the inner Bay of Fundy and at the entrance to the bay. In part contemporaneous

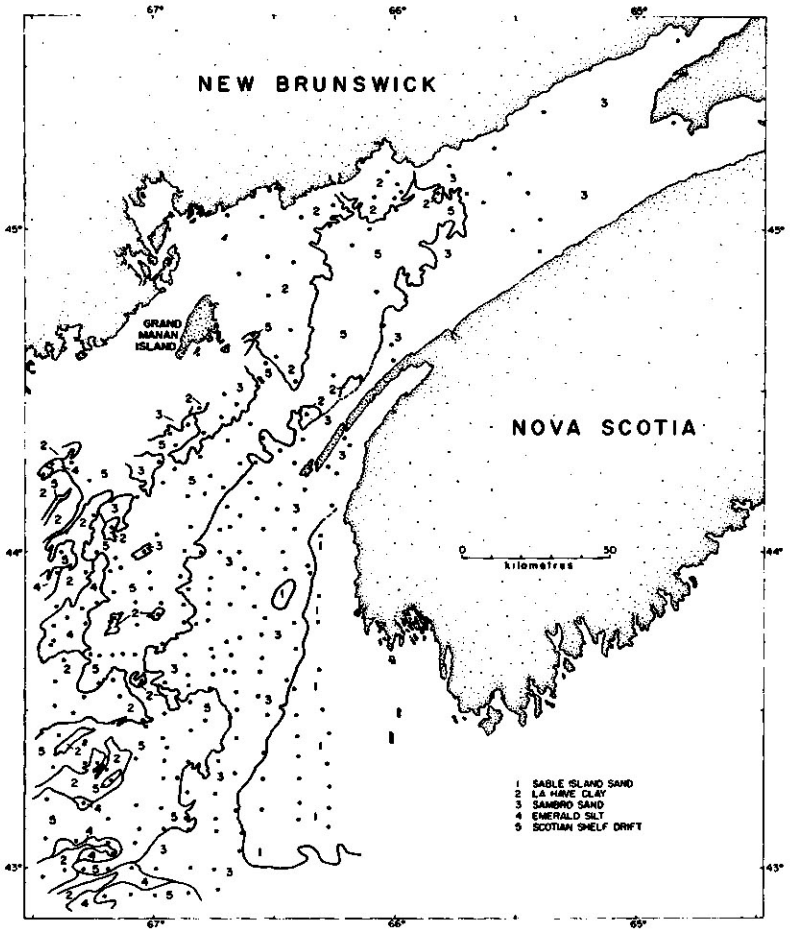

Fig 1. Sedimentary units in the Bay of Fundy and eastern Gulf of Maine (after Fader et al 1977).

with the drift is a deposit of proglacial clayey and sandy silt, the Emerald silt. This unit, which in places occupies pockets in the drift and elsewhere interfingers with it, is confined to the outer Gulf of Maine. The Sambro sand in part overlies the Scotian Shelf drift and is in part a lateral equivalent of the Emerald silt. It is found at depths below about 120 m on the Scotian Shelf but extends into shallower depths in the Gulf of Maine and the Bay of Fundy. The sand is fine- to coarse-grained and forms a firm surface. Locally there may be more than 10% gravel. It is of widespread occurrence in the eastern Gulf of Maine and in the eastern Bay of Fundy. The LaHave clay overlies the Scotian Shelf drift and Emerald silt and is generally contemporaneous with the Sable Island sand and gravel. The clay is common in the western part of the map-area where it is present in isolated depressions over the surface of the drift. In the Bay of Fundy, the sizeable area of LaHave clay east and northeast of Grand Manan Island coincides generally with an area of relatively low current velocities. The Sable Island sand and gravel unit varies from predominantly medium- to coarse-grained, well sorted sand to predominantly coarse gravel with well rounded boulders. It occurs along the eastern margin of the Gulf of Maine at depths less than 90 m.

Methods

As stated previously, 9 associations (biotopes) had been determined using cluster analysis based on presence/absence data (Wagner 1977). However, this method did not take into account the abundance of some species and the scarcity of others. The study also did not consider whether or not the individuals were actually living at the site of collection or if their presence there was the result of passive transport. In this regard the state of preservation of individual pelecypods and gastropods can be very informative. If the soft parts are present the individual was probably living at the site of collection. Lacking the soft parts, the shell itself can be used to determine whether or not the specimen was in situ. Intact pelecypod shells and fresh appearing gastropod shells (i.e. shells showing their original shiny surface or, for those species with a periostracum having the periostracum still adhering to the shell) have probably not been moved from the place where these organisms were living. The same may be said for disarticulated, but otherwise well preserved, pelecypod valves. Badly eroded shells and fragments suggest working of the deposit and possible transport of the shell material. Severe erosion of a shell is manifested in various ways. An ornamented shell may be largely or completely smoothed while a thick shell could be much reduced in thickness and a thin one partly destroyed.

The indicator assemblages established in the present study are based on the following criteria for each species: 1) the relative abundance of the species at each locality at which it is present, 2) whether or not the species was in situ or had been transported, and 3) the number of stations at which the species was found. To estimate the total number of specimens in a sample, and to determine the relative abundance of each species, a weighted value was given to each specimen as follows. A complete, in situ specimen was given a value of 1.0, a single pelecypod valve or a slightly to moderately worn gastropod received a value of 0.5, and a fragment was given a value of 0.1. These weighted values were then converted to percentages.

The change in census method, in conjunction with the extended areal coverage and greater number of species involved, has resulted in a change in the number of associations to 10 from the previously designated 9. Some of the assemblages correspond to those reported previously (Wagner 1977), whereas others differ significantly. In the present study only 1 species is designated as an index species for an assemblage; in the former study an index assemblage was used to define the respective biotopes. Criteria for the selection of an index species in this study are that it be present at 80%, or more, of the stations of the biotope for which it is index species and that, usually, it is the most abundant in situ species at each locality at which it occurs within the biotope. The term 'biotope' is used because the areas are based on assemblages that are, primarily, in situ rather than being based on a collection of specimens assembled after death (i.e. a taphotope). In those instances in which the most abundant species at a station is not the index form, the index species is generally present and along with other species comprise an association that can be related to a particular biotope. In the few cases where no index species was present, the stations were assigned to a biotope on a 'best fit' basis, using geographic proximity and subordinate species association criteria. Geographic distribution of the biotopes is shown in Figure 2. Table I is a complete list of species and the biotope(s) in which each species occurs.

Results and Discussion

A total of 220 additional stations have been added to the original 38 occupied in 1975. At 68 of these the grab sampler came up empty. A further 26 samples were

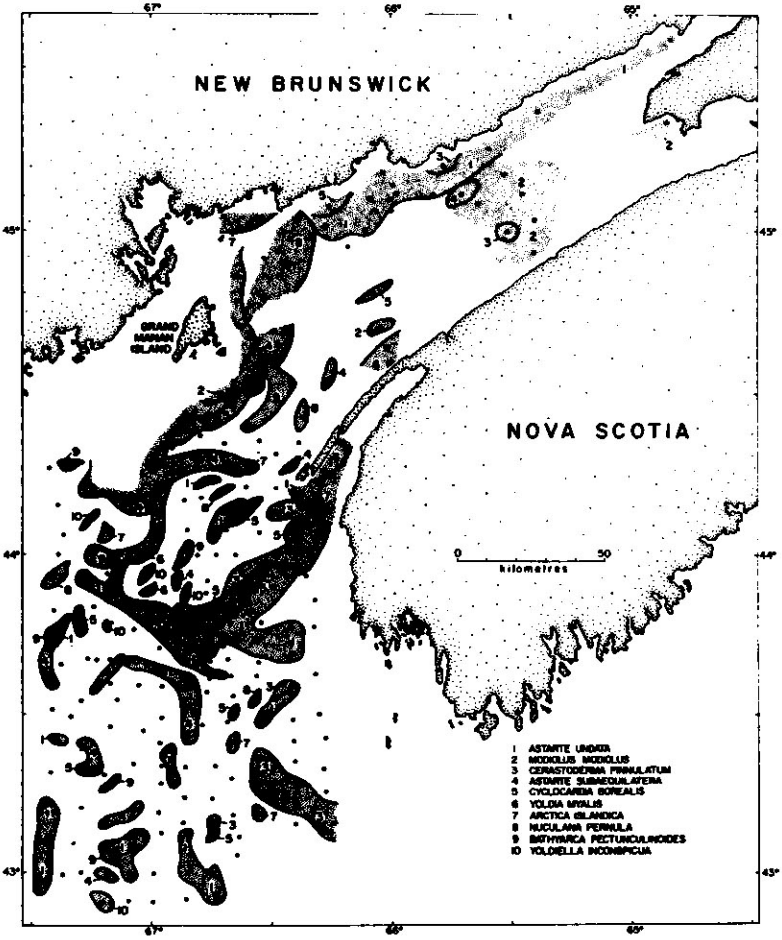

Fig 2.
Areal distribution of biotopes in the Bay of Fundy and eastern Gulf of Maine (Barren areas and areas yielding only unidentifiable fragments are unshaded).

lacking molluscs or yielded only unidentifiable fragments (Fig 2). The additional coverage has increased the number of species identified by 11 pelecypods and 4 gastropods for a total of 113 species (Appendix). Only shelled gastropods were encountered in the samples.

BIOTOPES

The 10 biotopes are defined in the following terms. An index species is designated based on the criteria outlined previously and used to establish the geographic distribution and number of biotopes. Then the common species, i.e. those having a frequency of 20%, or more of the stations in the biotope, are determined as are species apparently restricted to the biotope. The typical depth range and preferred substrate for each biotope are determined on the basis of the occurrence of in situ specimens of the index species. Table I lists all species identified and indicates in which biotope(s) each species occurs. Common species and restricted species for each biotope may be determined from this table. Index species, depth range, and typical substrate for each biotope are listed in Table II.

BIOTOPE I. Biotope 1 is ubiquitous in terms of water depth and ranges between 33 and 243 m. Two main occurrences are along the north shore of the Bay of Fundy and across the central part of the eastern Gulf of Maine. Depth range in the former area is between 33 and 93 m and in the latter area between 78 and 212 m. Other ex-

Table I Percentage occurrence of species in terms of the number of stations at which the species occurs in a particular biotope/the total number of stations in that biotope. Index species occurrences are in italics.

BIOTOPE	1	2	3	4	5	6	7	8	9	10
NUMBER OF STATIONS	53	8	19	26	17	7	8	9	11	5
Astarte subaequilatera Sowerby	6	25	16	*88*	35	43	13	22	45	40
Astarte undata Gould	*91*	63	42	23	24	-	13	22	18	20
Bathyarca pectunculinoides (Scacchi)	15	-	-	27	12	14	-	22	*91*	40
Yoldiella inconspicua Verrill and Bush	2	-	-	4	-	-	-	11	9	*80*
Placopecten magellanicus (Gmelin)	25	13	63	19	29	29	13	11	9	-
Anomia squamula Linné	23	63	21	23	18	14	13	-	9	-
Anomia simplex d'Orbigny	19	-	21	19	18	-	13	11	45	-
Nuculana pernula (Müller)	19	38	5	15	6	-	13	*88*	9	-
Hiatella arctica (Linné)	8	75	32	4	12	14	-	-	9	-
Periploma fragile (Totten)	4	-	-	-	-	14	13	22	9	-
Chlamys islandica (Müller)	15	38	21	19	18	-	-	-	9	-
Puncturella noachina (Linné)	98	38	16	12	12	-	-	-	9	-
Nucula tenuis (Montagu)	8	-	5	12	-	-	-	22	9	-
Epitonium greenlandicum (Perry)	4	13	11	8	-	-	-	11	18	-
Astarte striata (Leach)	2	-	-	-	-	-	13	-	18	-
Oenopota declivis (Lovén)	8	-	-	12	18	-	-	-	9	-
Turbonilla interrupta (Totten)	2	-	-	8	6	-	-	-	9	-
Palliolum imbrifer (Lovén)	4	-	5	4	-	-	-	-	9	-
Neptunea decemcostata (Say)	6	-	11	-	-	-	-	-	9	-
Cerastoderma pinnulatum (Conrad)	26	63	95	15	18	43	13	11	-	-
Cyclocardia borealis (Conrad)	25	50	53	27	*88*	43	13	11	-	-
Natica clausa Broderip and Sowerby	8	-	-	4	6	14	-	11	-	-
Thyasira gouldii (Philippi)	2	38	5	-	-	-	13	11	-	-
Axinopsida orbiculata (Sars)	2	-	-	-	-	14	-	11	-	-
Colus pubescens (Verrill)	2	-	-	4	-	-	13	22	-	-
Palliolum striatum (Müller)	8	13	21	-	-	-	-	11	-	-
Yoldia myalis (Couthouy)	6	38	32	4	6	86	13	-	-	-
Crenella glandula Totten	4	38	11	8	6	14	13	-	-	-

BIOTOPE	1	2	3	4	5	6	7	8	9	10
NUMBER OF STATIONS	53	8	19	26	17	7	8	9	11	5
Propebela turricula (Montagu)	4	25	5	4	-	14	25	-	-	-
Pandora gouldiana Dall	2	-	5	-	-	14	25	-	-	-
Cylichna alba Brown	2	-	-	4	6	-	13	-	-	-
Arctica islandica (Linné)	9	-	15	-	-	43	*100*	-	-	-
Nassarius trivittatus (Say)	2	-	-	-	-	14	13	-	-	-
Lunatia pallida (Broderip and Sowerby)	6	13	11	-	-	14	13	-	-	-
Ensis directus (Conrad)	2	-	-	-	-	-	13	-	-	-
Modiolus modiolus (Linné)	8	*100*	16	8	18	29	-	-	-	-
Tellina agilis Stimpson	4	-	-	-	6	14	-	-	-	-
Clinocardium ciliatum (Fabricius)	6	-	-	-	-	14	-	-	-	-
Velutina velutina (Müller)	6	38	11	-	6	-	-	-	-	-
Crenella decussata (Montagu)	2	-	5	8	6	-	-	-	-	-
Mya arenaria Linné	2	-	5	-	6	-	-	-	-	-
Astarte castanea (Say)	2	-	-	-	6	-	-	-	-	-
Tachyrhynchus erosus (Couthouy)	2	-	11	12	-	-	-	-	-	-
Crucibulum striatum (Say)	2	-	11	4	-	-	-	-	-	-
Nuculana minuta (Fabricius)	2	-	-	4	-	-	-	-	-	-
Retusa obtusa (Montagu)	2	-	-	8	-	-	-	-	-	-
Crassostrea virginica (Gmelin)	2	25	5	-	-	-	-	-	-	-
Margarites costalis (Gould)	2	-	16	-	-	-	-	-	-	-
Mercenaria mercenaria (Linné)	2	-	5	-	-	-	-	-	-	-
Spisula polynyma (Stimpson)	2	-	5	-	-	-	-	-	-	-
Mya truncata Linné	4	-	5	-	-	-	-	-	-	-
Buccinum sp.	4	-	11	-	-	-	-	-	-	-
Liocyma fluctuosa (Gould)	2	-	5	-	-	-	-	-	-	-
Astarte borealis Schumacher	2	-	-	-	-	-	-	-	-	-
Macoma sp.	2	-	-	-	-	-	-	-	-	-
Mesodesma arctatum (Conrad)	2	-	-	-	-	-	-	-	-	-
Musculus niger (Gray)	2	-	-	-	-	-	-	-	-	-
Thyasira flexuosa (Montagu)	2	-	-	-	-	-	-	-	-	-
Yoldiella frigida (Torell)	2	-	-	-	-	-	-	-	-	-
Buccinum undatum Linné	-	13	-	-	-	-	13	11	-	-
Delectopecten vitreus (Gmelin)	-	13	-	-	-	-	-	11	-	-
Littorina littorea Linné	-	13	-	-	-	14	-	-	-	-

BIOTOPE	1	2	3	4	5	6	7	8	9	10
NUMBER OF STATIONS	53	8	19	26	17	7	8	9	11	5
Trichotropis borealis Broderip and Sowerby	-	13	5	8	12	-	-	-	-	-
Crenella faba (Müller)	-	13	-	-	6	-	-	-	-	-
Turritellopsis acicula (Stimpson)	-	13	-	4	-	-	-	-	-	-
Panomya arctica (Lamarck)	-	13	5	-	-	-	-	-	-	-
Acirsa costulata (Mighels and Adams)	-	25	-	-	-	-	-	-	-	-
Anachis avara (Say)	-	13	-	-	-	-	-	-	-	-
Macoma calcarea (Gmelin)	-	38	-	-	-	-	-	-	-	-
Moelleria costulata (Möller)	-	25	-	-	-	-	-	-	-	-
						-	-	-	-	-
Yoldia limatula (Say)	-	13	-	-	-	-	-	-	-	-
Thracia septentrionalis Jeffreys	-	-	11	-	6	-	-	-	-	-
Alvania janmayeni (Friele)	-	-	5	-	-	-	-	-	-	-
Cingula aculeus (Gould)	-	-	5	-	-	-	-	-	-	-
Colus pygmaeus (Gould)	-	-	5	-	-	-	-	-	-	-
Dacrydium vitreum (Holböll)	-	-	5	-	-	-	-	-	-	-
Limopsis minuta (Philippi)	-	-	5	-	-	-	-	-	-	-
Lischkeia ottoi (Philippi)	-	-	5	-	-	-	-	-	-	-
Neptunea despecta (Linné)	-	-	5	-	-	-	-	-	-	-
Oenopota harpularia (Couthouy)	-	-	5	-	-	-	-	-	-	-
Skeneopsis planorbis (Fabricius)	-	-	5	-	-	-	-	-	-	-
Spisula solidissima (Dillwyn)	-	-	5	-	-	-	-	-	-	-
Propebela cancellata (Mighels and Adams)	-	-	-	4	-	-	-	-	9	-
Colus spitzbergensis (Reeve)	-	-	-	4	-	43	-	11	-	-
Alvania carinata Mighels and Adams	-	-	-	4	-	14	13	-	-	-
Yoldia sapotilla (Gould)	-	-	-	4	-	-	13	-	-	
Admete couthouyi (Jay)	-	-	-	4	-					-
Calliostoma occidentale (Mighels and Adams)	-	-	-	4	-	-	-	-	-	-
Cyclopecten pustulosus Verrill)	-	-	-	4	-	-	-	-	-	-
Lepeta caeca (Müller)	-	-	-	4						
Limacina lesueurii (d'Orbigny)	-	-	-	4	-	-	-	-	-	
Margarites groenlandicus (Gmelin)	-	-	-	4	-	-	-	-	-	

BIOTOPE	1	2	3	4	5	6	7	8	9	10
NUMBER OF STATIONS	53	8	19	26	17	7	8	9	11	5
Megayoldia thraciaeformis (Storer)	-	-	-	4		-	-	-	-	-
Palliolum subimbrifer (Verrill and Bush)	-	-	-	4		-	-	-	-	-
Scaphander punctostriatus Mighels	-	-	-	4		-	-	-	-	-
Solariella varicosa (Mighels and Adams)	-	-	-	4		-	-	-	-	-
Boreotrophon clathratus (Linné)	-	-	-	-		-	-	-	-	-
Buccinum ciliatum (Fabricius)	-	-	-	-	6	-	-	-	-	-
Musculus discors (Linné)	-	-	-	-	12	-	-	-	-	-
Colus stimpsoni (Mörch)	-	-	-	-	-	14	13	-	-	-
Lunatia triseriata (Say)	-	-	-	-	-	14	-	11	-	20
Aporrhais occidentalis (Beck)	-	-	-	-	-	14	-	-	-	-
Nucula proxima Say	-	-	-	-	-	14	-	-	-	-
Nuculana messanensis (Seguenza) ?	-	-	-	-	-	14	-	-	-	-
Pandora inornata (Verrill and Bush)	-	-	-	-	-	14	-	-	-	-
Thyasira equalis (Verrill and Bush)	-	-	-	-	-	14	-	-	-	-
Velutina undata Brown	-	-	-	-	-	14	-	-	-	-
Nucula delphinodonta Mighels and Adams	-	-	-	-	-	-	13	-	-	20
Haminoea solitaria (Say)	-	-	-	-	-	-	13	-	-	-
Hydrobia totteni Morrison	-	-	-	-	-	-	13	-	-	-
Lucinoma filosa (Stimpson)	-	-	-	-	-	-	13	-	-	-
Lyonsia hyalina (Conrad)	-	-	-	-	-	-	13	-	-	-
Solariella obscura (Couthouy)	-	-	-	-	-	-	13	-	-	-
Yoldiella fraterna (Verrill and Bush)	-	-	-	-	-	-	-	-	-	60

Table II. Depth and substrate relationships of the molluscan biotopes.

BIOTOPE	INDEX SPECIES	DEPTH* RANGE "A"	DEPTH** RANGE "B"	SUBSTRATE
1	*Astarte undata*	33-243m	33-243m	Scotian Shelf drift, Sambro sand
2	*Modiolus modiolus*	64-73m	27-73m	Sambro sand
3	*Cerastoderma pinnulatum*	34-128m	34-137m	Sambro sand
4	*Astarte subaequilatera*	79-223m	55-223m	Scotian Shelf drift
5	*Cyclocardia borealis*	60-174m	60-230m	Sambro sand
6	*Yoldia myalis*	33-156m	33-165m	Sambro sand
7	*Arctica islandica*	31-40m	29-40m	Sambro sand, La Have clay
8	*Nuculana pernula*	62-241m	62-241m	La Have clay
9	*Bathyarca pectunculinoides*	190-232m	134-245m	Scotian Shelf drift
10	*Yoldiella inconspicua*	148-192m	148-256m	Scotian Shelf drift, La Have clay, Sambro sand

* DEPTH RANGE "A" - Depth range for the biotope based on occurrences of complete specimens of the index species

** DEPTH RANGE "B" - Depth range for the biotope including occurrences of single valves of the index species

pressions of this biotope in the Gulf of Maine are patchy; the greatest depth observed was 243 m. The majority of the 53 stations included in Biotope 1 were divided about equally between the Scotian Shelf drift and the Sambro sand substrates. The index species, *Astarte undata* was identified from 29 stations other than those of Biotope 1, being present in all biotopes except Biotope 6. The depth range observed for in situ specimens of 33 to 243 m indicates a downward extension of range for *A. undata* from the range of 9 to 190 m derived from the literature (references marked with an asterisk). *Astarte's* prefer a coarse, often gravelly substrate in areas of moderate water movement. They burrow shallowly so that the inhalent and exhalent apertures at the posterior tip of the shell project a few millimetres above the surface of the substrate. The buried animals have been observed to emerge at night and crawl on the sediment surface, but the reason for this behavior is unknown (Stanley 1970). *A. undata* favors the Scotian Shelf drift and the Sambro sand substrate, although a few complete individuals were collected also from the Emerald silt, the LaHave clay, and the Sable Island sand and gravel. The 5 restricted species (Table I) in this biotope were present at only 1 station each.

BIOTOPE 2. This biotope is relatively restricted; it occurs over a depth range of 27 to 73 m and is associated with the Sambro sand. Although this biotope includes only 8 stations, it contains 18 species that are present in 20% of the stations. However, many of these are common in other biotopes as well. Three of the common species are restricted to the biotope. The biotope occurs in the central and upper parts of the Bay of Fundy. A single-station occurrence at a depth of 141 m south of Grand Manan Island was characterized by disarticulated, but unabraded, valves of the index species, *Modiolus modiolus,* plus numerous fragments of *M. modiolus.* Although *M. modiolus* was the most abundant constituent at this station, the assemblage could possibly have been assigned to another biotope.

In addition to being present at the 8 stations of Biotope 2, *M. modiolus* was found at 14 other stations distributed among Biotopes 1, 3, 4, 5 and 6. Literature records suggest a depth range for *M. modiolus* between low water and 280 m. Complete specimens were found in the study area at depths between 27 and 180 m with the majority no deeper than about 90 m. *M. modiolus* is a common cold-water mussel. It attaches on rocky shores, but at greater depths and on soft substrates it forms part of the infaunal benthos. The species is gregarious and is found typically in groups of from 30 to 40 individuals occupying a one-half square meter area (Stanley 1970). All but two occurrences of complete specimens of this suspension-feeder were in the Sambro sand.

BIOTOPE 3. The major occurrences of Biotope 3 are in the eastern part of the Gulf of Maine. A northern occurrence of this biotope has a general depth range between 34 and 106 m with 2 stations at 137 m. At these latter 2 stations only single valves of the index species, *Cerastoderma pinnulatum,* were recovered (this may indicate a borderline situation). A southern expression of this biotope occurs within a depth range of 57 to 128 m. Two single-station occurrences in the central Bay of Fundy were at depths of 62 and 70 m. The substrate for these 2 stations, as well as for the northern group of stations in the Gulf of Maine, is the Sambro sand. The southern group of Gulf of Maine stations are in the Sable Island sand.

Cerastoderma pinnulatum was found at 31 stations other than those of Biotope 3 and in all biotopes except Biotopes 9 and 10. Depth range for the species according to the literature is between 0 and 110 m. In the study area in situ specimens were found as deep as about 140 m and these were usually associated with a sand substrate. This is in keeping with its function as a suspension feeder. Most occurrences were in the Sambro sand with the Sable Island sand second in importance.

BIOTOPE 4. This biotope has a relatively patchy distribution and is best expressed in the western part of the Bay of Fundy with 1 station in the central part of the bay. Several other areas occur in the Gulf of Maine. The shallowest occurrence is at 55 m, but most occurrences of the biotope usually fall within the 110 to 223 m range. This biotope is typically associated with the Scotian Shelf drift, although there are several occurrences on the LaHave clay and Sambro sand and one on the Emerald silt.

The index species, *Astarte subaequilatera,* was present at 88% of the stations of Biotope 4 as well as at 25 stations distributed fairly equally among the other 9 biotopes. Substrate does not appear to be critical for this species. The Scotian Shelf drift was most favorable, but the species was also common in the Sambro sand and the LaHave clay. The species was found at depths between 30 and 230 m in the study area; elsewhere it is known from depths as great as 780 m. This species is similar in life style to *A. undata.*

BIOTOPE 5. Biotope 5 also shows a comparatively heterogeneous distribution. All but 2 localities are in the Gulf of Maine. The strongest expression of this biotope is in an area adjacent to Biotope 4 south of Grand Manan Island. The inclusion of

presumably untransported single-valve occurrences of the index species would give a tentative lower limit of range for this biotope of 230 m compared to 174 m based on in situ specimens of the index species. This biotope is strongly associated with the Sambro sand.

Cyclocardia borealis, the index species, also a suspension feeder, was present at 88% of the stations in Biotope 5 and at 39 stations in other biotopes. It is associated with Biotopes 1, 2, 3, 4, 6, 7, and 8 as well as with 5. The depth range for this species in the study area is between 30 and 180 m although most specimens were collected from depths less than 90 m. This accords well with the low water to 90 m cited in the literature (references marked with an asterisk). The species favors sand substrate and the majority of occurrences in the study area were in the Sambro sand followed by the Sable Island sand and LaHave clay. It is usually found in areas of moderately strong currents (Stanley 1970).

BIOTOPE 6. The chief expression of this biotope is in the south-western Bay of Fundy area. Two single-station occurrences have been identified in the Gulf of Maine at depths of 156 and 165 m. The depth range for the Bay of Fundy stations is between 33 and 156 m, with 4 of these 5 stations less than 85 m. The biotope is usually associated with the Sambro sand.

The index species, *Yoldia myalis,* also occurs in biotopes other than Biotope 6 (see Table I). Complete specimens were collected over a depth range of 30 to 160 m with most coming from depths of less than 90 m. This is in agreement with previous studies (references marked with an asterisk). *Y. myalis* was found almost exclusively in the Sambro sand. The species is a deposit feeder. When buried, proboscidial feeding takes place completely beneath the sediment surface. It can also move quite actively on the sediment surface (Stanley 1970).

BIOTOPE 7. This is a shallow-water biotope of restricted depth range. It is recognized in the southern approaches to the Bay of Fundy (depth 31 - 33 m) and off the New Brunswick coast north of Grand Manan Island (29-40 m). Four isolated occurrences in the Gulf of Maine were at depths between 82 and 212 m. Three of these were based on fragmentary evidence and the fourth on a single, small, complete specimen that may have been adventitious. In each case, however, the strongest association, based on other criteria, appears to be with Biotope 7. The stations in the entrance to the Bay of Fundy were associated with the Sambro sand and those off the New Brunswick coast with the LaHave clay.

Arctica islandica, index species for the biotope, was identified from only 9 stations in other biotopes. Complete specimens were recorded from Biotopes 1 and 6, and fragments only from Biotope 3. Occurrences of this species were divided equally between the Sambro sand and the LaHave clay. Nicol (1951) gives a depth range of between 10 and 280 m for the species. In the study area, complete specimens were found at depths down to 156 m. In New England waters, *A. islandica* is harvested as a moderately important source of sea food (Jacobson & Emerson 1971).

BIOTOPE 8. This biotope is found, primarily, northeast of Grand Manan Island adjacent to the New Brunswick coast at depths between 62 and 133 m. An isolated occurrence was identified in the entrance to the Bay of Fundy (depth 166 m) and 4 such occurrences were noted in the Gulf of Maine between 102 and 241 m. The biotope is associated primarily with the LaHave clay.

The index species, *Nuculana pernula,* was found at 19% of the stations in Biotope 1, 15% in Biotope 4 and 5%, 6%, 12%, and 9% respectively in Biotopes 3, 5, 7, and 9. In Biotope 8, it was present at 88 of the stations. The majority of in situ occurrences were in the LaHave clay with the Scotian Shelf drift being secondary in importance. Complete specimens were found over a range of 20 to 250 m in the study area, a considerable extension over the literature record of 25 to 60 m. *N. per-*

nula's association with a fine-grained substrate is consistent with its role as a deposit feeder (Stanley 1970).

BIOTOPE 9. The 2 major expressions of this biotope are in the Gulf of Maine southeast and southwest of Grand Manan Island and there are several isolated occurrences elsewhere in the Gulf of Maine. This biotope is indicative of relatively deep waters; the observed depth range is between 134 and 245 m. Most stations comprising the biotope were associated with the Scotian Shelf drift.

The index species, *Bathyarca pectunculinoides,* was present at 90% of the stations of Biotope 9. It was also represented in Biotopes 1, 4, 5, 6, 8 and 10. The preferred substrate appears to be the Scotian Shelf drift, a substrate that provides suitable support for this bysally attached species. Four occurrences of in situ specimens were also noted in the LaHave clay. The species was found at depths between 60 and 240 m, well within its recorded range of 9 to 1400 m (references marked with an asterisk).

BIOTOPE 10. Although this biotope is represented by only 5 isolated occurrences, the abundance of *Yoldiella inconspicua* at four of these sites and its rarity in other biotopes, corroborates the validity of distinguishing this faunal association as a biotope. The fifth station is assigned to Biotope 10 because of the presence of *Yoldiella fraterna. Y. fraterna,* a species unique to the biotope, was present at 60% of the stations. All occurrences of Biotope 10 are in the Gulf of Maine and its depth ranges between 148 and 256 m. Most stations were associated with the Scotian Shelf drift, with 1 each in the Sambro sand and the LaHave clay.

Yoldiella inconspicua was present also in Biotopes 1, 4, 8, and 9. In the study area complete specimens were collected from depths between 140 and 230 m which is in agreement with previous observations. *Y. inconspicua* is a minute form having a maximum length of 3 mm. As a member of the Superfamily Nuculacea it is probably a deposit feeder.

Summary and Conclusions

The Bay of Fundy—eastern Gulf of Maine area supports an extensive and varied molluscan fauna composed of at least 63 species of pelecypods and 49 species of gastropods. Ten biotopes have been defined and an index species has been designated for each. The salient features of each biotope are outlined in Table II.

Single valves of pelecypods, if unabraded, were probably in situ where collected. Therefore, their use is valid in determining the depth range of the biotopes. Reference to Table II shows that, in general, the depth range for most biotopes is not altered by the addition of single-valve-only occurrences. Only for Biotopes 5 and 10 is there an appreciable extension of the lower limit. In the case of Biotope 5 the lower limit based on complete shells represents a considerable extension of the lower limit of the index species, *Cyclocardia borealis.* For stations with only single valves of *C. borealis* similarity of assemblages was also considered in assigning them to Biotope 5. Thus, the lower limit of 230 m would seem to be valid for this biotope. The lower limit of 256 m for Biotope 10 is well within the depth range of the index species.

As a rule, deposit feeders are most abundant in fine-grained sediments in quiet waters and suspension feeders are characteristic of coarse-grained sediments under more agitated conditions and also of hard substrates (Stanley 1970). In the Bay of Fundy—Gulf of Maine area the biotopes and their index species, for the most part, conform to this pattern.

In conclusion, analysis of the molluscan faunas indicates 10 biotopes, each characterized by an index species and a distinctive suite of accessory species. Each biotope is a mappable entity (Fig 2) with definite depth range and substrate relation-

ships. The 7 biotopes with index species that are suspension feeders are associated primarily with coarse and/or hard substrates and areas of pronounced current action. Those biotopes characterized by deposit feeding index species relate, in general, to finer sediments and quieter waters.

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* Key reference for faunal reference list and for depth ranges of index species.

Appendix: Faunal Reference List

Gastropoda

Acirsa costulata (Mighels and Adams)—Morris, 1973, pl. 44, fig. 6
= *Turritella costulata* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 50, pl. 4, fig. 20.

Admete couthouyi (Jay)—Abbott, 1974, p. 248, fig. 2705
= *Cancellaria couthouyi* Jay, 1839, A catalogue of shells in the collection of John C. Jay, M.D., with descriptions, edition 3, p. 77.

Alvania carinata Mighels and Adams—Morris, 1973, p. 136, pl. 38, fig. 13
= *A. carinata* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 49.

Alvania janmayeni (Friele)—Macpherson, 1971, p. 38, pl. 2, fig. 11
= *Rissoa Jan Mayeni* Friele, 1878, Nyt. Mag. f. Naturvid., vol. 24, no. 3, p. 224, pl. 1, figs. 4a, b.

Anachis avara (Say)—Abbott, 1974, p. 195, fig. 2049
= *Columbella avara* Say, 1822, Jour. Acad. Nat. Sci., Philadelphia, vol. 2, p. 230.

Aporrhais occidentalis (Beck)—Abbott, 1974, p. 143, fig. 1576
= *Rostellaria occidentalis* Beck, 1836, Mag. de Zool., vol. 6, classe 5, pl. 72 and text.
Boreotrophon clathratus (Linné)—Abbott, 1974, p. 189, fig. 1971
= *Murex clathratus* Linné, 1767, Syst. Nat., ed. 12, vol. 1, p. 1223.
Buccinum ciliatum (Fabricius)—MacGinitie, 1959, p. 113, pl. 10, figs. 8, 9.
= *Tritonium ciliatum* Fabricius, 1780, Fauna Gron., p. 401.
Buccinum undatum Linné—Abbott, 1974, p. 203, fig. 2188
= *B. undatum* Linné, 1758, Syst. Nat., ed. 10, p. 740.
Calliostoma occidentale (Mighels and Adams)—Abbott, 1974, p. 42, fig. 305
= *Trochus occidentalis* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 47.
Cingula aculeus (Gould)—Abbott, 1974, p. 74, fig. 652
= *Rissoa aculeus* Gould, 1841, Rept. Invert. Massachusetts, ed. 1, p. 266.
Colus pubescens (Verrill)—Abbott, 1974, p. 208, fig. 2284
= *Sipho pubescens* Verrill, 1882, Trans. Connecticut Acad., vol. 5, p. 501, pl. 43, fig. 6, pl. 57, fig. 25.
Colus pygmaeus (Gould)—Abbott, 1974, p. 209, fig. 2286
= *Sipho pygmaeus* Gould, 1841, Rept. Invert. Massachusetts, ed. 1, p. 284.
Colus spitzbergensis (Reeve)—Abbott, 1974, p. 209, fig. 2288
= *Fusus spitzbergensis* Reeve, 1855, *in* Belcher, Last of the Arctic voyages 2, Appendix, p. 395, pl. 32, fig. 6.
Colus stimpsoni (Mörch)—Abbott, 1974, p. 208, fig. 2283
= *Fusus stimpsoni* Mörch, 1867, Vid. Medd. Natur. Foren., p. 83.
Crucibulum striatum (Say)—Abbott, 1974, p. 140, fig. 1548
= *Calyptraea striatum* Say, 1826, Jour. Acad. Nat. Sci., Philadelphia, vol. 5, p.216.
Cylichna alba Brown—Morris, 1973, p. 269, pl. 73, fig. 7
= *C. alba* Brown, 1827, Illustr. Conch. Great Britain, p. 3, pl. 19, figs. 43, 44.
Epitonium greenlandicum (Perry)—Abbott, 1974, p. 121, fig. 1247
= *Scalaria greenlandica* Perry, 1811, Conchology, app., pl. 28, fig. 8.
Haminoea solitaria (Say)—Abbott, 1974, p. 320, fig. 4017
= *Bulla solitaria* Say, 1822, Jour. Acad. Nat. Sci., Philadelphia, vol. 2, p. 245.
Hydrobia totteni Morrison—Abbott, 1974, p. 79, fig. 716
= *H. totteni* Morrison, 1954 (previously known as *H. minuta)*
Lepeta caeca (Müller)—Abbott, 1974, p. 34, fig. 186
= *Patella caeca* Müller, 1776, Zoologicae, Danicae prodromus, p. 237.
Limacina lesueurii (d'Orbigny)—Abbott, 1974, p. 324, fig. 4045
= *Atlanta lesueurii* d'Orbigny, 1836, Voyage ed Amérique méridionale, vol. 5, p. 177, pl. 20, figs. 12-15.
Lischkeia ottoi (Philippi)—Abbott, 1974, p. 39, fig. 265
= *Trochus ottoi* Philippi, 1844, Enum. Moll. Siciliae, vol. 2, p. 227, pl. xxviii, fig. 9.
Littorina littorea Linné—Abbott, 1974, p. 67, fig. 549
= *L. littorea* Linné, 1758, Syst. Nat., ed. 10, p. 761.
Lunatia pallida (Broderip and Sowerby)—Abbott, 1974, p. 156, fig. 1693
= *Natica pallida* Broderip and Sowerby, 1829, Zool. Jour., vol. 4, pt. 15, p. 372.
Lunatia triseriata (Say)—Abbott, 1974, p. 156, fig. 1691
= *Natica triseriata* Say, 1826, Jour. Nat. Sci., Philadelphia, vol. 5, p. 209.
Margarites costalis (Gould)—Abbott, 1974, p. 36, fig. 212
= *Trochus costalis* Gould, 1841, Rept. Invert. Massachusetts, p. 252.
Margarites groenlandicus (Gmelin)—Abbott, 1974, p. 36, fig. 215
= *Trochus groenlandicus* Gmelin, 1791, Syst. Nat., ed. 13, p. 3574.

Moelleria costulata (Möller)—Abbott, 1974, p. 61, fig. 501
= *Margarita costulata* Möller, 1842, Naturhist, Tidsskrift., ser. 1, vol. 4, p. 81.
Nassarius trivittatus (Say)—Abbott, 1974, p. 224, fig. 2459
= *Nassa trivittata* Say, 1822, Jour. Acad. Nat. Sci., Philadelphia, vol. 2, p. 231.
Natica clausa Broderip and Sowerby—Abbott, 1974, p. 159, fig. 1718
= *N. clausa* Broderip and Sowerby, 1829, Zool. Jour., pt. 15, p. 372.
Neptunea decemcostata (Say)—Abbott, 1974, p. 213, Color pl. 12, fig. 2354
= *Fusus decemcostatus* Say, 1826, Jour. Acad. Nat. Sci., Philadelphia, vol. 5, p. 214.
Neptunea despecta (Linné)—Abbott, 1974, p. 213, fig. 2359
= *Murex despectus* Linné, 1758, Syst. Nat., ed. 10, p. 754.
Oenopota declivis (Lovén)—Macpherson, 1971, p. 115, pl. 7, fig. 10
= *Tritonium declive* Lovén, 1846, Kongl, Svenska Vetensk-Akad. Forhandl., vol. 3, p. 13.
Oenopota harpularia (Couthouy)—Abbott, 1974, p. 286, fig. 3386
= *Fusus harpularia* Couthouy, 1838, Boston Jour. Nat. Hist., vol. 2, pt. 1, p. 106, pl. 1, fig. 10.
Propebela cancellata (Mighels and Adams)—Abbott, 1974, p. 284, fig. 3316
= *Fusus cancellatus* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 52, pl. 4, fig. 18.
Propebela turricula (Montagu)—Abbott, 1974, p. 284, fig. 3315
= *Murex turricula* Montagu, 1803, Testacea Britannica, ed. 1, vol. 2, p. 262, pl. 9, fig. 1.
Puncturella noachina (Linné)—Abbott, 1974, p. 22, fig. 57
= *Patella noachina* Linné, 1771, Mantissa plantarum altera generum editionis VI et specierum editionis II. Addendum, p. 551.
Retusa obtusa (Montagu)—Abbott, 1974, p. 321, fig. 4024
= *Bulla obtusa* Montagu, 1808, Testacea Britannica, vol. 1, p. 223.
Scaphander punctostriatus Mighels—Abbott, 1974, p. 315, fig. 3954
= *S. punctostriatus* Mighels, 1841, Proc. Boston Soc. Nat. Hist., vol. 1, p. 49.
Skeneopsis planorbis (Fabricius)—Abbott, 1974, p. 81, fig. 735
= *Helix* (?) *planorbis* Fabricius, 1780, Fauna Groenlandica, p. 394.
Solariella obscura (Couthouy)—Abbott, 1974, p. 40, fig. 271
= *Turbo obscurus* Couthouy, 1838, Boston Jour. Nat. Hist., vol. 2, no. 1, p. 100, pl. 3, fig. 12.
Solariella varicosa (Mighels and Adams)—Abbott, 1974, p. 41, fig. 276
= *Margarita varicosa* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 46.
Tachyrhynchus erosus (Couthouy)—Abbott, 1974, p. 94, fig. 896
= *Turritella erosa* Couthouy, 1838, Boston Jour. Nat. Hist., vol. 2, no. 1, p. 103, pl. 3, fig. 1.
Trichotropis borealis Broderip and Sowerby—Abbott, 1974, p. 138, fig. 1518
= *T. borealis* Broderip and Sowerby, 1829, Zool. Jour., vol. 4, pt. 15, p. 375.
Turbonilla interrupta (Totten)—Abbott, 1974, p. 305, fig. 3754
= *Turritella interrupta* Totten, 1835, Amer. Jour. Sci., 1st ser., vol. 28, p. 352.
Turritellopsis acicula (Stimpson)—Richards, 1962, p. 77, pl. 15, fig. 34 (as *Turritella (Turritellopsis) acicula)*
= *Turritella acicula* Stimpson, 1851, Proc. Boston Soc. Nat. Hist., vol. 4, p. 15.
Velutina undata Brown—Abbott, 1974, p. 146, fig. 1604
= *V. undata* Brown, 1839, Mem. Wernierian Nat. Hist. Soc., Edinburgh, vol. 8, p. 102, pl. 1, fig. 15.

Velutina velutina (Müller)—Abbott, 1974, p. 146, fig. 1602
= *Bulla velutina* Müller, 1776, Zoologicae Danicae prodromus, p. 242.

PELECYPODA

Anomia simplex d'Orbigny—Abbott, 1974, p. 451, Color pl. 20, fig. 5232
= *A. simplex* d'Orbigny, 1845, Moll. Cubana, vol. 2, p. 367, pl. 38, figs. 31-33.
Anomia squamula Linné—Abbott, 1974, p. 452, fig. 5236
= *A. squamula* Linné, 1758, Syst. Nat., ed. 10, p. 1131.
Arctica islandica (Linné)—Abbott, 1974, p. 518, fig. 5823
= *Venus islandica* Linné, 1758, Syst. Nat., ed. 10, p. 1131.
Astarte borealis Schumacher—Abbott, 1974, p. 480, fig. 5515
= *A. borealis* Schumacher, 1817, Essai d'un nouveau systeme des habitations des Vers testaces, p. 47, pl. 17, fig. 1.
Astarte castanea (Say)—Abbott, 1974, p. 481, fig. 5522
= *Venus castanea* Say, 1822, Jour. Acad. Nat. Sci., Philadelphia, vol. 4, p. 273.
Astarte striata (Leach)—MacGinitie, 1959, p. 167, pl. 22, figs. 14-16
= *Nicania striata* Leach, 1819, Ross's Voyage, Appendix 2, p. 176.
Astarte subaequilatera Sowerby—Abbott, 1974, p. 480, fig. 5517
= *A. subaequilatera* Sowerby, 1854, Thes. Conch., vol. 2, no. 2, p. 36.
Astarte undata Gould—Abbott, 1974, p. 480, fig. 5519
= *A. undata* Gould, 1841, Rept. Invert. Massachusetts, p. 80.
Axinopsida orbiculata (Sars)—MacGinitie, 1959, p. 172, pl. 20, fig. 2
= *Axinopsis orbiculata* Sars, 1878, Mollusca regionis arcticae Norvegiae, p. 63, pl. 19, figs. 11a-d.
Bathyarca pectunculinoides (Scacchi)—Abbott, 1974, p. 424, fig. 4990
= *Arca pectunculinoides* Scacchi, 1833, Sc. Ann. Civ. duc Sic., vol. 7, p. 82.
Cerastoderma pinnulatum (Conrad)—Abbott, 1974, p. 488, fig. 5586
= *Cardium pinnulatum* Conrad, 1831, Jour. Acad. Nat. Sci., Philadelphia, vol. 6, p. 260, pl. 11, fig. 8.
Chlamys islandica (Müller)—Abbott, 1974, p. 444, Colour pl. 19, fig. 5147
= *Pecten islandicus* Müller, 1776, Zoologicae Danicae prodromus, p. 248.
Clinocardium ciliatum (Fabricius)—Abbott, 1974, p. 487, fig. 5583
= *Cardium ciliatum* Fabricius, 1780, Fauna Gronl., p. 410.
Crassostrea virginica (Gmelin)—Abbott, 1974, p. 456, fig. 5274
= *Ostrea virginica* Gmelin, 1790, Syst. Nat., ed. 13, vol. 1, pt. 6, p. 3336.
Crenella decussata (Montagu)—Abbott, 1974, p. 430, fig. 5052
= *Mytilus decussatus* Montagu, 1808, Testacea Britannica, suppl., p. 69.
Crenella faba (Müller)—Abbott, 1974, p. 431, fig. 5054
= *Mytilus faba* Müller, 1776, Zoologicae Danicae prodromus, p. 250.
Crenella glandula Totten—Abbott, 1974, p. 430, fig. 5051
= *C. glandula* Totten, 1834, American Jour. Sci., vol. 26, p. 367.
Cyclocardia borealis (Conrad)—Abbott, 1974, p. 478, fig. 5493
= *Cardita borealis* Conrad, 1831, American Marine Conchol., p. 39.
Cyclopecten pustulosus (Verrill)—Abbott, 1974, p. 445, fig. 5160
= *Pecten pustulosus* Verrill, 1873, American Jour. Sci., vol. 5, p. 14.
Dacrydium vitreum (Holböll)—Abbott, 1974, p. 436, fig. 5102
= *?Mytilus vitrea* Holböll, in Moller, 1842, Naturhist. Tidsskrift, vol. 4, no. 1, p. 92.
Delectopecten vitreus (Gmelin)—Abbott, 1974, p. 446, fig. 5173
= *Pecten vitreus* Gmelin, 1791, Syst. Nat., vol. 1, p. 3228 (?).

Ensis directus (Conrad)—Abbott, 1974, p. 494, fig. 5627
= *Solen directus* Conrad, 1843, Proc. Acad. Nat. Sci., Philadelphia, vol. 1, p. 325.
Hiatella arctica (Linné)—Abbott, 1974, p. 541, fig. 6019
= *Mya arctica* Linné, 1767, Syst. Nat., ed. 12, p. 1113.
Limopsis minuta (Philippi)—Abbott, 1974, p. 425, fig. 5001
= *Pectunculus (Limopsis) minutus* Philippi, 1836, Enum. Moll. Siciliae, vol. 1, p. 63, pl. 5, fig. 3.
Liocyma fluctuosa (Gould)—Abbott, 1974, p. 528, fig. 5906
= *Venus fluctuosa* Gould, 1841, Rept. Invert. Massachusetts, p. 87, fig. 50.
Lucinoma filosa (Stimpson)—Abbott, 1974, p. 461, fig. 5325
= *Lucina filosa Stimpson*, 1851. Shells of New England, vol. A7, no description.
Lyonsia hyalina (Conrad)—Abbott, 1974, p. 554, fig. 6078
= *Mya hyalina* Conrad, 1831, Jour. Acad. Nat. Sci., Philadelphia, vol. 6, p. 261, pl. 11, fig. 12.
Macoma calcarea (Gmelin)—Abbott, 1974, p. 505, fig. 5711
= *Tellina calcarea* Gmelin, 1791, Syst. Nat., ed. 13, vol. 1, pt. 6, p. 3236.
Megayoldia thraciaeformis (Storer)—Abbott, 1974, p. 418, fig. 4918
= *Nucula thraciaeformis* Storer, 1838, Boston Jour. Nat. Hist., vol. 2, p. 122.
Mercenaria mercenaria (Linné)—Abbott, 1974, p. 523, fig. 5861
= *Venus mercenaria* Linné, 1758, Syst. Nat., ed. 10, p. 686.
Mesodesma arctatum (Conrad)—Morris, 1973, p. 72, pl. 27, fig. 12
= *Mactra arctata* Conrad, 1830, Jour. Acad. Nat. Sci., Philadelphia, vol. 6, p. 257, pl. 11, fig. 1.
Modiolus modiolus (Linné)—Abbott, 1974, p. 434, fig. 5088
= *Mytilus modiolus* Linné, 1758, Syst. Nat., ed. 10, p. 706.
Musculus discors (Linné)—Abbott, 1974, p. 432, fig. 5065
= *Mytilus discors* Linné, 1767, Syst. Nat., ed. 12, p. 1159.
Musculus niger (Gray)—Abbott, 1974, p. 432, fig. 5064
= *Modiola nigra* Gray, 1824, Parry's first voyage, 1819-20, suppl. to appendix, p. 244.
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= *M. arenaria* Linné, 1758, Syst. Nat., ed. 10, p. 670.
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