April 30, 1974

THE DISTRIBUTION and ECOLOGY of
COMMON MARINE and ESTUARINE PELECYPODS
in the DELAWARE BAY AREA

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ABSTRACT

Samplings from 1967 to 1973 of the marine-estuarine pelecypods of the Delaware Bay region indicates that about half of the 44 common species are true estuarine while the other half are evenly distributed between euryhaline and stenohaline marine species, with only a single oligohaline species, Ranga cuneata. The latter case is a northern range extension for this southern species.

INTRODUCTION

This research was undertaken to determine the distribution and ecology of common marine and estuarine pelecypods in the Delaware Bay area. Increased attention to pollution problems has renewed interest in benthic ecology. As a result, a series of local surveys have been conducted during different taxonomic groups (Watling and Maurer 1972 a, b, Watling et al, 1975). This paper represents a part of those surveys.

Lowden (1965) provided an annotated checklist of marine mollusca which covered Delaware Bay and New Jersey ocean beaches and enclosed bays. Watling and Maurer (1974) prepared a guidebook for the Delaware Bay region fauna which included a taxonomic key for the marine and estuarine mollusca. Moreover, some studies on pelecypods collected among oyster beds were also reported (Maurer and Watling 1973 a, b).

METHODS

This report is based on samples collected from 1967 to 1973 with a wide variety of sampling gear; epibenthic dredge, oyster dredge, hard clam dredge, hydraulic surf clam dredge, Van Veen bottom grab (0.1 m2), Pettenkofen bottom grabs (0.1 m2, 0.01 m2), and 15 mm mesh screen, preserved in buffered formalin. Selected organisms from the qualitative (dredge) samples were preserved in a similar manner.

Standard hydrographic data (temperature, salinity, dissolved oxygen) were collected for many of the samples together with samples of the sediment. The sediment samples were dried and sieved through a graded sieve series to determine sediment particle size.

RESULTS AND DISCUSSION

A list of the species discussed in this paper together with a summary of their ecology is presented in tabular form. Salinity values, spawning and substrate data are derived from our data in the Delaware Bay region and from other sources (Chesley 1953, Loosemore et al. 1966, Chesley and Andrews 1971). Notations for burrowing behavior are drawn from Stanley (1970). Carrilker (1967) developed a scheme of geographic divisions, salinity

ranges, types and distribution of organisms in estuaries. His scheme is adopted to facilitate comparison with other estuaries.

Among 44 species, 20 species are designated as true estuarine, 11 as euryhaline marine, 12 as stenohaline marine, and one as oligohaline. These designations represent the maximum distribution of these species rather than exceptional or marginal occurrences.

OLIGOHALINE

Ranga cuneata is the only local oligohaline species. It was reported from upper Chesapeake Bay and Elk River, Maryland (Pfitzenmayer and Drobeck 1964). Subsequently, Gallagher and Wells (1969) indicated that it should be expected in upper Delaware Bay.

Dead shells were collected near the eastern end of the Chesapeake-Delaware Canal by the Field Station. Recently several specimens were sampled from Delaware waters (J. Lindsay and Ron Smith, personal communication). This represents a northern range extension for this species. One specimen (29 mm in length) was collected August 20, 1971 in 1.0 m of water from mud bottom off Oakwood Beach, New Jersey. A second specimen was collected August 15, 1972 in 1.6 m of water from a mud and detritus bottom 500 m north of Appoquinimink Creek. Although not normally considered as oligohaline species, Mya arenaria and Macoma balthica have been reported from salinities as low as 5.5%. In European and American estuaries (Segerstrale 1957, Bird 1970). These species must occur in the bay in great abundance between the St. Jones River and Woodland Beach because the volume of their shell debris is large. Other local species (Modiolus demissus and Brachidontides recurrent) also extend their range into areas where salinity becomes lower than 5.5%, but they more properly belong to true estuarine species.

TRUE ESTUARINE

Amygdalium papryra, My Mellonula planulata, and Modiolus demissus are found attached by byssal threads to oysters. In the rivers, M. demissus and A. papryra are most commonly attached to marsh vegetation or partly buried in soft sediment. The ribbon mussel, M. demissus, is more common intertidally on roots of Spartina alterniflora than subtidally (Lent 1967), while A. papryra is always far less abundant than M. demissus and occurs subtidally. The ribbon mussel is uncommon in the bay except at Woodland Beach. Here the proximity of the marshes as a source of food stock favors setting on any firm substrate. Kunkel (personal communication) informs us that the hooked mussel, Brachidontes recurvus was at one time frequently collected above the Cohansey River, but is now very rare. The reason for its decline is unknown, but it was coincident with the mid-1960's drought.

Two bivalves show an affinity for a specific substrate. Petricola philadelphiae and Barnea truncata are characteristic of sections of the Murderkill, St. Jones, and Leipsic rivers with substrates of hard clay and packed marsh debris.

Infaunal species such as Macoma balthica, M. term., Mya arenaria, Ensis directus, Solen viridis, Tegula plebeius, and T. lineata mainly occur in mud, fine sand, and shelly-mud bottoms. High density (200/0.1 m2) populations of juvenile razor clams, Ensis directus, were found in sandy shoal areas bordering the ship channel, particularly from the mouth of the bay to the Miah MauL shoal. The above species together with Solemya velum (50 individuals per 1/15 m2) is also very abundant in the fine sands of Rehoboth and Indian River Bays. The soft clam, Mya arenaria, occurs in mud (> 50% silt-clay) bottoms of the smaller bays.

The oyster, Crassostrea virginica, is a dominant member of the estuarine community and locally ranges from the Cape May Flat to north of Arnolds Point. Maximum development of natural seed beds extends from Woodland Beach to Fort Mahon on the Delaware side of the Bay and from Egg Island Point to north of Arnolds Point on the New Jersey side. In addition to its commercial significance, the oyster forms the nucleus of a community that contains many species (Maurer and Watling 1973 a, b).

Anomia simplex was formerly reported in...
abundance in New Jersey oyster beds where the salinity is above 30 ppt (Kunkel, personal communication). Our experience with *A. simplex* is primarily restricted to Rehoboth and Indian River Bays where it is found attached to algae, rocks, and shells.

Two small (< 2 cm) bivalves, *Gemma gemma* and *Mulinia lateralis*, are locally very common, but their maximum distributions are dissimilar. *Mulinia lateralis* is found in muddy and sandy substrates and is one of the most abundant pelecypods in Delaware Bay. Great numbers (8-10,000/0.1 m²) of *M. lateralis* shells in channels and troughs near the mouth of the bay attest to its abundance. *Gemma gemma* inhabit a silk (30% silt-clay) or muddy-sand substrate and occur in the bay in relatively small numbers. It is, however, extremely abundant in Rehoboth and Indian River Bays, where counts of subtidal populations were at least 280,000/0.1 m². Both species are ecologically significant, because a number of fish, invertebrates, and birds feed on these bivalves (Seliner 1967, Calabrese 1969).

The hard clam, *Mercenaria mercenaria*, is commonly collected in fine sand with some gravel in Delaware Bay. In Delaware Bay it ranges from Woodland Beach to the ocean, although it is most abundant in the lower Bay from south of Port Madison to Broadkill Beach (Keck et al. 1972). Further, the hard clam occurs in commercial numbers in Rehoboth and Indian River Bays, coincident with the occurrence of the hard clam in the smaller bays. We have found it only occasionally in the ocean, but it may be more common there.

### Euryhaline Marine

*Tellina versicolor*, *Donax fuscus*, and *Spisula solidissima* occur very near open shore beaches. In fact, *Donax fuscus* may be considered an intertidal species. These species are primarily restricted to clean sand with some gravel. The surf clam, *Spisula solidissima*, is an important offshore commercial species (Yancey and Welch 1968). Laboratory observations showed that *S. solidissima* was unable to survive the diurnal tidal fluctuation in the Broadkill River (14-28%).

Species such as *Pondera gouldiana*, *Astarte undata*, *Venetorio borealis*, *Cerastoderma pinnaclatum*, *Abra equitalis*, and *Arctica islandica* occur in deeper water (> 12 m) in coarse sand. However, *P. gouldiana* is collected from the Cape Henlopen flats. Fragments of *Ceramus pseudostata* shells commonly wash ashore on Delaware's Atlantic coast but we have not been able to collect live. None of these species is abundant with the exception of *A. islandica*. It probably occurs in commercial numbers, but has not been vigorously marketed.

**SUMMARY OF ECOLOGY**

Salinities in parentheses represent values from published literature, while those not in parentheses represent our data. The substrate is classified by median sediment size, in range: fine sand, 0.063-0.25; medium sand, 0.25-0.50; coarse sand, 0.50-2.00. *Rangia cuneata* (Gray). Salinity, 0.10-4.0; (0-20 %O), oligohaline, spawning months, April through June; substrate, silt-clay and fine sand; mode, infralittoral feeder, slow burrower.
Brachiodontes recurvus (Rafinesque): Salinity, 8-15 %, (0-20 %), true estuarine; spawning months, April through December; substrate, rocks and oysters; mode, epifaunal suspension feeder with strong byssus. Modiolus demissus (Dillwyn): Salinity, 5-25 %, (2-30 %), true estuarine; spawning months, May through October; substrate, marsh grass and algae, occasionally rocks; mode, semi-buried suspension feeder, weak byssus. Boreus truncatus (Say): Salinity, 13-25 %, (10-30 %), true estuarine; spawning months, April through November; substrate, hard clay; mode, infraunal suspension feeder, moderately rapid burrower. Cyrtopleura costata (Linne): Salinity, 13-25 %, (10-30 %), true estuarine; substrate, hard clay; mode, infraunal suspension feeder, moderately rapid burrower. Arcuatula bulbifera (Linne): Salinity, 10-25 %, (5-25 %), true estuarine; substrate, marsh grass, algae and oysters; mode, epifaunal suspension feeder with byssus. Mya arenaria (Linne): Salinity, 5-20 %, (5-25 %), true estuarine; spawning months, March through May and September through November; substrate, silt-clay through medium sand; mode, infraunal suspension feeder, slow burrower. Macoma balthica (Linne): Salinity, 10-26 %, (5-25 %), true estuarine; substrate, marsh grass; algae and oysters; mode, epifaunal suspension feeder with byssus. Bancilla gouldi Bartch: Salinity, 15-35 %, (10-35 %), euryhaline marine; substrate, wood; infraunal deposit feeder, slow burrower. Teredo navalis Linne: Salinity, 15-35 %, (10-35 %), euryhaline marine; spawning months, June through October; substrate, wood; mode, infraunal suspension feeder, slow burrower. Macoma tenua (Say): Salinity, 15-35 %, (10-30 %), true estuarine; substrate, silt-clay through medium sand; mode, infraunal deposit feeder, moderately rapid burrower. Solenoida vivida Say: Salinity, 13-25 %, (7-32 %), true estuarine; substrate, fine sand and medium sand; mode, infraunal suspension feeder, rapid burrower. Ensis directus Say: Salinity, 13-25 %, (7-32 %), true estuarine; spawning months, January through April; substrate, fine sand and medium sand; mode, infraunal suspension feeder, rapid burrower. Siliqua costata (Say): Salinity, 15-25 %, (15-28 %), euryhaline marine; substrate, silt-clay through medium sand; mode, infraunal suspension feeder, rapid burrower. Tagelus plebeius (Lightfoot): Salinity, 13-30 %, (13-28 %), true estuarine; substrate, silt-clay through medium sand; mode, infraunal deposit feeder, slow burrower. Mullisia lateralis (Say): Salinity, 13-25 %, (10-35 %), true estuarine; spawning months, March through November; substrate, silt-clay through medium sand; mode, infraunal suspension feeder, moderately rapid burrower. Corbula contracta Say: Salinity, 20-30 %, (15-35 %), euryhaline marine; substrate, silt-clay and fine sand; mode, epifaunal suspension feeder, slow burrower. Solenoida ulvae Say: Salinity, 17-25 %, (15-30 %), true estuarine; substrate, silt-clay and fine sand; mode, infraunal suspension feeder, rapid burrower. Mysella planulata Stimpson: Salinity, 15-25 %, (15-26 %), true estuarine; substrate, silt-clay and fine sand; mode, infraunal suspension feeder, weak byssus. Anomia simplex Orsogna: Salinity, 15-30 %, (10-30 %), true estuarine; spawning months, April through October; substrate, algae, hard shell, rocks; mode, epifaunal suspension feeder, weak byssus. Pholadinae (Conrad): Salinity, 15-30 %, (15-28 %), true estuarine; spawning months, April through August; substrate, silt-clay through medium sand; mode, infraunal suspension feeder, moderate burrower. Gemma gemma (Totten): Salinity, 16-30 %, (15-33 %), true estuarine; substrate, silt-clay and fine sand; mode, infraunal suspension feeder, moderately rapid burrower. Anadara transversa (Say): Salinity, 18-30 %, (18-32 %), euryhaline marine; spawning months, May through September; substrate, algae, silt-clay through medium sand; mode, infraunal suspension feeder, weak byssus, slower burrower. Noetia ponderosa (Say): Salinity, 17-30 %, (15-35 %), euryhaline marine; spawning months, June through November; substrate, algae, silt-clay through medium sand; mode, infraunal suspension feeder, weak byssus, slow burrower. Mytilus edulis Linne: Salinity, 20-35 %, (15-35 %), euryhaline marine; spawning months, January through December; substrate, rock, shell; mode, epifaunal suspension feeder, strong byssus in clusters. Pinacolus philadelphicus Lamarck: Salinity, 15-25 %, (10-32 %), euryhaline marine; spawning months, March through November; substrate, hard clay; mode, infraunal suspension feeder, moderately rapid burrower. Pandora goodi (Say): Salinity, 23-35 %, (20-35 %), euryhaline marine; substrate, fine sand through coarse sand; mode, infraunal suspension feeder, slow burrower. Patella undata Goud: Salinity, 25-35 %, (22-35 %), euryhaline marine; substrate, medium sand and coarse sand; shell; mode, infraunal suspension feeder, slow burrower. Nucula proxima Say: Salinity, 25-35 %, (20-35 %), euryhaline marine; substrate, silt-clay and fine sand, organic mud; mode, infraunal deposit feeder, moderately rapid burrower. Venericorda borealis (Conrad): Salinity, 25-35 %, (22-35 %), euryhaline marine; substrate, medium sand and coarse sand; shell; mode, infraunal suspension feeder, slow burrower. Cerastoderma pinnulatum (Conrad): Salinity, 25-35 %, (22-35 %), euryhaline marine; substrate, medium sand and coarse sand; shell; mode, infraunal suspension feeder, moderately rapid burrower. Donax faxtor Say: Salinity, 29-35 %, (26-35 %), euryhaline marine; spawning months, June through October; substrate, medium sand and coarse sand; shell; mode, infraunal suspension feeder, rapid burrower. Abra aequata (Say): Salinity, 29-35 %, (25-35 %), euryhaline marine; substrate, medium sand and coarse sand; shell; mode, infraunal suspension feeder (?), moderately rapid burrower (?). Yoldia limatula (Say): Salinity, 25-35 %, (22-35 %), euryhaline marine; substrate, silt-clay and fine sand, organic mud; mode,
**ACKNOWLEDGMENTS**

Our associates, Wayne Leathem and Peter Kinner, provided much of the raw data for this paper. Because of their efforts we were able to expand the species list. Mr. John Lindsay and Mr. Ron Smith, Ichthyological Associates, generously shared their collecting data on Banie canueta. Since the latter is a northern range extension, Mr. Lindsay and Mr. Smith deserve recognition for their contribution. Finally, Dr. R. Tucker Abbott kindly checked several identifications and encouraged us to develop this account.

**LITERATURE CITED**


**BOOK REVIEW**


Of monographic proportions, this regional study provides an immense amount of data on the biology of 103 species and subspecies in 37 genera and subgenera of an area encompassing more than 1/3 of North America. Ten families (2 bivalve, 3 prosobranch and 5 pteropod) are reviewed with the species, limacinae and plankorids being among the more species. For certain taxonomic groups this study constitutes the first modern systematic treatment, and many of the taxa have never been critically reviewed, properly described or adequately illustrated.

Geographically, the Canadian Interior Basin comprises both the Hudson Bay Basin and the Canadian portion of the Arctic Basin. Ecologically, the incursions of ice and freshwater into the greater area of the Mackenzie, Churchill, and Saskatchewan. The front endpapers provide a colored map of the principal drainage basins and the rear covers detail, in color, topographic and geomorphic features. The geologic column is the Precambrian Shield, a poor source of limestone and therefore not particularly hospitable to shellfish. A more suitable substrate, the Hudson Bay Lowlands provides a more calcareous rich environment and is characterized by low species diversity and by large population sizes typical of highly variable environments.

Approximately 10 years of field work during which nearly 600 stations were sampled and over 3000 lots collected, form a basis for this study. Including material from various sources, ultimately over 100,000 specimens were examined. In conjunction with fossil evidence, temperature preferences, and distributional data, the probable faunal origins are analyzed for each species. In an enlightening introduction, previous research and the geologic history of the area are surveyed.

The major portion of the text consists of the systematic section. Although each species is provided with a synonymy, the treatment is irregular and incomplete. As the author himself points out, not all synonyms are listed.
and few citations of type specimens are included. For example, rather than attempt to assess the validity of all North American nomenclatural Gyraulus, an effort is made to evaluate the status of all taxa recorded from the study area. Following a short diagnosis, a more detailed description is given for each species. An illustration, a list of specimens examined and a map of the species' distribution in the study area are augmented with comments on overall distribution, a discussion of biology and ecology, and remarks on closely related species and probable synonyms. Clear, dichotomous keys, references to page numbers and illustrations, aid in identification of each family, genus, species, and subspecies.

The taxonomy of freshwater mollusks has always constituted a considerable problem. Dr. Clarke employed some biometric methods to describe the variation in these species. He utilized these data to detect subspecies, to discover the meaning or implication of geographically correlated morphometric characteristics, and to describe more fully the variability exhibited by some species. Adding that evidence of gene exchange between otherwise distinguishable groups of populations is indicative of the existence of subspecies whereas no gene exchange means that two or more distinct species are involved, Dr. Clarke recognized a dozen polytypic species, some with as many as 3 subspecies in the study area. An examination of the distribution of one of these polytypic species, for example Valvata sizeri with its 3 polytopic subspecies, V.s. sincera, V.s. ontariensis, and V.s. helicoida shows that all three may live in the same river system (Albany and St. Louis drainages) and even near or in the same body of water (Lake Nipigon). To me, such a pattern casts doubt on the interpretation of these populations as subspecies since subspecies are, by definition, geographical isolates.

Certain complex nomenclatorial problems are resolved. To insure stability and allow the continued widespread usage of such important hydrobiid generic names as Amnicola and Pomatiopsis, a neotype is designated for Paludina lustrica Say, 1821, the type species of Amnicola. An attendant oddity is that this specific name, though having priority, is considered a nomen oblitum and A. lustrica, Pilsbry, 1898, a subjective synonym, utilized.

Among the outstanding contributions in this volume are the extremely useful distinctions between easily confused species, the thorough accounts of previously very poorly known species, and the comprehensive analyses of certain species. Lymnaea columnella and Succinea ovalis are very similar and frequently misidentified, but here they are clearly differentiated conchologically and anatomically (p. 26).

Many intrinsically intriguing biological facts are brought to light. Documenting the tenacity and perseverance of some mollusks are the extreme northern occurrences of certain species: the cosmopolitan sphaerid Fasciolus cestreum on Raffin and Victoria Islands, the panboreal physid Aplexa hypo- rum also on Victoria Island, and the Beringian Lymnaea thebanesis at home on the Arctic Coastal Plain. Additional specific results include the synonymization of Lymnaea emarginata with L. catarciapum (p. 328) and the recognition of the European Gyraulus albus as distinct from the Nearctic G. deflectus (p. 396).

In summary, this work is truly a magnum opus, constituting the most comprehensive treatment of the mollusks of a faunal area in North America and the most thorough analysis of many intriguing taxa. Setting a high standard of excellence, it forms the foundation for any future work on the freshwater mollusks of Canada and, indeed, the United States. An invaluable treatise and exemplary source book for the limacologist and aquatic biologist, it is a must for the library of any malacologist and a fitting memorial to the author's late wife, Louise, to whom the work is dedicated.

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