THE DISTRIBUTION and ECOLOGY of COMMON MARINE and ESTUARINE PELECYPODS in the DELAWARE BAY AREA[3]

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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 marines, with only a single oligohaline species, Rangia 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 dealing with different taxonomic groups (Watling and Maurer 1972 a, b, Watling et al, 1973). This paper represents a part of those surveys.

Lowden (1965) provided an annotated checklist of marine molluscs 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 molluscs. 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 m^2), Petersen bottom grabs (0.1 m^2 1/15 m^2). Several areas on Coast and Geodetic Survey Maps 1218 and 411 which received intensive sampling are: 1) quantitative samples off Cape Henlopen, 13 transects from the capes to Woodland Beach, Cape Henlopen flat, Rehoboth, Indian River, and Little Assawoman Bays, eight miles east of Rehoboth, 2) qualitative samples include the above sites together with heavy sampling in Delaware's oyster beds. All quantitative samples were sieved through a 1.0 mm mesh screen and the residual on the screen was preserved in 10% 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 telescopic form. Salinity values, spawning and substrate data are derived from our data in the Delaware Bay region and from other sources (Chanley 1958, Loosanoff *et al.* 1966, Chanley and Andrews 1971). Notations for burrowing behavior are drawn from Stanley (1970). Carriker (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

Rangia cuneata is the only local oligohaline species. It was reported from upper Chesapeake Bay and Elk River, Maryland (Pfitzenmeyer 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 sand bottom off Oakwood Beach, New Jersey. A second specimen was collected August 15, 1972 in 1.8 m of water from a mud and detritus bottom 200 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 ‰ 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 *Brachiodontes recurvus*) also extend their range into areas where salinity becomes lower than 5 ‰, but they more properly belong to true estuarine species.

TRUE ESTUARINE

Amygdalum papyria, Mysella planulata, and *Modiolus demissus* are found attached by byssal threads to oysters. In the rivers, *M. demissus* and *A. papyria* are most commonly attached to marsh vegetation or partly buried in soft sediment. The ribbed mussel, *M. demissus,* is more common intertidally on roots of *Spartina alterniflora* than subtidally (Lent 1967), while *A. papyria* is always far less abundant than *M. demissus* and occurs subtidally. The ribbed mussel is uncommon in the bay except at Woodland Beach. Here the proximity of the marshes as a source of brood stock favors heavy setting on any firm substrate. Kunkel (personal communication) informs us that the hooked mussel, *Brachiodontes 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 pholadiformis* 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. tenta, Mya arenaria, Ensis directus, Solen viridis, Tagelus plebeius,* and *T. divisus* mainly occur in mud, fine sand, and shelly-mud bottoms. High density *(200/0.1* m^2) 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 m^2) 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 Port 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

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abundance in New Jersey oyster beds where the salinity is above 20 ‰ (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 (8-10,000/0.1m^2) of *M. lateralis* shells in channels and troughs near the mouth of the bay attest to its abundance. *Gemma gemma* inhabit a silty (20% 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 as high as 280,000/m^2. Both species are ecologically significant, because a number of fish, invertebrates, and birds feed on these bivalves (Sellmer 1967, Calabrese 1969).

The hard clam, *Mercenaria mercenaria*, is commonly collected in fine sand with some clay. In Delaware Bay it ranges from Woodland Beach to the ocean, although it is most abundant in the lower Bay from south of Port Mahon 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 is that of *Pitar morrhuana*, which is commonly collected but in considerably lower numbers. Both species are on the borderline between true estuarine species and euryhaline marine species because they frequently occur near high salinity inlets or in the ocean.

EURYHALINE MARINE

Two species which occur in oceanic salinity but also extend into the estuary are the wood borers, *Bankia gouldi* and *Teredo navalis*. Evidence of their work can be found in wooden pilings along Delmarva and Delaware Bay beaches. *Teredo navalis* has a wide tolerance to salinity and *B. gouldi* occurs in Chesapeake Bay in water with a mean salinity of 9.3 ‰ and a range of 3.3‰– 15.6 ‰ (Scheltema and Truitt 1954, Nair and Saraswathy 1971). Among other euryhaline marine species *Siliqua costata* and *Tellina agilis* are considered rapid burrowers and *Corbula contracta*, *Lyonsia hyalina*, *Anadara ovalis*, *A. transversa*, and *Noetia ponderosa* are considered slow burrowers (Stanley 1970). *Tellina agilis* is a dominant species in fine sand (0.25 mm median sediment size) near the mouth of the Bay. A codominant species occurring with *T. agilis* is *Nucula proxima* which is common in sediments with high (> 50%) silt-clay content (Maurer et al. 1973). *Tellina agilis* is also common on the Cape Henlopen flats. This tellinid may also occur with *L. hyalina*, which is most common in sediment with 20-40% silt-clay. The ark shells, *Anadara transversa* and *A. ovalis*, occur in the ocean but are more frequently collected in algae beds of the smaller bays. In contrast, *Noetia ponderosa* is more common in the ocean.

STENOHALINE MARINE

Tellina versicolor, *Donax fossor*, and *Spisula solidissima* occur very near open shore beaches. In fact, *Donax fossor* may be considered an intertidal species. These species are primarily restricted to clean sand with shell and 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 *Pandora gouldiana*, *Astarte undata*, *Venericardia borealis*, *Cerastoderma pinnulatum*, *Abra aequalis*, and *Arctica islandica* occur in deeper water (> 12 m) in coarse sand. However, *P. gouldiana* is collected from the Cape Henlopen flat. Fragments of *Cyrtopleura costata* shells commonly wash ashore on Delaware's Atlantic coast but we have not collected any alive. None of these species is abundant with the exception of *A. islandica*. It probably occurs in commercial numbers, but has not been vigorously marketed.

Yoldia limatula also is common in the ocean, but it has the same affinity for sediment with high silt-clay content as *N. proxima*. Both species occur together locally. *Nucula proxima* is more dominant in shallow and semi-enclosed water than *Yoldia limatula*. *Mytilus edulis* is found attached to rocks, wrecks, and jetties near the mouths of bays and in the ocean. It occasionally occurs in such numbers to form small lenticular reefs in rivers (e.g. Broadkill) along the lower Bay.

The Bay scallop, *Argopecten irradians* is occasionally obtained in Rehoboth and Indian River Bay. This species is not abundant, but when it occurs it is associated with algae in the smaller bays. We have found it only occasionally in the ocean, but it may be more common there.

COMMUNITY STUDIES

In an earlier study, the habitat zone, substrate, form, and feeding type of molluscan communities of Beaufort, North Carolina, were described (Bird 1970). With the caveats of different sampling design, methods, and treatment of pelecypod molluscs alone, comparison of Bird's data with ours show the following similarities and differences. From estuary mouth to the head he named three communities: *Tellina, Mulinia — Syndosmya [Abra], Retusa; Syndosmya [Abra] — Aligena;* and *Macoma balthica*. Only the *Macoma* community was sharply delineated. The association of the estuary mouth graded into the shallow open-ocean community of the area, the *Tellina — Spisula* community.

There was no attempt here to define pelecypod communities *per se*. Instead, particular suites of species were recognized based on salinity distribution. Following Carriker's (1967) outline for biota and salinity divisions, pelecypods (*Spisula, Donax, Astarte, Venericardia*) occurring in local stenohaline marine conditions would probably agree with Bird's (1970) open ocean community (*Spisula — Tellina*). Pelecypods (*Tellina, Lyonsia, Anadara, Corbula*) locally recognized as euryhaline marine species may be equated with Bird's *Tellina, Mulinia — Syndosmya [Abra] Retusa* community. Those species (*Macoma, Modiolus, Mulinia, Brachiodontes*) which are true estuarine forms may fit Bird's *Macoma* community.

Two other comparisons can be made. The range of salinity of species distribution reported by Bird (1970) is narrower than salinity ranges for similar species in this study. This tends to telescope molluscan assemblages towards the mouth of the estuary. As a result, differences between his results and ours are more superficial than significant. The important fact remains that the relative sequence of pelecypod assemblages is very similar in both areas. He commented that community boundaries were gradational even between open ocean and estuary-mouth communities. Gradual shifting of relative abundance of the most abundant species rather than wholesale change in species composition characterized community flux. We agree with Bird's (1970) findings in that in some cases it was difficult to distinguish among true estuarine, euryhaline marine, and stenohaline marine species. Controlling mechanisms to explain these differences remain to be studied.

In summary, there are approximately 44 common species of marine-estuarine pelecypods in the Delaware Bay region. As might be expected about 50% are true estuarine species. The other 50% are evenly distributed between euryhaline and stenohaline marine species with a single bonafide oligohaline species (*Rangia cuneata*). The latter is a northern range extension. The designation of stenohaline marine and oligohaline species is easier to determine than euryhaline marine or true estuarine forms.

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 mm: fine sand, 0.063-0.25; medium sand, 0.25-0.50; coarse sand, 0.50-2.00.

Rangia cuneata (Gray): Salinity, 0-10 ‰, (0-20 ‰), oligohaline; spawning months, April through June; substrate, silt-clay and fine sand; mode, infaunal suspension 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.

Barnea truncata (Say): Salinity, 13-25 ‰, (10-30 ‰), true estuarine; spawning months, April through November; substrate, hard clay; mode, infaunal suspension feeder, moderately rapid burrower.

Cyrtopleura costata (Linné): Salinity, 13-25 ‰, (10-30 ‰), true estuarine; substrate, hard clay; mode, infaunal suspension feeder, moderately rapid burrower [not found living].

Amygdalum papyria Conrad: Salinity, 8-25 ‰, (5-25 ‰), true estuarine; substrate, marsh grass, algae and oysters; mode, epifaunal suspension feeder with byssus.

Mya arenaria (Linné): Salinity, 5-20 ‰, (5-25 ‰), true estuarine; spawning months, March through May and September through December; substrate, silt-clay through medium sand; mode, infaunal suspension feeder, slow burrower.

Macoma balthica (Linné): Salinity, 10-25 ‰ , (5-25 ‰), true estuarine; spawning months, March through May and August through November; substrate, silt-clay through medium sand; mode, infaunal deposit feeder, moderately rapid burrower.

Bankia gouldi Bartsch: Salinity, 15-35 ‰, (10-35 ‰), euryhaline marine; substrate, wood; infaunal suspension feeder, slow burrower.

Teredo navalis Linné: Salinity, 15-35 ‰, (10-35 ‰), euryhaline marine; spawning months, June through October; substrate, wood; mode, infaunal suspension feeder, slow burrower.

Macoma tenta (Say): Salinity, 15-25 ‰, (10-30 ‰), true estuarine; substrate, silt-clay through medium sand; mode, infaunal deposit feeder, moderately rapid burrower.

Solen viridis Say: Salinity, 13-28 ‰, (7-28 ‰), true estuarine; substrate, fine sand and medium sand; mode, infaunal suspension feeder, rapid burrower.

Ensis directus Conrad: Salinity, 13-28 ‰, (7-32 ‰), true estuarine; spawning months, January through April; substrate, fine sand and medium sand; mode, infaunal suspension feeder, rapid burrower.

Siliqua costata (Say): Salinity, 15-25 ‰ , (15-28 ‰), euryhaline marine; substrate, silt-clay through medium sand; mode, infaunal suspension feeder, rapid burrower.

Tagelus plebeius (Lightfoot): Salinity, 13-30 ‰ , (13-28 ‰), true estuarine; substrate, silt-clay through medium sand; mode, infaunal deposit feeder, slow burrower.

Mulinia lateralis (Say): Salinity, 13-28 ‰ , (10-35 ‰), true estuarine; spawning months, March through November; substrate, silt-clay through medium sand; mode, infaunal suspension feeder, moderately rapid burrower.

Corbula contracta Say: Salinity, 20-30 ‰ , (15-35 ‰), euryhaline marine; substrate, silt-clay and fine sand; mode, infaunal suspension feeder, slow burrower.

Crassostrea virginica (Gmelin): Salinity, 13-30 ‰ , (0-35 ‰), true estuarine; spawning months, June through September; substrate, rocks and shells; mode, epifaunal suspension feeder, in clusters.

Solemya velum Say: Salinity, 17-25 ‰ , (15-28 ‰), true estuarine; substrate, silt-clay and fine sand; mode, infaunal suspension feeder, rapid burrower.

Mysella planulata Stimpson: Salinity, 15-25 ‰ , (13-28 ‰), true estuarine; substrate, algae, hard shell, rocks; mode, epifaunal suspension feeder, weak byssus.

Anomia simplex Orbigny: Salinity, 15-30 ‰ , (10-30 ‰), true estuarine; spawning months, April through October; substrate, algae, hard shells, rocks; mode, epifaunal suspension feeder, calcified byssus.

Pitar morrhuana (Linsley): Salinity, 17-30 ‰ , (15-35 ‰), true estuarine; spawning months, May through August; substrate, silt-clay through medium sand; mode, infaunal suspension feeder, moderately rapid burrower (?)

Mercenaria mercenaria (Linne): Salinity, 15-30 ‰ (10-35 ‰), true estuarine; spawning months, May through October; substrate, silt-clay through medium sand, some shell; mode, infaunal suspension feeder, moderately rapid burrower.

Tagelus divisus (Spengler): Salinity, 15-25 ‰ , (15-29 ‰), true estuarine; substrate, silt-clay through medium sand; mode, infaunal deposit feeder, rapid burrower.

Lyonsia hyalina (Conrad): Salinity, 18-30 ‰ , (15-28 ‰), euryhaline marine; spawning months, February through May; substrate, silt-clay and fine sand; mode, infaunal suspension feeder, slow burrower.

Tellina agilis Stimpson: Salinity, 13-35 ‰ , (12-35 ‰), euryhaline marine; spawning months, March through July; substrate, silt-clay through medium sand; mode, infaunal deposit and suspension feeder, rapid burrower.

Tellina versicolor DeKay: Salinity, 20-35 ‰ , (15-35 ‰), stenohaline marine; substrate, fine sand through coarse sand; mode, infaunal deposit and suspension feeder, rapid burrower.

Anadara ovalis (Bruguière): Salinity, 15-30 ‰ , (15-35 ‰), euryhaline marine; spawning months, May through October; substrate, fine sand through coarse sand; mode, infaunal suspension feeder, weak byssus, slow burrower.

Argopecten irradians (Lamarck): Salinity, 20-35 ‰ , (17-35 ‰), stenohaline marine; spawning months, April through August; substrate, algae; mode, vagile suspension feeder, weak byssus.

Gemma gemma (Totten): Salinity, 18-30 ‰ , (13-32 ‰), true estuarine; substrate, silt-clay and fine sand; mode, infaunal suspension feeder, moderately rapid burrower.

Anadara transversa (Say): Salinity, 18-30 ‰ , (15-32 ‰), euryhaline marine; spawning months, May through September; substrate, algae, silt-clay through medium sand; mode, infaunal 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, infaunal suspension feeder, weak byssus, slow burrower.

Mytilus edulis Linné: Salinity, 20-35 ‰ , (15-35 ‰), stenohaline marine; spawning months, January through December; substrate, rock, shell; mode, epifaunal suspension feeder, strong byssus in clusters.

Petricola pholadiformis Lamarck: Salinity, 15-29 ‰ , (10-32 ‰), euryhaline marine; spawning months, March through November, substrate, hard clay; mode, infaunal suspension feeder, moderately rapid burrower.

Pandora gouldiana Dall: Salinity, 23-35 ‰ , (20-35 ‰), stenohaline marine; substrate, fine sand through coarse sand; mode, infaunal suspension feeder, slow burrower.

Astarte undata Gould: Salinity, 25-35 ‰ , (22-35 ‰), stenohaline marine; substrate, medium sand and coarse sand, shell; mode, infaunal suspension feeder, slow burrower.

Nucula proxima Say: Salinity, 25-35 ‰ , (20-35 ‰), euryhaline marine; substrate, silt-clay and fine sand, organic mud; mode, infaunal deposit feeder, moderately rapid burrower.

Venericardia borealis (Conrad): Salinity, 25-35 ‰ , (22-35 ‰), stenohaline marine; substrate, medium sand and coarse sand, shell; mode, infaunal suspension feeder, slow burrower.

Cerastoderma pinnulatum (Conrad): Salinity, 25-35 ‰ , (22-35 ‰), stenohaline marine; substrate, medium sand and coarse sand, shell; mode, infaunal suspension feeder, moderately rapid burrower.

Donax fossor Say: Salinity, 29-35 ‰ , (25-35 ‰), stenohaline marine; spawning months, June through October; substrate, medium sand and coarse sand, shell; mode, infaunal suspension feeder, rapid burrower.

Abra aequalis (Say): Salinity, 29-35 ‰ , (25-35 ‰), stenohaline marine; substrate, medium sand and coarse sand, shell; mode, infaunal deposit feeder (?), moderately rapid burrower (?)

Yolida limatula (Say): Salinity, 25-35 ‰ , (22-35 ‰), stenohaline marine; substrate, silt-clay and fine sand, organic mud; mode, infaunal deposit feeder, rapid burrower.

Spisula solidissima (Dillwyn): Salinity, 27-35 ‰, (10-35 ‰), stenohaline marine; spawning months, March through May and September through November; substrate, clean, coarse sand, shell, medium sand; mode, infaunal suspension feeder, rapid burrower.

Arctica islandica (Linné): Salinity, 30-35 ‰, (28-35 ‰), stenohaline marine; spawning months, June through October; substrate, clean, medium sand and coarse sand, shell; mode, infauna.

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BOOK REVIEW

THE FRESHWATER MOLLUSCS OF THE CANADIAN INTERIOR BASIN. *By Clarke, Arthur H. 1973. Malacologia, 13(1-2): 1-509, 9 text figures, 9 tables, 87 maps, 28 plates (1-14 in color, 15-28 in black and white), 35 charts.*

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 pulmontate) are reviewed with the sphaeriids, lymnaeids and planorbids being among the more speciose. 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, including such extensive river systems as the Mackenzie, Churchill, and Saskatchewan. The front endpapers provide a colored map of the principal drainage basins and the rear covers detail, in color, phytogeographic and geomorphic features. Dominating the geologic scene is the Precambrian Shield, a poor source of limestone and therefore not particularly hospitable for shelled animals. A more suitable substrate, the Hudson Bay Lowland provides a more calcium 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 nominal *Gyraulus*, an effort is made to evaluate the status of all taxa recorded from the study area. Following a short diagnosis, a longer, 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, with 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. Adducing 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 sincera* with its 3 polytopic subspecies, *V.s. sincera*, *V.s. ontariensis*, and *V.s. helicoidea* shows that all three may live in the same river system (Albany and Severn 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. walkeri* 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 columella* and *Succinea ovalis* are very similar and frequently misidentified, but here they are clearly differentiated conchologically and anatomically (p. 293).

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 sphaeriid *Pisidium casertanum* on Baffin and Victoria Islands, the panboreal physid *Aplexa hypnorum* also on Victoria Island, and the Beringian *Lymnaea atkaensis* at home on the Arctic Coastal Plain. Additional specific results include the synonymization of *Lymnaea emarginata* with *L. catascopium* (p. 328) and the recognition of the European *Gyraulus albus* as distinct from the Nearactic *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 limnologist 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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FROG MOTIFS ON ARCHAEOLOGICAL MOLLUSKS OF HOHOKAM AND MOGOLLON INDIAN CULTURES

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ABSTRACT

Thirty-seven pendants and eight bracelets carved with frog motifs, or overlaid with turquoise mosaic, comprise this initial checklist. Of the carved pendants without overlay, several motific groups can be identified. Pendants and bracelets were made from whole valves of various species, such as Glycymeris gigantea *(Reeve) and* G. maculatus *(Broderip). Other shells were used but less frequently. Carved frog pendants are found throughout the Hohokam and Mogollon culture areas and were frequently excavated in connection with burials.*

This is a preliminary report on carved shell ornaments from archaeological remains of prehistoric Indian cultures in the Southwest. In the current phase of study, a checklist of frog images is being compiled and motific groups are being catalogued. For reasons which go beyond this assembly and subdivision of objects and data, records are being made of archaeological contexts in which frog images were found in the hope that significant frequency patterns will emerge from the data.

We assume that discovery of carved shell ornaments in archaeological remains means that these objects had intrinsic value to certain prehistoric people. We also assume that by studying these objects we might

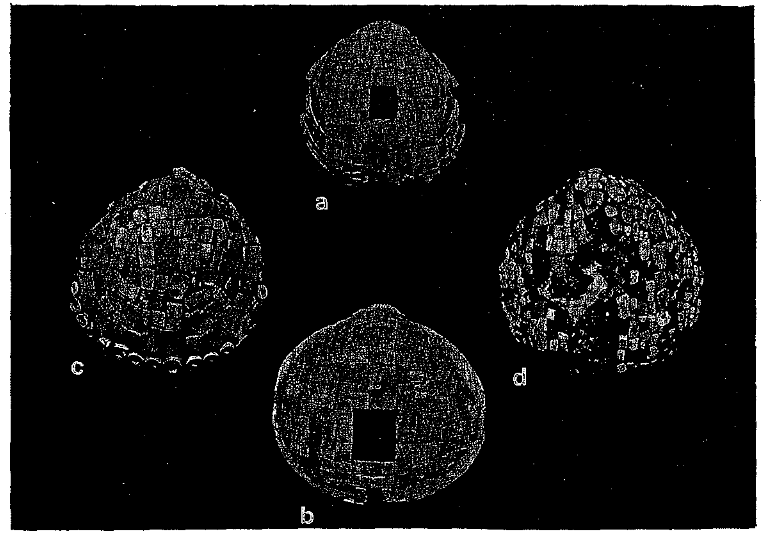

FIG. 1 *Overlaid Shell Pendants. Photograph by Helga Teiwes, Arizona State Museum, catalogue nos. GP39336, GP9895, GP10768 and GP5765.*