DISTRIBUTION AND ABUNDANCE OF THE JAPANESE SNAIL, *VIVIPARUS JAPONICUS*, AND ASSOCIATED MACROBENTHOS IN SANDUSKY BAY, OHIO[1, 2]

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ABSTRACT

A survey of the macrobenthos of Sandusky Bay, Lake Erie, in June, 1963, provided information on the abundance and distribution of the introduced Japanese snail, *Viviparus japonicus*, which has become a nuisance to commercial seine fishermen. The abundance and distribution varied considerably within the bay; at the time of the survey, most snails were found near the north-central shore. Environmental characteristics were nearly uniform and had no apparent effect on the distribution; concentrations in different areas at different times appeared to result from water movements induced by winds. The time of the study coincided with a period of reproduction; young-of-the-year snails were most abundant in areas where adults were most common. The frequency distributions of shell height and diameter suggested the presence of two age groups of adults in the population. Considerable natural mortality was seen, both at the time of the study and in other seasons. Only three other gastropods were observed in the bay; the most abundant was another viviparid, *Campeloma decisum*. Other mollusks present were four species of Sphaeriidae and 18 species of Unionidae. A summary of invertebrates found, other than the mollusks, is also presented.

INTRODUCTION

Great numbers of the Japanese snail, *Viviparus japonicus*, are sometimes caught by commercial seine fishermen in Sandusky Bay, Lake Erie. This species has become a nuisance in the commercial fishery, primarily during the spring fishing season. Local fishermen have reported that they sometimes catch two tons in a seine haul. Although no records are available concerning the time of introduction of the Japanese snail into the bay, fishermen in the area recall that one bushel of these animals was brought from Maryland by Clinton Reiley in the 1940's and stocked as a possible food for channel catfish, *Ictalurus punctatus*, an important species of commercial fish in western Lake Erie. The nuisance caused by the Japanese snail prompted this survey to determine its distribution and abundance in the bay and to evaluate the associated macrobenthos.

Published records of the distribution of the Japanese snail in the United States are few. Hannibal (1911) and Johnson (1923) recorded it from California and Massachusetts, respectively. It has become widespread, particularly in the north-central and northeastern states (Clench, 1962). We have seen specimens from Green Bay, Lake Michigan, and from the extreme western shore of Lake Erie, as well as from Sandusky Bay.

Two other species of *Viviparus* listed from North America (Walker, 1918), *V. contectoides* and *V. malleatus*, are found in the Great Lakes region. The latter has been collected in bottom trawls near the Bass Islands in western Lake Erie.

PHYSICAL CHARACTERISTICS OF SANDUSKY BAY

Sandusky Bay, located on the south shore of western Lake Erie, is 24.0 km long and 6.5 km wide. Two causeways at Bay View, Ohio, divide it into the Upper Bay and the Lower Bay (fig. 1a). Subsequent to this study, another causeway was constructed about 0.5 km west of the west causeway shown in figure 1a.

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The margin of the Upper Bay is predominantly marshland; that of the Lower Bay is elevated and its south shore is occupied largely by industry or dwellings. The marshland is occasionally flooded by lake water forced into the bay by strong northeasterly winds.

The maximum natural depth of the bay is less than 4.0 m. The shipping channel from Cedar Point to the city of Sandusky, however, is dredged to a depth of 6.1–7.6 m. Bottom composition is mostly mud, with a few small scattered patches of a mixture of gravel, sand, and mollusk shells. Rooted bottom vegeta-

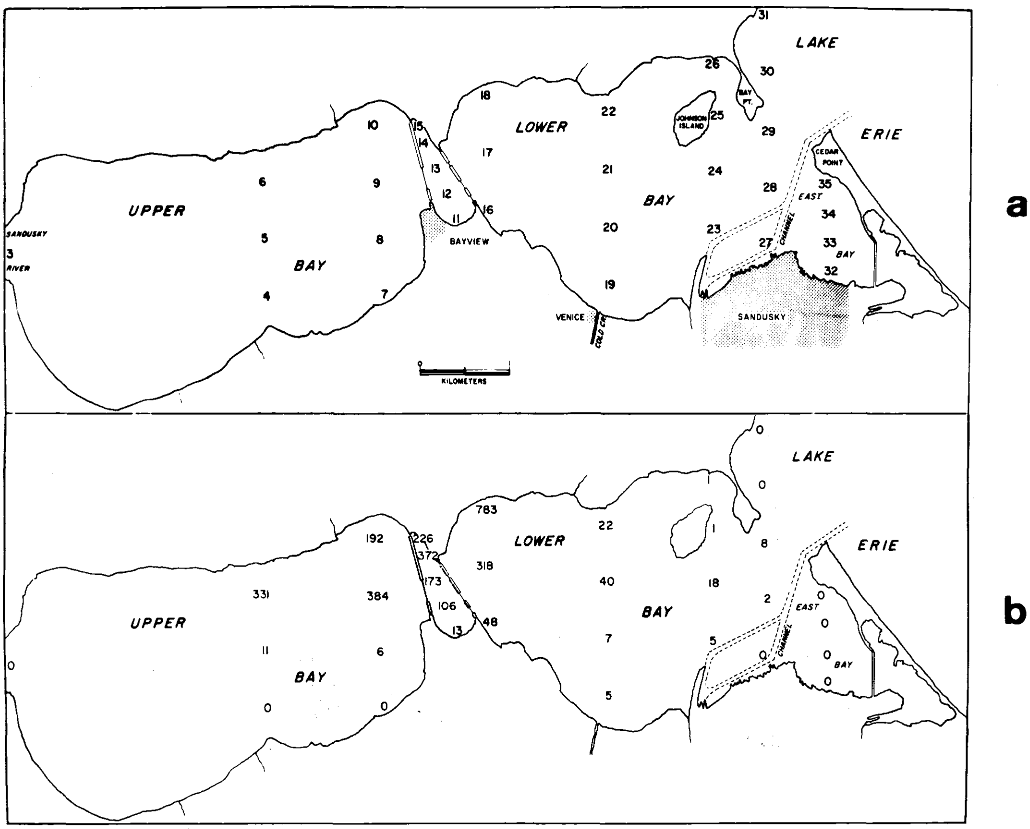

FIGURE 1. Map of Sandusky Bay showing location of stations where samples were collected (a), and numbers of *Viviparus japonicus* collected by trawl at each station (b). Stations 1 and 2, in the Sandusky River, are not shown.

tion is sparse and consists mainly of small beds of sago pondweed, *Potamageton pectinatus*. The combination of shallow water, mud bottom, scanty bottom vegetation, and frequently shifting winds causes the bay waters to be perpetually turbid. Secchi disk measurements are usually less than 0.3 m. Surface water temperatures have been known to reach 30° C in the summer. Bottom water temperatures ranged from 16° to 24° C during our investigation, June 4–21, 1963.

MATERIALS AND METHODS

Bottom samples were taken at 35 stations about ¼ and ½ mile (0.4 km and 0.8 km) apart, usually on north-south lines across Sandusky Bay (fig. 1a). Data collected at each station were bottom water temperature, depth, sediment type, and abundance of mollusks and other macrobenthos. The temperature of bottom water was measured with a resistance thermometer.

Large mollusks were sampled with a 16-foot semiballoon otter trawl with ½-inch-mesh cod end (stretch measure). A chain was attached to the foot rope of the trawl to help ensure the collection of specimens that were partially buried in the sediment. The trawl was towed by a 16-foot outboard motorboat at 2–3 mph (1.7–2.6 knots) for 5 minutes. One tow was made at each station. Each tow covered about 0.1 hectare of bottom. An otter trawl was also used with "moderate" success by Stansbery (1961) to collect naiad mussels near South Bass Island, Lake Erie.

Bottom samples for other macrobenthos were taken initially with a Petersen dredge (stations 32–35), but it was too awkward and heavy for use from a small boat; a 6- by 6-inch Ekman dredge was used at the remaining stations. Three dredge samples were taken at each station. Samples were washed through a U. S. standard No. 30 wire screen and the residue was preserved in 5-percent formalin for later examination.

All mussels were first immersed in a solution of sodium nembutal, a relaxing method described by van der Schalie (1953), then fixed in 10-percent formalin. Ultimately, some were transferred to 95-percent ethanol and others were transferred to a saturated aqueous solution of propylene phenoxytol. Both preservatives were effective.

Gastropods resisted relaxation in nembutal and consequently could not be fixed properly. Crystalline menthol dissolved in warm water and methanesulfonate (M.S. 222) were tried as relaxants, but were ineffective. Personnel of the U. S. Bureau of Commercial Fisheries sea lamprey research program suggested 3 compounds which they had found to have a relaxing effect on some mollusks. These chemicals were α-styrylpyridine, 3-trifluormethyl-4-nitrophenol (TFM), and 3,4,6-trichloro-2-nitrophenol. Bioassay tests of these 3 compounds at 10, 20, 30, 40, 50, 60, and 70 ppm were made at ambient room temperatures (20°–25° C). Little or no relaxation was evident after 24 hours in the α-styrylpyridine and TFM solutions. However, all specimens in the 40- and 50-ppm solutions of 3,4,6-trichloro-2-nitrophenol (Dow Chemical Company, Midland, Michigan) were relaxed. Upon immersion in 10-percent formalin, the snails did not withdraw and later examination revealed that fixation was satisfactory.

THE JAPANESE SNAIL

The Japanese snail is viviparous and the largest operculate snail in the Great Lakes. At birth the shell of the young is approximately 5.5 mm in height and 4.5 mm in diameter. It is shaped like a toy top, pallid in color, and has rows of epidermal bristles on the whorls that disappear as it grows. In the adult, the shell is a deep brown and the whorls are inflated, or more rounded, than in the young. The only external feature that we found to distinguish sex was the modified (blunter, shorter, and thicker) right tentacle of the adult male (fig. 2). This organ is similarly modified in both the juvenile and adult *V. contectoides* (Van Cleave and Lederer, 1932), but in the juvenile Japanese snail we found no such dissimilarity.

The 3,787 specimens collected from Sandusky Bay included two size groups: juveniles that were less than 10 mm high and adults that were more than 30 mm high. Three adults and 9 juveniles were taken in dredge samples; all others were caught with the trawl.

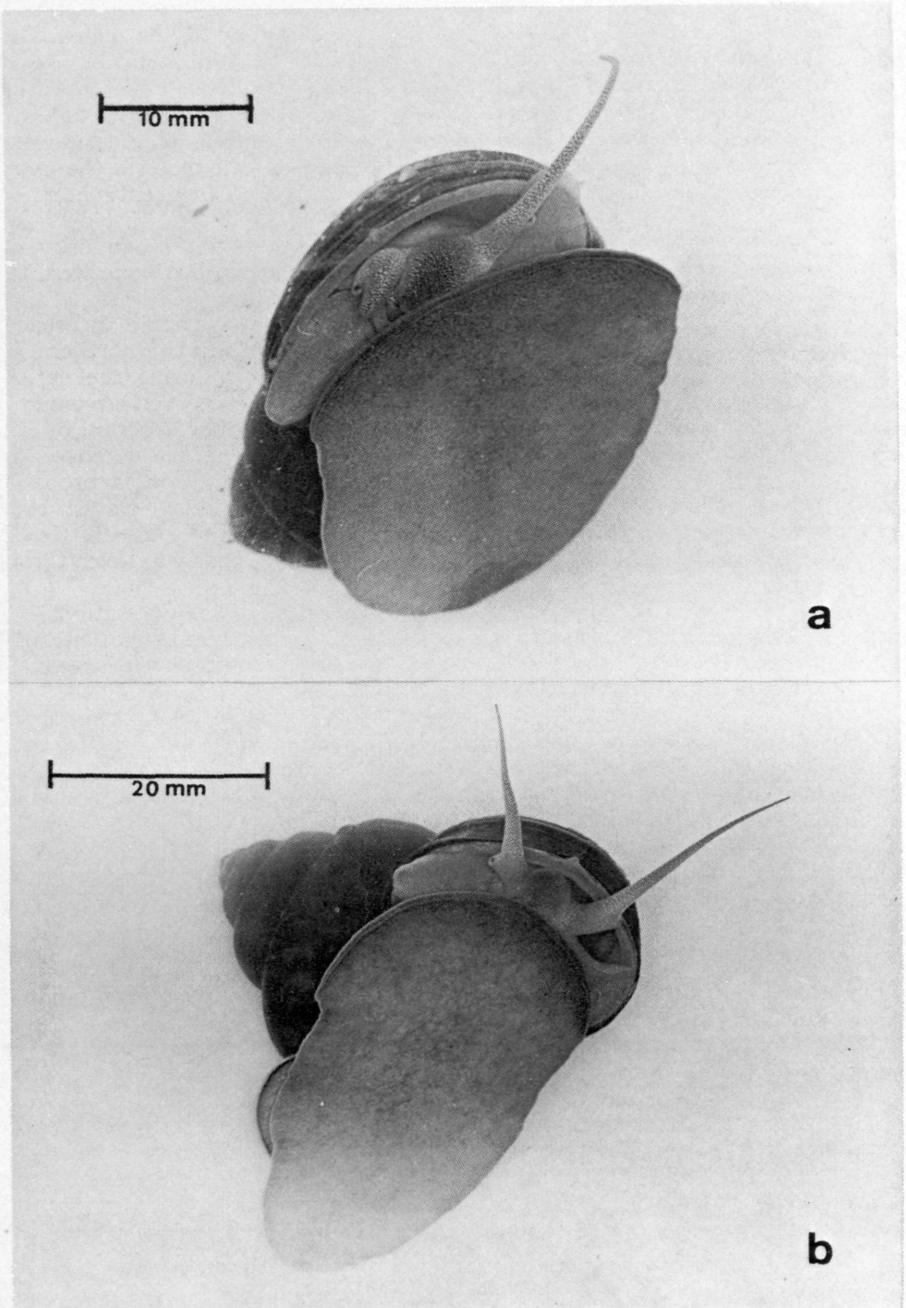

FIGURE 2. *Viviparus japonicus* from Sandusky Bay, Ohio: adult male (a), and adult female (b).

Distribution and Abundance

The abundance of adult Japanese snails varied considerably from station to station during our survey. The greatest numbers were taken at stations near the north shore of the central portion of Sandusky Bay (fig. 1b). The largest catch was 783 snails taken in a single trawl haul at station 18. Few adults were found along the southern shore; none were captured in similar hauls made in the southeast corner of the Lower Bay, although we have frequently seen them in the marshes along the southeast extremity of the Lower Bay in water a few centimeters deep. No Japanese snails were taken at the two stations in Lake Erie just outside the mouth of the Lower Bay. None were taken at the mouth of the Sandusky River (station 3); two were captured at station 2 near the mouth, but none were taken at station 1, about 0.8 km upstream.

The distribution of Japanese snails in Sandusky Bay is variable and seems to be influenced by the wind. The heavy concentrations along the northern shore probably resulted from the southerly winds that occurred during the period of investigation. In the time since our survey, we have often observed large numbers of snails taken by seine fishermen along the south shore after a period of strong northerly winds. Conversely, after strong southerly winds, the catch of snails along the north shore increases. This shift in the distribution is probably a direct result of water movements caused by the prevailing winds. Depth, bottom type and character, turbidity, and water temperature seemingly have little effect on the distribution of the snail, for these characteristics are nearly uniform throughout the bay.

Juvenile (young-of-the-year) snails were taken at 15 of the 35 stations. The number taken by trawl, however, was probably not an accurate measure of the population density of juveniles, because the mesh size of the trawl was large enough to permit the escape of many.

Young were most abundant in areas where adults were most common, presumably because the time of the collections coincided with a period of reproduction; live females held in the laboratory at this time produced many young. The largest number of young snails taken in a single tow was 239, in the west-central part of Lower Bay (station 17). In north-central Upper Bay (station 6), where 146 live young were taken, about 150 dead snails and empty shells of young were also found. Very few dead snails or empty shells of young were observed at other stations.

Age Composition

Frequency distributions of measurements of greatest shell height and diameter of 294 adult Japanese snails were made in an attempt to distinguish age groups (fig. 3). Van Cleave and Lederer (1932) have shown that the males of *V. contectoides* are smaller than the females. Although we noted among the larger Japanese snails that the males tended to be slightly smaller than the females, we did not measure the sexes separately to determine the degree of sexual dimorphism. Greatest shell diameters for the combined males and females ranged from 22 to 46 mm, and greatest heights from 30 to 65 mm; both measurements showed a bimodal distribution, suggesting that two age groups of adults were present. We believe that each mode is composed of the males and females of a single age group, and that the smaller individuals of each mode are predominantly males and the larger ones females.

Natural Mortality

During a preliminary survey of the area in March, 1963, many decomposing Japanese snails were seen floating in the bay. This mortality probably resulted from winter kill, old age, or both. Considerable mortality was also noticed in the marshes bordering the bay during the summer, when the marshland was drying up and many snails were stranded on hard, sun-baked mud and clay.

ASSOCIATED MACROBENTHOS

Although the Japanese snail was our primary concern, gross observations of associated invertebrates taken at each station were also made. The most common organisms were gastropods (other than the Japanese snail) and pelecypods (table 1). A synopsis of macrobenthos other than mollusks is given in table 2.

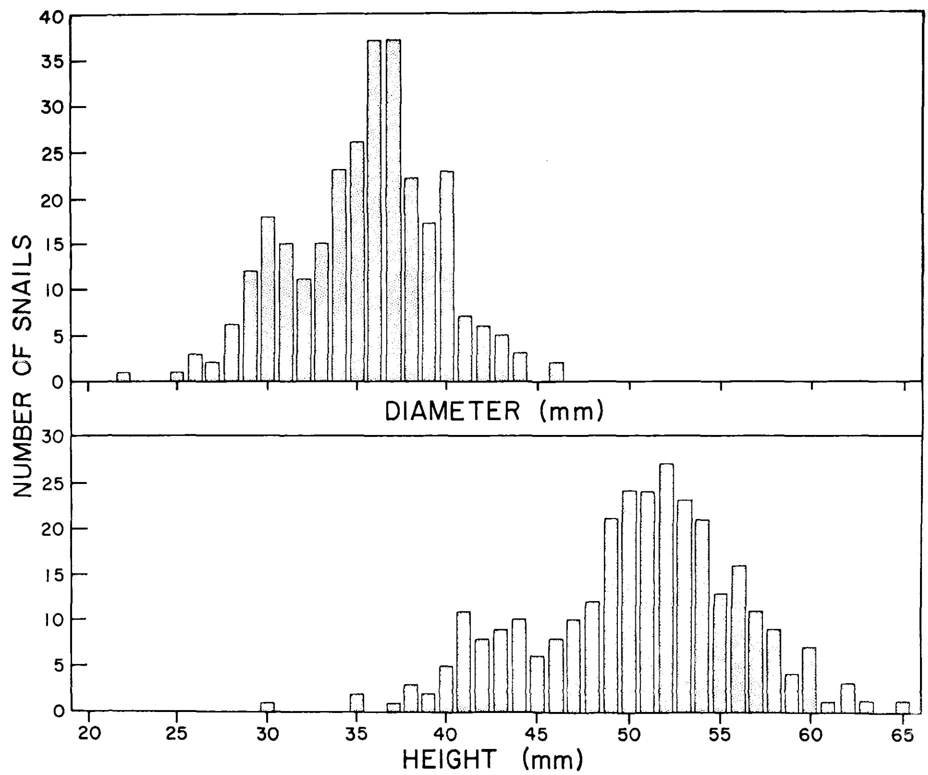

FIGURE 3. Frequency distributions of greatest shell height and greatest shell diameter of 294 adult *Viviparus japonicus* from Sandusky Bay.

Gastropoda

The second-most-abundant snail in the bay was another viviparid, *Campeloma decisum*. It was distributed throughout the entire bay, but was most abundant near the mouth of Sandusky Bay, where nearly 90 percent of the 72 specimens were taken. The distribution of *Pleurocera acuta* was scattered, although nearly 45 percent of the specimens were collected from the protected area between the two causeways (stations 11–15). One *Bulimus tentaculatus* was obtained (station 23); because no individuals of this small species were taken by dredge, we concluded that the species was sparsely distributed.

TABLE 1

*Number of mollusks taken in trawl hauls and dredge samples from Sandusky Bay, Lake Erie, in June 1963, listed in order of abundance**

species	trawl hauls	dredge samples
Gastropoda		
Viviparus japonicus (van Martens)		
Adult	2,972	3
Juvenile	803	9
Campeloma decisum (Say)	57	15
Pleurocera acuta Rafinesque	18	0
Bulimus tentaculatus (Linnaeus)	1	0
Pelecypoda		
Sphaeriidae		
Sphaerium transversum (Say)	147	73
Pisidium henslowanum (Sheppard)	0	9
Pisidium compressum Prime	0	1
Pisidium casertanum (Poli)	0	1
Unionidae		
Lampsilis siliquoidea (Barnes)	63	0
Truncilla donaciformis (Lea)	62	0
Carunculina parva (Barnes)	16	1
Proptera alata (Say)	14	0
Obliquaria reflexa Rafinesque	11	0
Anodonta grandis Say	10	0
Quadrula pustulosa Lea	7	1
Truncilla truncata Rafinesque	7	0
Quadrula quadrula (Rafinesque)	5	0
Amblema costata Rafinesque	5	0
Leptodea fragilis Rafinesque	4	0
Ligumia recta latissima (Rafinesque)	3	0
Fusconaia flava (Rafinesque)	3	0
Ligumia nasuta (Say)	2	0
Pleurobema cordatum coccineum (Conrad)	1	0
Lampsilis ventricosa (Barnes)	1	0
Elliptio dilatatus (Rafinesque)	1	0
Anodonta imbecillis Say	1	0

*The classification of the snails follows Goodrich (1932) and Berry (1943); the Sphaeriidae follow Herrington (1962); and, the Unionidae are classified according to Heard and Burch (1966).

Pelecypoda

The family Sphaeriidae was represented by species of *Pisidium* and *Sphaerium*, which are common in Lake Erie. *S. transversum*, a species very abundant at the mouth of the Detroit River (Carr and Hiltunen, 1965), was the most abundant fingernail clam in Sandusky Bay. Although it is not large in size, it was so abundant that many, including nepionics, were captured even in the trawl. The greatest concentration was in the Lower Bay. Sixty-six percent of all *S. transversum* taken by both trawl and dredge were from stations 17 and 18, where adult Japanese snails were also most abundant. Dredge samples from these stations yielded 1,048 *S. transversum* per m^2. At station 6, all individuals (15) of this species caught were dead; because no decomposition was apparent, the mortality must have been recent. This was the station from which the many empty shells of juvenile Japanese snails, discussed previously, were obtained.

A total of 216 Unionidae were taken with the trawl. Almost 50 percent were caught at stations 13, 17, and 29. *Lampsilis siliquoidea* and *Truncilla donaciformis* made up nearly 58 percent of all unionids taken.

Langlois (1954) listed 33 unionid species that have been reported from western

Lake Erie. Carr and Hiltunen (1965) discovered one additional species (*Leptodea laevissima*). In the present study, 18 of these species were found in Sandusky Bay.

TABLE 2

Summary of invertebrates other than mollusks in Ekman dredge samples from Sandusky Bay, Lake Erie, June 4–21, 1963

Taxonomic group	Remarks*
Hydra spp.	Present at stations 30 and 35.
Nemata	Present in nearly all samples.
Bryozoa	Found on *Viviparus japonicus* shells at few stations.
Hirudinea	One collected at each of stations 17 and 27.
Oligochaeta	Group well represented at all stations. *Branchiura sowerbii* Beddard most common; present at all but 7 stations. Greatest number (24) found at station 31.
Polychaeta	Twenty-three *Manayunkia speciosa* Leidy found only at station 35.
Cladocera and Copepoda	Present at all stations. Most numerous at stations 30 and 31. *Leptodora kindtii* (Focke) frequently present.
Amphipoda	*Gammarus* sp. present at 4 scattered stations; most (6) were at station 23.
Isopoda	One *Asellus militaris* Hay taken at each of stations 17, 24, and 30 and 4 at station 23.
Diptera	Heleidae were present at 6 stations. Tendipedidae were present at all but 3 stations. *Coelotanypus concinnus* (Coquillett) and species of *Tendipes*, *Procladius*, and *Pelopia* predominated. One specimen of *Chaoborus* sp. was found at station 3.
Ephemeroptera	*Hexagenia* sp. was found at 10 stations, most of which are in the Lower Bay. Number of individuals present at each station ranged from 1 to 3. Three specimens of Caenidae were present at station 23. One unidentified specimen taken at station 16.
Trichoptera	One specimen of *Oecetis* sp. was collected at station 26.
Hydracarina	Present at 6 scattered stations.

*See figure 1 for location of stations.

ACKNOWLEDGMENTS

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Most of the mollusks collected have been deposited in the Museum of Zoology of The University of Michigan.

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