Supershrimp: Deep Bioturbation in the Strait of Canso, Nova Scotia

Abstract. Axius serratus, *a crustacean thought to be extremely rare, was discovered in large numbers in polluted regions of the Strait of Canso. The shrimp may live deeper than 3 meters in the sediment; burrows are kept open to at least 2.5 meters. Sediment contained in old filled burrows is anomalous in its distribution of particle size and its content of water, organic carbon, and trace elements. These anomalous qualitites affect the geotechnical properties of sediments on the sea floor.*

Recent studies of the benthic ecology of a portion of the eastern coast of Canada revealed large populations of a burrowing shrimp, of a species previously thought to be extremely rare. The shrimp occurs in areas subject to heavy discharge of industrial pollutants, makes extremely deep burrows, and is associated with sediment having altered physical, geotechnical, and geochemical properties.

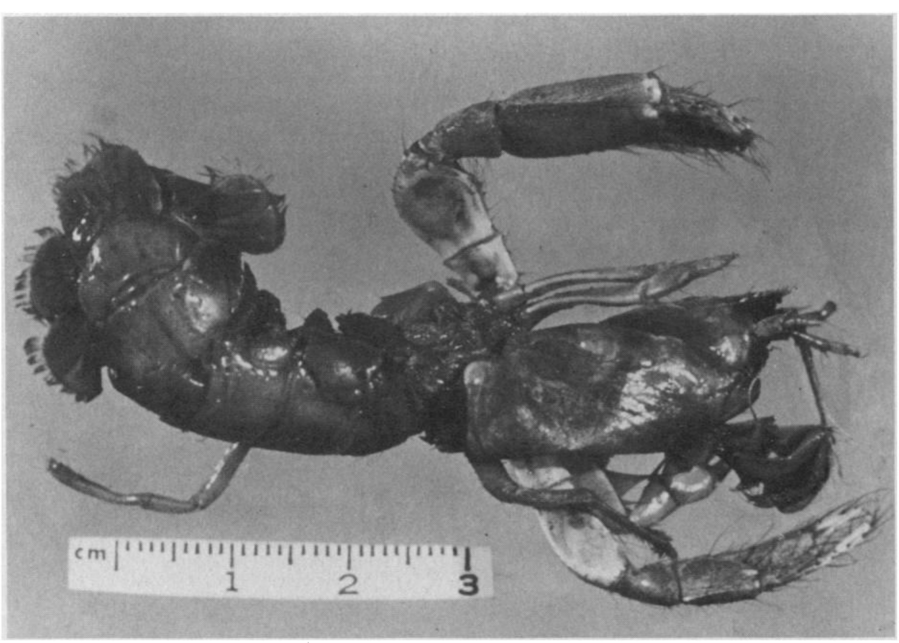
In 1954, a causeway was completed between mainland Nova Scotia and Cape Breton Island across the Strait of Canso. Construction of the causeway inadvertently created an excellent year-round deep-water harbor. Recognizing the ideal setting for port facilities, industry began to move into the area. Located at present on the strait south of the causeway are a gypsum drywall plant, a pulp and paper mill, a heavy water plant, and an oil refinery. Further industrial developments are planned.

During the summer of 1973, a team of scientists and technicians from the Atlantic Geoscience Centre began an integrated multidisciplinary study of the impact of man on the marine environment of the Strait of Canso (*1*). Off Eddy Point on the south side of the causeway, a live shrimp (Fig. 1) was found intact in its burrow 10 cm below the surface of the cored sediment. The burrow continued the length of the 110-cm core. All the cores taken south of the causeway contained shrimp burrows. Filled burrows penetrated by the core sample appear as oval or semicircular patches of reddish brown sand, similar to surface sediment, and are often surrounded by oxidized halos. No shrimp burrows were identified from cores taken north of the causeway, which suggests that the shrimp has invaded the relatively more polluted habitats south of the causeway only since the advent of industrial development about 1960.

The shrimp was identified as *Axius serratus* Stimpson 1852, a species noted only five times from the Atlantic coast of North America (*2*). Only one individual has been reported from the Canadian coastline (*2*). It belongs to the superfamily Thalassinidae, or "mud shrimp," which are noted for their burrowing ability (*3*). *Axius serratus* has been found off New England in 10 to 42 fathoms (18 to 77 m) of water. The genus *Axius* occurs in depths of water from intertidal to 381 fathoms (697 m).

Investigations by scuba divers in the summer of 1974 indicated that *A. serratus* is common south of the causeway. The belief that the genus is rare arose as a result of the difficulties involved in capturing deep-burrowing organisms. Open burrows were found in all areas studied in depths from 7.5 to 11.5 m, the maximum depth sampled. Open burrows were most abundant in the highly polluted sediments adjacent to the urban and industrialized shores, areas barren of living foraminifera, mollusca, and ostracods (*1*). Burrow openings are 1 to 3 cm in diameter, and lack the volcano-like cone of sediment produced by *Callianassa*, a related shrimp. We investigated occupancy of open burrows and the extent of linked burrow complexes by squirting solutions of potassium permanganate down the burrows: a live shrimp will forcibly expel the irritating dye. Dye expulsion indicated that all open burrows were occupied and generally had only one opening to the surface. No connected burrow complexes were found. In the areas studied, average population density was about nine per square meter. Maximum population densities were found in highly polluted areas.

To investigate the burrows at depth, a high-capacity underwater suction dredge was constructed. The sediment-water



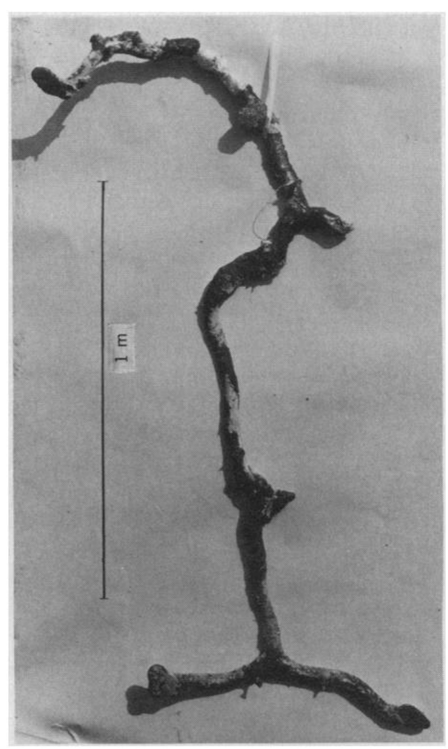


Fig. 1 (left). *Axius serratus*, the live specimen obtained from a cored sample by the Atlantic Geoscience Centre. The thorax was damaged and the carapace distorted during the cutting of the core. Fig. 2 (right). Polyester resin cast of burrow of *Axius serratus*, front view, oriented as it occurred in the sediment. The upper 30 to 40 cm were not recovered.

slurry sucked up by the dredge was passed through a fine mesh bag to collect any organisms present. Although several square meters of bottom were excavated to a depth of 3 m, no live shrimp were recovered. The burrow systems are evidently deeper than 3 m, and the animals are able to escape the dredge by seeking lower levels.

The dredge was used to remove the upper meter of sediment in several areas of high burrow concentration. Fresh sediment was then used to refill excavated areas. Overnight, burrows were reestablished in the same densities, and in approximately the same locations.

Polyester casts were made of burrows, using a modification of Shinn's technique (*4*), which allows the diver to mix the resin on the bottom. To remove the hardened casts the next day required one diver to steady the cast and hold the hose of the suction dredge, and another, headdown in the hole, to guide the dredge around the cast. One of the casts recovered (Fig. 2) is 2.2 m high, but the upper 30 to 40 cm of the burrow were not recovered. The burrow system is open and more than 2.5 m deep in the substrate. To the best of our knowledge this represents the deepest verified bioturbation ever recorded. In some of the cores, skeletons of recent marine foraminifera were carried down and emplaced in Pleistocene lacustrine clays.

Casts have a vertically oriented semicircular cross section, a characteristic that can also be identified in the cores. Many of the burrows were lined with eel grass, which adhered to the exterior of the casts. Several casts have a knobby exterior, similar to that of the trace fossil *Ophiomorpha nodosa* (*5*). As Seilacher pointed out (*6*), any trace fossil may have been produced by several different species of animals. Burrows of *A. serratus* have the same cross section as *Alpheus* (*4*), although their orientations differ. *Alpheus* burrows have a flat "floor" and an arched "roof"; *A. serratus* burrows have one flat and one curved "wall." Burrows of *A. serratus* have a morphology and knobby exterior similar to burrows made by *Callianassa*.

The presence of these deep burrows in the Strait of Canso is potentially of tremendous sedimentological and geochemical importance because of the profound disruption in the normal stratigraphic layering of sediments. Computer simulation of burrow complexes indicates that, in areas of average population density (nine burrows per square meter), it is virtually impossible to recover an undisturbed core. One of the cores taken in the original Atlantic Geoscience Centre study shows six burrow intersections over a total length of 1.2 m. The accuracy of age dating and stratigraphic work depends on the recognition of these burrowed areas. In areas with a high density of burrows, such work is virtually impossible.

Surface sediment south of the causeway where *A. serratus* occurs contains more water and organic carbon than otherwise similar sediment north of the causeway. The sand in the burrows also contains an unusual amount of water and exhibits different geotechnical properties from the surrounding sediment. Water content is often so high that the burrow infillings are thixotropic. Where *A. serratus* is abundant, therefore, much of the sea floor is underlain, to a depth of at least 2 m, by unstable sediment-water mixtures.

The rate of the geochemical reaction reaches a maximum value at the sediment-water interface. A burrow is an extension of this interface, and the burrows in the study areas increase the area of interface by a factor of at least 4. Sediment filling the burrows contains less clay and organic carbon than does the surface sediment it resembles, and is also associated with anomalous concentrations of lead, zinc, copper, and iron.

In the ecologically sensitive Strait of Canso, the activities of *Axius serratus* are important in burying and recycling pollutants, concentrating trace elements, and accelerating the rate of reaction at the sediment-water interface (*1*).

GEORGE S. PEMBERTON
MICHAEL J. RISK
Department of Geology, McMaster University, Hamilton, Ontario, Canada L8S 4M1
DALE E. BUCKLEY
Atlantic Geoscience Centre, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2

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7. We thank J. Fournier of the Canadian Oceanographic Identification Centre for the identification of *Axius serratus*, Dr. R. Venter for computer simulations, and R. Cavan for diving assistance in hazardous conditions. Supported by Research Agreement 1135-D13-4-68/75 with the Canada Department of Energy, Mines and Resources.

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Alpha-Adrenergic Receptor Identification by [^{3}H]Dihydroergocryptine Binding

Abstract. *A radioactively labeled α-adrenergic antagonist, [^{3}H]dihydroergocryptine, binds specifically to a site on rabbit uterine membranes. Binding is rapid, reaching equilibrium in less than 17 minutes at 25°C. Adrenergic agonists compete for this binding site with an order of affinities identical to the pharmacological potency order of these agents as α-adrenergic agonists (epinephrine > norepinephrine ≫ isoproterenol). The (−) stereoisomers of epinephrine and norepinephrine are 30 times more potent in competing for the site than the corresponding (+) stereoisomers. α-Adrenergic antagonists, such as phentolamine and phenoxybenzamine, potently compete for the binding sites while the β-adrenergic antagonist propranolol does not. Structural analogs of catecholamines that are devoid of α-adrenergic physiological activity do not compete for [^{3}H]dihydroergocryptine binding sites. These data suggest that α-adrenergic receptors can be directly identified and studied by [^{3}H]dihydroergocryptine binding.*

The diverse physiological effects of the endogenous catecholamines epinephrine and norepinephrine can be divided into two groups designated alpha and beta. This classification (*1*), which is based on the characteristic potency orders of catecholamines in stimulating these responses and on the selective inhibition of the responses by specific antagonists, has suggested that two distinct types of catecholamine receptors mediate the responses. Typical adrenergic responses mediated by α-adrenergic receptors are contraction of vascular, bronchial, and uterine smooth muscle. Typical β-adrenergic responses are relaxation of smooth muscle and stimulation of cardiac contractility.

Until recently adrenergic receptors, as well as other hormone receptors, were defined only in a functional sense, and their existence as physicochemical entities was inferred but not documented. The use of radioactively labeled hor-