Life Below the Ross Ice Shelf, Antarctica

Abstract. *Samples and observations under 420 meters of ice and 430 kilometers from the open sea on the Ross Ice Shelf at a water depth of 597 meters revealed an unusual assemblage of benthic organisms. Scavenging amphipods, an isopod, and fish were present but a living infauna was absent. The observations may be accounted for by sampling or spatial bias, or by extremely low or fluctuating trophic resources.*

For many years scientists of various disciplines hoped to drill a hole through a permanent antarctic ice shelf for a variety of reasons (*1*). A principal reason was to discover whether or not life was present and how it functioned in the waters under such a shelf far from the productive open sea. The Ross Ice Shelf Project (RISP) was organized to drill a hole or holes through the Ross Ice Shelf. In 1977 to 1978 a hole was successfully drilled at a site known as J9 about 430 km from the open Ross Sea (82°22.5′S, 168°37.5′W) through 420 m of ice which was underlain by a water column 237 m thick (*2*). Water depth was 597 m. Here we found the first-known biota living under a permanent ice shelf far from the open sea.

The biota we found (Table 1) was unlike those expected by other workers. Because the thickness of the ice precludes primary production at the surface, the original RISP planners had suggested that a subice biome might be absent altogether or that a highly specialized, novel assemblage might be found in which photosynthetic organisms utilize light from other bioluminescent organisms in a self-sustaining ecosystem (*3*). Catches through cracks near the edge of the Ross Ice Shelf and in an area with a very thin ice cover on George VI Sound Ice Shelf (*4*) revealed a somewhat typical antarctic assemblage (*5*). However, this assemblage could not support any hypothesis because it was all collected from sites that were not characteristic of most of the area below large ice shelves (*6*).

For purposes of planning, we anticipated that we might find either an abundant antarctic biota supported by high concentrations of nutrients carried under the ice by currents (*5*), or a sparse but diverse biota in a low nutrient situation analogous to that of the oligotrophic deep sea (*7*). In order to test these ideas, we used the RISP down- and side-looking television camera, photographic observations, trapping techniques, and bottom sampling (*8*). The television was used to observe the undisturbed bottom and bait, whereas the photography focused on the water column and bottom. Traps were steel frames 20 cm in diameter covered with 1.25-cm wire mesh with conical entrances at either end and bags of seal meat tied inside. The sphincter sampler consisted of a steel barrel 1 m long with a cutting edge at the lower end together with a sailcloth sphincter that rotated shut upon withdrawal from the sediment. Lead weights were stacked on top of the barrel to maximize the diameter (22.5 cm) of the sampler relative to the predicted working diameter of the ice hole (25 cm). Bottom sediments were penetrated by rapid but controlled descent for the last 10 to 20 m, and they were retained relatively undisturbed in a plastic barrel liner.

We began biological work on 15 December 1977 using the down-looking television as part of a general inspection of the hole, water column, and bottom. The sea bed was first viewed at 2000 hours and appeared as a muddy surface devoid of any animal tracks or trails but with blocky clasts several centimeters across of indurated clay and silt. After 10 minutes an unidentifiable animal glided swiftly across the field of view. About 25 minutes later, another animal, probably a crustacean (resembling, in its large eyes and thin body, a mysid shrimp) swam in front of the lens. Later, at 0230 hours on 16 December, a plastic bottle trap containing a smaller perforated bottle with seal meat bait in it reached the bottom with the side-looking television lens. After about 2 minutes, amphipods approached the bottle, and we continued to observe them for 4 hours. A dozen or more individuals were observed, but as they did not remain in the small field of view an accurate count could not be obtained. The animals were actively swimming in and out of, and around the bottle. One of these amphi-

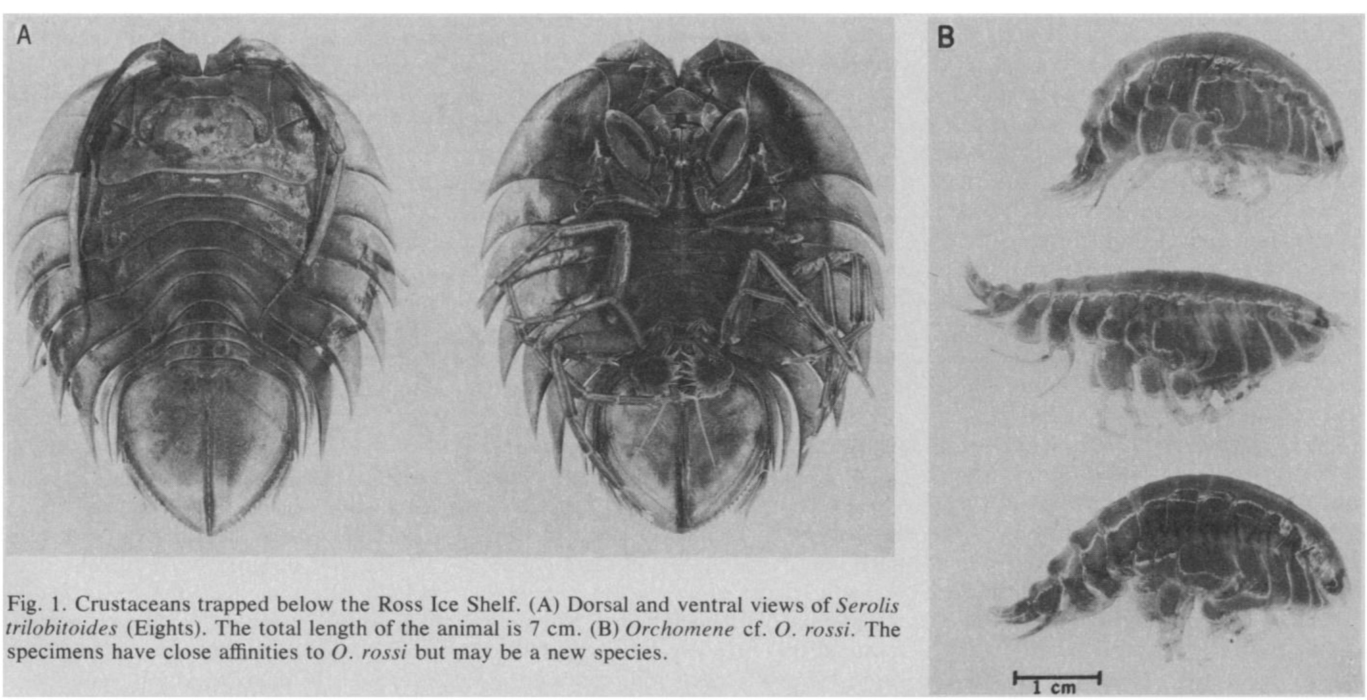

Fig. 1. Crustaceans trapped below the Ross Ice Shelf. (A) Dorsal and ventral views of *Serolis trilobitoides* (Eights). The total length of the animal is 7 cm. (B) *Orchomene* cf. *O. rossi*. The specimens have close affinities to *O. rossi* but may be a new species.

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Table 1. List of organisms observed or retrieved from below the Ross Ice Shelf at J9. Data from (16).

Organism	Televised	Photo-graphed	Trapped	Skeletons in mud
Foraminiferida				X
Bivalvia				X
Gastropoda				X
Polychaete (?) tubes				X
Mysidae?	X			
Euphausiidae?	X			
Amphipoda				
Orchomene plebes			X	
Orchomene rossi			X	
Orchomene n. sp.?			X	
Ostracoda				X
Isopoda				
Serolis trilobitoides (Eights)			X	
Fish				
Trematomus cf. *T. loennbergii*		X		
(?) *Gymnodraco acuticeps*		X		

pods, *Orchomene plebes*, was captured in the trap.

On 20 December another run was made with the side-looking television lens and a baited plastic bottle. After 5 minutes, the first amphipod appeared. Numerous individuals, ranging in size up to approximately 4 cm, moved in and out of view and squirmed around the bottle causing mud to stick to their backs. The next day a cloth bait bag was hung below the television camera. As soon as it touched the sea floor, amphipods grabbed onto the bag and then rarely moved until it was retrieved 2 hours later. In contrast to the bait bottle used previously, the animals could feed directly on the bait through the bag and thus did not display the frantic search observed before. Some amphipods clung to the bag as it was retrieved, one individual remaining all the way into the ice hole. During the ascent and approximately 50 m off the bottom another animal, also probably a crustacean, passed rapidly through the field of view.

On 22 December, two wire traps with bait bags were placed on the bottom for 3 hours 45 minutes. Four amphipods were caught. In two later trapping runs of $5^1/_2$ and 6 hours we caught 131 amphipods and one isopod (Fig. 1). In another run, three traps snagged on the bottom of the ice hole and fell to the sea bottom, where they were later observed with the television.

On 1 to 2 January 1978, the television camera was placed inside a wire trap and lowered to the bottom. Amphipods again appeared quickly and soon several hundred were clinging in bunches to the bait bags. On lifting this assembly from the bottom, a large number of animals fell or swam out of the trap, and as it approached the lower-salinity, higher-temperature, and fuel-contaminated water near the ice hole, the remaining amphipods became very active and many more were lost. A total of 125 amphipods were retrieved, suggesting that there may have been as many as 400 to 500 in the trap originally. Bottom photographs taken at this time show two fish, possibly of different species (*9*). We believe the fish and abundant crustaceans had been attracted to the area by the sampling activities and bait lost on the bottom, much as happens when bait cans are left on the oligotrophic deep-sea floor (*10*).

We obtained ten nearly undisturbed sphincter samples with a total surface area of about 0.33 m^2. Because of ice-shelf movement, these samples were taken along a track 12 m long. Two disturbed, partial samples were also taken. The samples were sliced into 1-cm thick sections and preserved in buffered formalin or kept refrigerated for later radiography. The sediment, a massive silt-clay diamicton derived from underlying Miocene deposits (*11*), showed no traces on the surface of animal activity, no bioturbation, and no fecal pellets. Laboratory analysis of the radiographs and mud samples failed to reveal any living infauna. Meiofaunal bivalve, gastropod, ostracod, and foraminifera skeletons were found.

In many respects the area under J9 resembles the oligotrophic deep sea: bacterial numbers in the sediment are nearly equivalent (*12*), total organic carbon is only slightly greater (*13*), and vagile scavengers predominate. It differs in lacking an infauna. The oligotrophic deep sea, including that of the high Arctic, has on the order of 100 species of megafaunal and meiofaunal (including foraminifera) taxa per square meter and three times as many individuals (plus 3000 foraminifera) per square meter (*7*, *14*). Thus, if the comparison had held, in our 0.33-m^2 sample we might have expected 30 species and 100 living individuals.

There are six possible interpretations for our observations. (i) Our sample size was inadequate to capture an infauna. We suspect that an infauna of larger organisms is absent at J9 because the sediment surface and radiographs showed no traces of remnant infaunal activity; we would expect that over the long period of time the sediments were exposed, sooner or later it would have been burrowed. (ii) The infauna is patchy under the shelf. We have no way of testing this hypothesis other than by additional sampling at other sites. Again, because of the lack of animal traces and bioturbation, we assume that the patches remain stationary, that if they do move they never crossed our sampling track, or that they do not exist. (iii) The J9 sediment cannot be burrowed. Sediment returned to southern California was quickly and successfully burrowed by that local infauna, demonstrating that in a disturbed state, at least, the sediment was not inhospitable. (iv) Anaerobic conditions restrict the fauna. No reliable measurements were made at J9, but there is no evidence in the sediments of low oxygen concentrations. (v) Nutrient supply is so low that an infauna cannot survive. Although low nutrient regimes have been associated with high species richness (*7*, *14*), at some point nutrient supply must get so low that animals cannot survive. Perhaps the sediment under the Ross Ice Shelf is such a place. If the bacterial standing crop were aggregated (*12*) or productivity were slow at J9, then the energy received by organisms might not compensate for that utilized in searching for it. Likewise, if the organisms living in the water column (*12*) are quickly utilized by the scavengers, perhaps so little is left that an infauna cannot be supported. (vi) Trophic resources are temporally unstable. In areas of trophic instability species richness is commonly decreased (*15*). Possibly the trophic resources fluctuate under the ice shelf since they are ultimately derived from the highly seasonal open Ross Sea 430 km to the north. Thus fluctuating resources could depress species richness while the low nutrient level could result in low biomass.

Which of these hypotheses or of others that may be suggested is correct cannot be determined on the basis of the 1977 to 1978 samples. Additional material will be collected again at J9 in 1978 to 1979, but the many questions will be answered only when we obtain samples from elsewhere under the shelf. The Ross Ice Shelf may be a natural experiment in which the relation between aspects of trophic resources and community structure can be observed.

JERE H. LIPPS
Department of Geology and *Institute of Ecology, University of California, Davis 95616*

T. E. RONAN, JR.
Department of Earth and Space Sciences, University of California, Los Angeles 90024

T. E. DELACA
Department of Geology and *Institute of Ecology, University of California, Davis*

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Fish, Crustaceans, and the Sea Floor Under the Ross Ice Shelf

Abstract. *Baited traps and a camera lowered through the Ross Ice Shelf, Antarctica, at a point 475 kilometers from the open Ross Sea and to 597 meters below sea level revealed the presence of fish, many amphipods, and one isopod. Biological or current markings were not evident on a soft bottom littered with subangular lumps. A fish was caught through a crevasse 80 kilometers from the shelf edge.*

Until recently, the existence of life in the relatively deep cul-de-sacs beneath the large Antarctic ice shelves was primarily a topic of speculation (*1*). Evidence for life was limited to the collection of specimens in or through natural cracks in the shelf ice: diatoms obtained near the surface 520 km from the open sea (*2*) and amphipods and a fish obtained about 25 km from the leading edge and at depths of 40 to 75 m (*3*). Fish have also been taken from a proglacial lake adjacent to another ice shelf (*4*). Since the completion of an access hole through the Ross Ice Shelf at 82°22.5′S, 168°37.5′W, 475 km from the open Ross Sea (*5*) several additional pieces of evidence for life have been obtained. We report here some of the observations made with a camera (*6*) and baited traps (*7*). These observations were made near the sea floor, 597 m below sea level and 237 m below the base of the ice shelf. Temperature was −1.86°C (0.5°C above the in situ freezing point) and salinity was 34.83 per mil (*8*). Tidal currents were measured with amplitudes up to 17 cm per second (*9*).

The traps collected over 130 large (4 cm) red gammarid amphipods, *Orchomene* cf. *O. rossi*, and small amphipods, *Orchomene plebes* sp. (*10*); and one 7-cm isopod, *Seriolis trilobitoides* (*11*). Examination of the guts of several of the large amphipods revealed no contents other than bait (*12*). Brood pouches of some of the large amphipods contained eggs and juveniles (*13*). The amphipods and isopod were examined for bioluminescence while they were still alive, but no luminescence was observed. During several years of trapping benthic animals near the shelf edge in McMurdo Sound, we (A.L.D. and J.A.R.) failed to trap either the large amphipod or the isopod. However, the isopod is common in other parts of Antarctica (*14*). Baited hooks attached to the trap line in the lower 50 m of the water column failed to catch any fish (*15*).

Several hundred photographs were taken of the sea floor during five camera lowerings. They show a soft bottom littered with subangular pieces of material (Fig. 1). Markings made by currents or by animals were not seen in any of the photographs, in marked contrast to many observations we (P.M.B. and S.S.J.) have made of the sea floor north of the ice shelf in the Ross Sea (*16*). A relatively small area was photographed beneath the ice shelf because the movement of ice is only about 1 to 2 m per day.

Two photographs of fish were obtained. We identify one (Fig. 2A) as *Trematomus* sp., most likely *T. loennbergii*, less likely *T. lepidorhinus*, both of which are common at similar depths in McMurdo Sound and the Ross Sea (*17*). The animal in Fig. 2B is probably also a fish, but from the poor quality of the image we cannot exclude the possibility of its being a crustacean. The animal resembles a naked dragon fish, *Gymnodraco acuticeps*. The adults of that species are fairly common in shallow water in McMurdo Sound. However, a problem with this interpretation is that the presumed "snout" is too long for *Gymnodraco*, and the ratio of distance between the eyes to snout and lower jaw length is only half that of known *Gymnodraco* specimens. Another possible interpretation is that what appears to be a pointed snout is actually a crustacean being consumed by another species of fish, possibly a *Pogonophryne* or *Trematomus*. This is supported by the presence of three barely visible pairs of "appendages" attached to the "snout" (*18*).

In December 1976 we (A.L.D. and P.M.B.) lowered a trap through a crevasse on the Ross Ice Shelf near Minna Bluff, 80 km from the shelf edge (*5*). The ice thickness and water layer at this point are approximately 275 m and 500 m, respectively. A 28-g *Trematomus borchgrevinki* measuring 17 cm in length was caught 39 m below sea level during a 48-hour fishing period. This fish, which is also common to McMurdo Sound, had an empty gut.

It is likely that the fish beneath the ice shelf feed on the amphipods, but a food source for the amphipods and isopod is less obvious. The apparent paucity of organisms in the water column (*19*) and the absence of natural contents in the amphipod guts indicate that the food supply is scarce. The sighting of a possible mysid