swered 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.

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References and Notes

1. J. H. Zumberge, *Antarct. J. U.S.* **6**, 258 (1971).
2. J. W. Clough and B. L. Hansen, *Science* **203**, 433 (1979).
3. Ross Ice Shelf Steering Group, *RISP Science Plan* (RISP Management Office, Lincoln, Neb., 1974).
4. J. L. Littlepage and J. S. Pearse, *Science* **137**, 679 (1962); R. B. Heywood and J. J. Light, *Nature (London)* **254**, 591 (1975).
5. P. M. Arnaud, *Nature (London)* **256**, 521 (1975).
6. J. H. Lipps, W. N. Krebs, N. K. Temnikow, *ibid.* **265**, 232 (1977).
7. R. R. Hessler and P. A. Jumars, *Deep-Sea Res.* **21**, 185 (1974).
8. The RISP underwater television system was assembled by V. B. Kuechle, University of Minnesota, and operated chiefly by J. W. Clough, RISP office; the underwater photography was done by P. M. Bruchhausen and S. S. Jacobs, Lamont-Doherty Geological Observatory; traps were deisgned and built by A. L. DeVries, University of Illinois, and operated by J. Raymond, Alaska Fish and Game, and J. W. Clough; the bottom sampler was built by Crocker Nuclear Laboratory machine shop, University of California, Davis, under the supervision of T. E. DeLaca. The design was modified from J. C. Burke [*Limnol. Oceanogr.* **13**, 714 (1968)] with the assistance of R. R. Hessler, Scripps Institution of Oceanography.
9. P. M. Bruchhausen, J. A. Raymond, S. S. Jacobs, A. L. DeVries, E. M. Thorndike, H. H. DeWitt, *Science* **203**, 449 (1979).
10. R. R. Hessler, J. D. Isaacs, E. L. Mills, *ibid.* **175**, 636 (1972).
11. P. N. Webb, T. E. Ronan, Jr., J. H. Lipps, T. E. DeLaca, *Science* **203**, 435 (1979); T. E. Ronan, P. N. Webb, J. H. Lipps, T. E. DeLaca, *Antarct. J. U.S.*, in press.
12. F. Azam, J. R. Beers, L. Campbell, A. F. Carlucci, O. Holm-Hansen, F. M. H. Reid, D. M. Karl, *Science* **203**, 451 (1979).
13. T. E. Ronan and W. E. Reed, unpublished data.
14. A. Z. Paul and R. J. Menzies, *Mar. Biol.* **27**, 251 (1974).
15. J. W. Valentine, *Evolutionary Paleoecology of the Marine Biosphere* (Prentice-Hall, Englewood Cliffs, N.J. 1973), pp. 292–308.
16. J. H. Lipps, T. E. Ronan, Jr., T. E. DeLaca, W. J. Showers, S. S. Jacobs, P. M. Bruchhausen, P. Slattery, unpublished data.
17. We thank the RISP drill team, especially J. Browning of Browning Engineering Corp.; J. Rand, L. Hansen, D. Somerville and R. Bigl; J. W. Clough, P. Marshall, and W. Rierden of RISP; G. Llano, R. Cameron, D. Bresnahan, and K. Moulton, NSF Division of Polar Programs; Holmes and Narver, Inc.; and the U.S. Navy Antarctic Support Force for assistance. Supported by NSF grant DPP 76-21735 to J.H.L.

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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

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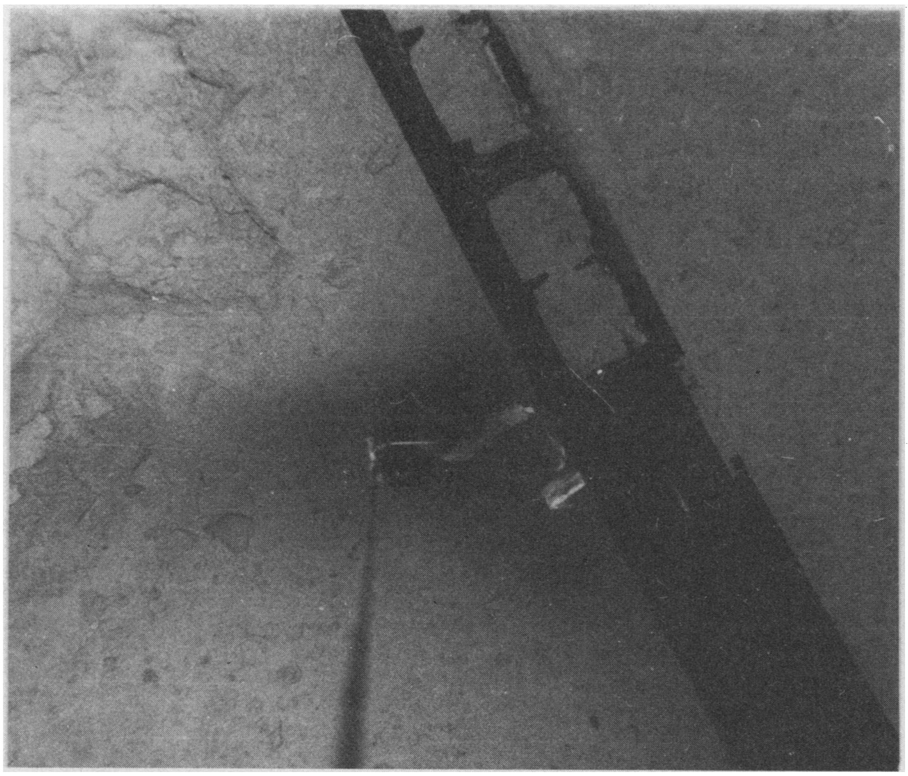

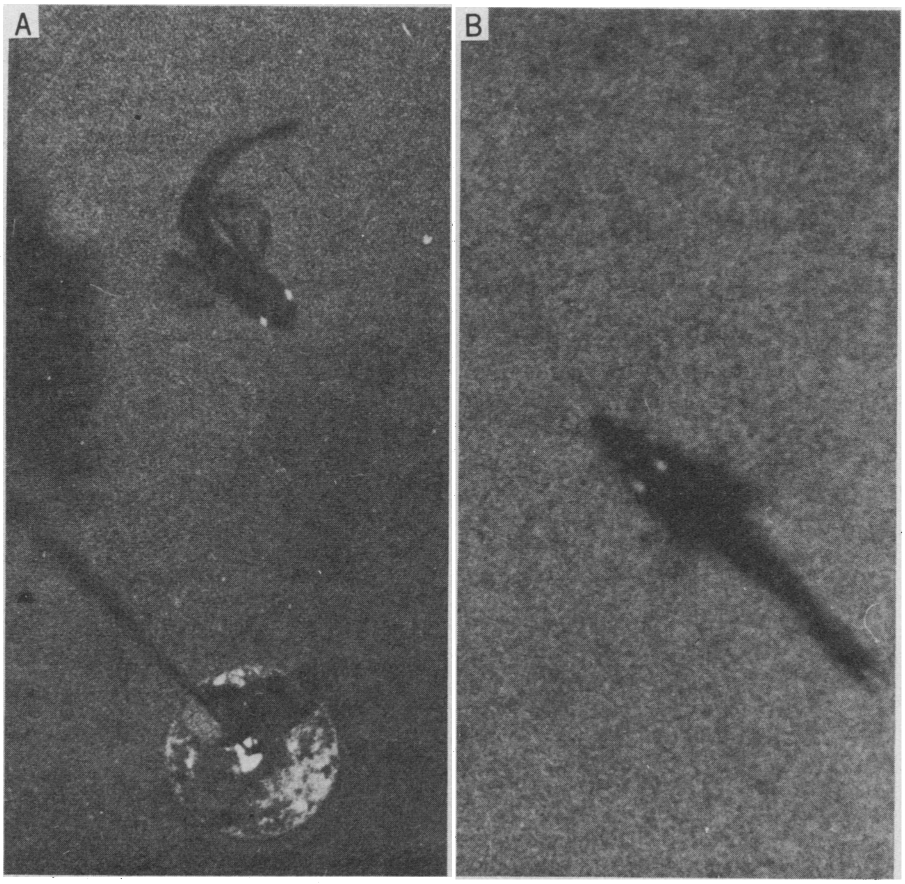

Fig. 1 (top). Photograph of the sea floor 597 m below sea level and 237 m beneath the Ross Ice Shelf at 82°22.5′S 168°37.5′W. The object appearing diagonally across the frame is a nephelometer with a width of 16 cm, lost when its supporting cable slipped from an iced-up sheave, breaking a weak link. The bottom at left of frame has been disturbed by another instrument. A weight with bait attached and supporting cable hangs beneath the camera. Fig. 2 (bottom). (A) An 18-cm *Trematomus (loennbergii?)* photographed near the sea floor beneath the Ross Ice Shelf. Bait is attached to the cylindrical weight that is suspended below the camera. (B) A 10- to 12-cm fish (?), possibly a *Gymnodraco acuticeps*, or a *Pogonophryne* or *Trematomus* with crustacean in its mouth, near the sea floor beneath the Ross Ice Shelf.

shrimp (*20*), which may have drifted under the shelf with the current, suggests that these animals are one food source for the community as well as a source of red pigment for the amphipods. The rapid aggregation at the site of amphipods with empty stomachs may support the concept of an opportunistic diet (*21*). Amphipods with empty guts have been trapped in the abyssal depths (>5000 m) of the Pacific (*22*). Crevasses through the Ross Ice Shelf (*2*) are very small in area and any phytoplankton food source is probably of negligible importance to the observed biota (*3*). The presence of these life forms beneath the ice shelf far from the open sea thus implies an active horizontal circulation that can move plankton and detritus southward from the Ross Sea. We do not know the extent of biological activity in the Ice Shelf Water that subsequently emerges from beneath the ice shelf (*8*), but oligotrophic conditions have been reported in the seawater moving away from the ice shelf in McMurdo Sound (*23*). Although high productivity levels would not be expected in water emerging from this presumably dark environment, the resident population may also act as efficient scavengers.

The fishes and invertebrates sampled near the shelf edge in McMurdo Sound show both variety and abundance (*24*). On the basis of our samples from beneath the Ross Ice Shelf, diversity and abundance there are considerably lower. However, these findings indicate that a significant biological community, apparently without unique forms, exists in a remote region beneath a large Antarctic ice shelf. Similar marine organisms will probably be found as far south as this sea extends—to within 500 km of the South Pole.

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References and Notes

1. J. H. Lipps, W. N. Krebs, N. K. Temnikow, *Nature (London)* **265**, 232 (1977).
2. P. J. Barrett, *ibid.* **256**, 390 (1975).
3. J. L. Littlepage and J. S. Pearse, *Science* **137**, 679 (1962).
4. R. B. Heywood and J. J. Light, *Nature (London)* **254**, 591 (1975).
5. J. W. Clough and B. L. Hansen, *Science* **203**, 433 (1979).
6. The camera system was designed to have a small diameter (15 cm) in order to fit through the proposed drill hole. When a larger hole became available the strobe reflector diameter was increased to 18 cm to provide better illumination. The length of the package is 137 cm. We use a 35-mm F/2.8. Leitz Summaron lens behind a plain glass window. A Brailsford motor transports 9 m of 35mm film, giving 200 exposures with an interval between them of 40 seconds. There is no shutter. Severe lens fouling occurred as a result of DFA (Diesel Fuel Arctic) and slush ice in the hole. The system designed to locate instrument distance above bottom did not perform as anticipated. These factors reduced photograph quality and necessitated the fabrication on site of a lens cap that could be removed below the ice shelf and a trigger weight to sense the bottom. Bait (a piece of knockwürst) was suspended below the camera on some lowerings, including the two on which fish were photographed.
7. The traps were first constructed of 1.3-cm mesh steel screen around a cylindrical steel frame 20 cm in diameter, 60 cm in length. The end of the trap that was up during transit through the hole contained a funnel opening. Later modifications included a finer mesh screen over the bottom quarter of the trap and 12 holes, 2.5 cm in diameter, in the upper part. Traps were self-guided through the hole by way of 45-cm cones made from eight steel rods on each end. Each trap contained three bags of seal meat. Holes were cut in the bait bags to permit easier entry to smaller animals and to reduce specimen losses to turbulence during raising of the trap. Water was poured over the bags and allowed to freeze to avoid contamination from hydrocarbons in the hole. The ice would later melt in the water column (*8*). Two traps were used on each of three separate lowerings, and were set on bottom for periods up to 5.8 hours.
8. S. S. Jacobs, A. L. Gordon, J. L. Ardai, Jr., *Science* **203**, 439 (1979).
9. S. S. Jacobs, P. M. Bruchhausen, J. L. Ardai, Jr., *Antarct. J. U.S.*, in press.
10. Identified by P. Slattery.
11. Identified by J. H. Lipps.
12. Examined by J. Bradford.
13. Examined by T. E. Ronan, Jr.
14. O. G. Kusakin, *Biol. Rep. Sov. Exped. Antarct. 1955–58* **3**, 220 (1968).
15. The lines were set for a total of 34 hook-hours (a product of time and number of hooks used). We (A.L.D. and J.A.R.) have used similar set lines in McMurdo Sound to catch the large antarctic cod (approximately 24 hook-hours per catch), which are abundant there between September and December [J. A. Raymond, *J. Mar. Technol. Soc.* **9**, 32 (1975)].
16. S. S. Jacobs, P. M. Bruchhausen, E. B. Bauer, "*Eltanin* Reports" (Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y., unpublished, 1970), pp. 304–339.
17. The *Trematomus* identification was first made by B. Meyer-Rochow, University of Waikato, New Zealand.
18. L. Watling (University of Maine) believes the "appendages" could be the last three peropods of an amphipod whose pleon is folded ventrally. On the original Ektachrome film are indications of cross stripes on the portion with "appendages"—possibly body segments. Further, there appears to be a color change near the first "appendage" pair, possibly demarking the upper jaw of the fish.
19. F. Azam, J. R. Beers, L. Campbell, A. F. Carlucci, O. Holm-Hansen, F. M. H. Reid, D. M. Karl, *Science* **203**, 451 (1979). We made a plankton tow through the water column beneath the ice shelf with a 15-cm-diameter, 0.25-mm mesh net. The collection vial yielded two sponge spicules and no bioluminescence. The net could have filtered a maximum of 4×10^3 liters of seawater, but may have retained ice collected during descent through the hole.
20. J. H. Lipps, T. E. Ronan, Jr., T. E. DeLaca, *ibid.*, p. 447.
21. P. M. Arnaud, *Nature (London)* **256**, 521 (1975).
22. E. Shulenberger and R. Hessler, *Mar. Biol.* **28**, 185 (1974).
23. P. K. Dayton and J. S. Oliver, *Science* **197**, 55 (1977).
24. J. Dearborn, thesis, Stanford University (1965); W. L. Tressler, in *Biologie Antarctique*, R. Carrick, M. Holdgate, J. Prevost, Eds. (Hermann, Paris, 1964), p. 323.
25. We thank J. L. Ardai, Jr., and the Ross Ice Shelf drillers from Browning Engineering, the U.S. Army Cold Regions Research and Engineering Laboratory, and the University of Nebraska for assistance with the fieldwork. This study was supported by NSF Division of Polar Programs grants C-726 (University of Nebraska), 76-11872 and 77-22209 to Columbia University, 76-82366 to the University of Illinois, and 76-21735 to the University of California, Davis. Lamont-Doherty Geological Observation contribution No. 2770.

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Occurrence and Metabolic Activity of Organisms Under the Ross Ice Shelf, Antarctica, at Station J9

Abstract. *Seawater samples below the Ross Ice Shelf were collected through an access hole at J9, approximately 400 kilometers from the Ross Sea, Antarctica. The 237-meter water column had sparse populations of bacteria (8.7×10^6 to 1.2×10^7 per liter), microplankters (10^2 to 10^3 per cubic meter), and zooplankters (10 to 20 per cubic meter) at the depths studied. Microbial biomass estimates from cellular adenosine 5′-triphosphate measurements were very low (10 to 150 nanograms of carbon per liter), comparable with values for the abyssal ocean. Microbial populations assimilated tritiated* D*-glucose, thymidine, uridine, and adenosine triphosphate at extremely low rates, comparable with deep-sea heterotrophic populations. Sediment samples had 10^7 to 10^8 bacteria per gram (dry weight), which were metabolically active as shown by respiration of uniformly labeled* D-[^{14}C]*glucose. From this study it cannot be determined whether these organisms in the water column and sediments constitute a functioning food web.*

The water under the Ross Ice Shelf, Antarctica, is a unique marine environment for living organisms; it has no euphotic zone because of virtually complete attenuation of light by the overlying layer of ice, which is 400 to 600 m thick. This physical environment is similar to the abyssal ocean in being cold ($\sim -2°C$) and aphotic, but differs with respect to the hydrostatic pressure; the water column at the drill site is 237 m deep, but the actual depth is 597 m because of the ice cover. Although there were a few reports (*1*) on the occurrence of fish and a diversified benthic fauna under the Ross Ice Shelf at short distances from the edge of the ice, it was not known prior to the Ross Ice Shelf Project (RISP) if any plants or animals existed at greater distances from the open Ross Sea.

During the 1977–1978 RISP field season an access hole was drilled at J9 (82°22.5′S, 168°37.5′W), approximately 400 km from the Ross Sea, which enabled us to sample the water column under the shelf. At all depths studied, we have found that the water column has sparse populations of micro- and macroorganisms, components of which might comprise a food web. These include bacteria, algae, microzooplankton, and large zooplankton.

The access hole was drilled with a Browning thermal drill (*2*). We sampled the water column below the ice at depths between 20 and 200 m by hydrocasts with Van Dorn bottles or with an impeller-type submersible pump. Since Diesel Fuel Arctic (DFA) fueled the thermal drill the hydrocast samples were often contaminated with DFA, as judged by their odor. Therefore, pumped samples were used primarily in this study.

Seawater samples were filtered through membrane filters or microfine glass-fiber filters, and the collected particulate matter was analyzed for adenosine 5′-triphosphate (ATP) as an indicator of viable cells (*3*). Low levels of ATP (0.04 to 0.6 ng liter^{-1}) (*4*) were found at all depths from 20 to 200 m below the ice. These values are two to three orders of magnitude lower than those for seawater in the Ross Sea (*5*). If a carbon/ATP ratio of 250 is used (*6*) there would be 10 to 150 ng of microbial cell carbon per liter of seawater.

Bacteria in seawater samples were enumerated by epifluorescent microscopy (*7*). Bacterial numbers were 1.2×10^7 per liter in the 66-m sample and somewhat lower in the deeper samples (8.7×10^6 to 9.5×10^6 per liter). A sample from 20-m depth was not available. Most bacteria were rod-shaped or coccoid. These bacterial densities are similar to those reported for deep-sea samples (*8*). Assuming each bacterium has 10^{-14} g of cell carbon (*9*) there would be roughly 100 ng of bacterial carbon per liter of seawater.

Microbial heterotrophic activity was measured as rates of assimilation and respiration of several isotopically labeled substrates (*10, 11*), and also by microautoradiography. D-Glucose assimilation and respiration of samples incubated at 0°C yielded turnover times (*10*) of the or-

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