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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

BULLETIN 176

The Fauna of the Ross Sea

PART 5

General Accounts, Station Lists, and Benthic Ecology

by
JOHN S. BULLIVANT
and
JOHN H. DEARBORN

New Zealand Oceanographic Institute

Memoir No. 32

1967

THE FAUNA OF THE ROSS SEA

PART 5

Photograph: E. J. Thornley

HMNZS *Endeavour* leaving Wellington for the Ice Edge

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FOREWORD

Each summer season since 1956–57 the New Zealand Oceanographic Institute has undertaken one or more research cruises in the Antarctic, initially as part of the International Geophysical Year programmes and their extensions, and latterly as part of the New Zealand Antarctic Research Programme.

The major efforts of the 1958–59 and 1959–60 seasons were devoted to an oceanographic survey of the Ross Sea in which, as well as associated hydrological information, sediment samples, plankton, and fish, substantial collections of benthic animals were obtained. Each of these expeditions was led by J. S. Bullivant.

The cooperation of the New Zealand Naval Board and of the Commanding Officer and ship's company of HMNZS *Endeavour* is gratefully acknowledged. The Antarctic Division has materially assisted the field and laboratory work by the secondment of staff and provision of equipment.

In 1957–58 biologists of the Commonwealth Trans-Antarctic Expedition made collections of benthic material from stations in McMurdo Sound and in the southern Ross Sea. Their collections have contributed significantly to the systematic studies of Ross Sea benthos now being undertaken.

From 1958 to 1961 Stanford University carried out a programme of marine biological research in the Antarctic under the leadership of Professor Donald E. Wohlschlag, the field work being led by J. H. Dearborn. While the Oceanographic Institute collections were mainly of deeper water faunas, the Stanford benthic invertebrate collections were made principally in the vicinity of McMurdo Sound. The available collections are thus in many ways complementary to one another.

The preliminary editing of the manuscripts has been done by Mrs P. M. Cullen and Dr D. E. Hurley.

J. W. BRODIE,
Director,
N.Z. Oceanographic Institute.

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New Zealand Oceanographic Institute Ross Sea Investigations, 1958–60: General Account and Station List*

by JOHN S. BULLIVANT

New Zealand Oceanographic Institute, Wellington

Abstract

A general account and station list of the New Zealand Oceanographic Institute surveys in the Ross Sea during the summers of 1958–59 and 1959–60 are given. Details of Trans-Antarctic Expedition marine collections and of later collections by the Institute are also presented.

INTRODUCTION

The International Geophysical Year and Trans-Antarctic Expedition operations opened the way for oceanographic studies in the Southern Ocean and Ross Sea by New Zealand scientists.

Dr R. W. Balham, biologist and meteorologist with the Ross Sea party of the Commonwealth Trans-Antarctic Expedition, wintered over at Scott Base during 1957, studying birds and seals, and making collections of fish and marine invertebrates through the ice in McMurdo Sound. Dr R. E. Barwick, then of the Zoology Department, Victoria University of Wellington, spent three successive summers between 1956 and 1959 in McMurdo Sound with T.A.E. and New Zealand field parties. During the 1956–57 and 1957–58 seasons he collected marine biological material with grab and trawl in McMurdo Sound. In the second summer he made four trawls from the New Zealand supply ship HMNZS *Endeavour* in the vicinity of McMurdo Sound (9–12 February 1958) taking also phytoplankton samples and making hydrological measurements.

The New Zealand Oceanographic Institute mounted extensive surveys in McMurdo Sound and the Ross Sea from *Endeavour* during the following summers, 1958–59 and 1959–60 (fig. 1), and the present report, completed in 1964, deals primarily with these.

Programme

For the summer of 1958–59 the Institute planned and occupied a series of stations in parallel lines from the coast (or ice barrier) north-eastward across the outer edge of the deep shelf bounding the Ross Sea. Observations at each station were to include a grab haul, a trawl, a reversing water bottle cast, a vertical plankton haul, and a phytoplankton sample.

The 1958–59 summer party comprised J. S. Bullivant, zoologist and leader; D. G. McKnight, assistant zoologist; A. G. Macfarlane, assistant

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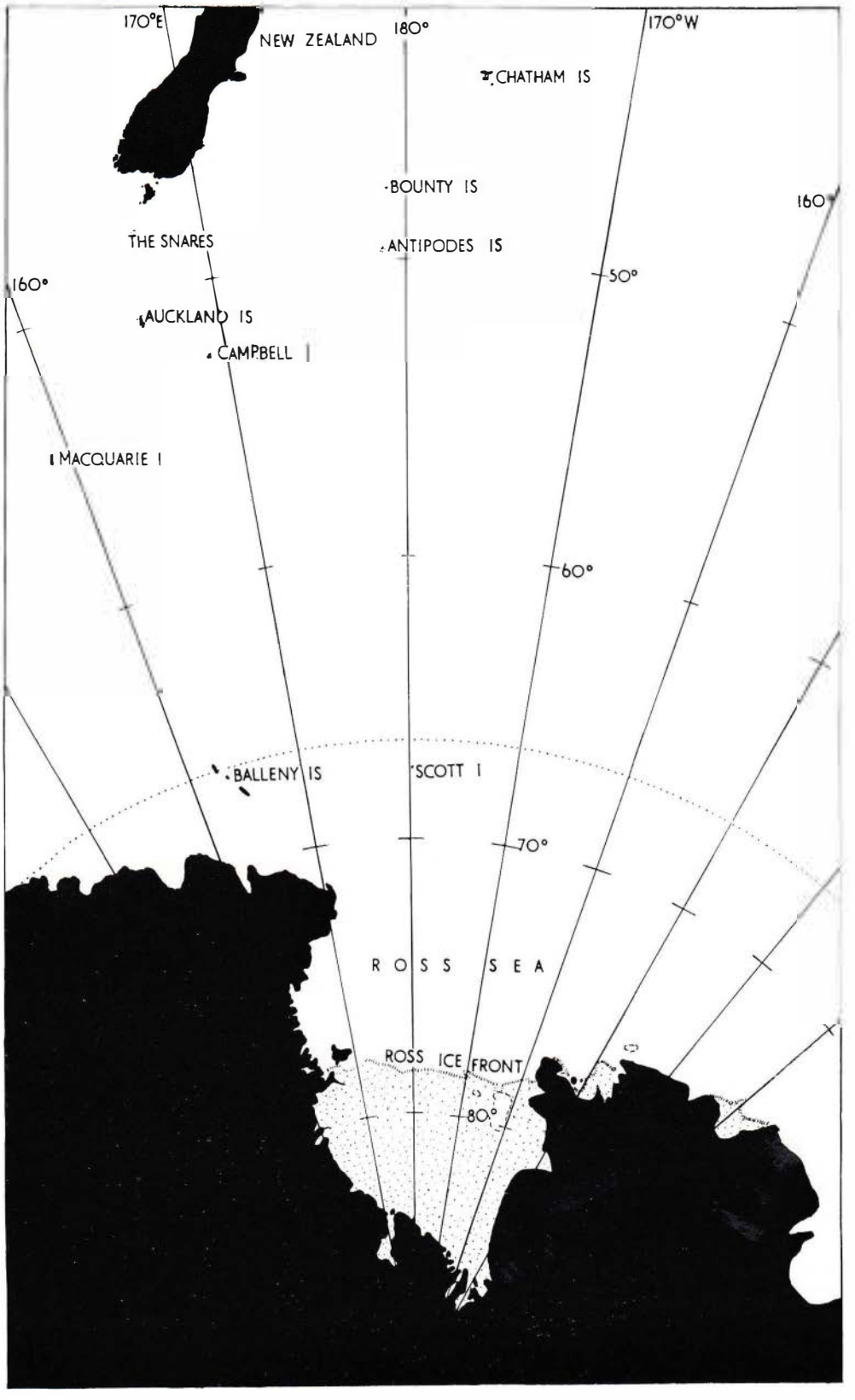


FIG. 1. Locality Map.

hydrologist (all of N.Z.O.I.); Dr R. K. Dell, zoologist (Dominion Museum, Wellington); J. Reseck, Jun., zoologist (Long Beach State College, California); N. A. Powell, student assistant (Antarctic Division, D.S.I.R.).

In the second summer, coordinated oceanographic and seismic refraction work was carried out with Geophysics Division, D.S.I.R. Oceanographic observations were concentrated on Pennell Bank and in McMurdo Sound, where previous investigations had shown the benthos to be rich and varied. It was hoped to take samples from shallow water to the edge of the deep shelf, and down the outer slope.

The 1959–60 summer oceanographic party was J. S. Bullivant, zoologist and leader (N.Z. Oceanographic Institute); G. A. Harlen, assistant zoologist; and E. C. French, technical assistant (both of Antarctic Division, D.S.I.R.).

The seismic party was Dr R. Adams, geophysicist and leader; R. G. Jenkins, assistant geophysicist; R. H. Garrick, assistant geophysicist (all of Geophysics Division, D.S.I.R.).

In the 1960–61 summer, the N.Z. Oceanographic Institute made a hydrological survey in the Ross Sea, during which Mr G. A. Harlen collected benthos at three positions along the Victoria Land coast.

Following the 1958–59 survey a number of systematists were personally invited to report on the benthic material collected. (For reports and progress see Appendix 1.)

The results of their work appears in the Series under the general title "Fauna of the Ross Sea", and deals with material taken during the five summers of collecting by New Zealand scientists in the Ross Sea; also with material collected by Dr John H. Dearborn, of the Stanford University Marine Biology Programme, who made comprehensive collections of marine invertebrates while studying the ecology of selected species during 25 months at McMurdo Sound.

The N.Z. Oceanographic Institute benthic collections were sorted at the Institute under the direction of the author; Dr J. H. Dearborn sorted and distributed the Stanford collections; and the material collected by the T.A.E. during the summers of 1956–57 and 1957–58 was sorted by expedition members and by Dr R. K. Dell and Dr J. C. Yaldwyn, who were responsible for curating this material at the Dominion Museum, Wellington.

PREVIOUS OCEANOGRAPHIC WORK

Early Expeditions

Sir James Clark Ross (1847) first sighted Victoria Land near Cape Adare on 11 January 1841 and, with his ships *Erebus* and *Terror*, charted the coast of Victoria Land and the edge of the Ross Ice Shelf. In the summer of 1842–43, Ross traversed the north-eastern area of the Ross Sea. He made several soundings and collected at least three bottom samples with the sounding line; off Cape Adare in 270 fm, off Franklin Island in 300 fm, and off the Ross Ice Shelf in 290 fm, taking fish, invertebrates, and rock samples. Sundry observations were made of water temperatures, animal life, ice formations, and currents; also phytoplankton was identified from pack-ice samples. These were the first oceanographic observations and collections made in the Ross Sea. Of the dredge hauls, Ross commented: "It was interesting amongst these creatures to recognise several that I had been in the habit of taking in equally high northern latitudes . . ".

Encouraged by the numerous sightings of whales which Ross's expedition reported, W. J. Bull led an expedition in the ship *Antarctic* to the Ross Sea in the summer of 1894–95 to hunt right whales. His party landed on one of the Possession Islands and at Cape Adare, and collected samples of rock, penguins, and lichens.

C. E. Borchgrevinck, a member of Bull's expedition, led the next exploring expedition in the *Southern Cross* to the Ross Sea – this was the British Antarctic Expedition of 1898–1900 – collecting some biological samples (Brit. Mus., 1902) and charting parts of the coast of Victoria Land and the edge of the Ross Ice Shelf.

Scott-Shackleton Period

Captain R. F. Scott's first expedition – the National Antarctic Expedition of 1901–04 – in the *Discovery* sailed along the Victoria Land coast and the Ross Ice Shelf charting the shore and ice edge and taking soundings. A base was established at Hut Point, McMurdo Sound, and the expedition remained in the area for two full years (Brit. Mus., 1907–12).

Naturalists with the party observed and made collections of Ross Sea birds and mammals. They made tide and current observations and dredged

marine organisms in McMurdo Sound: off Cape Adare (17 fm), off Coulman Island (8–15 fm) and at two stations (100 and 300 fm) at the eastern end of the Ross Ice Shelf. The benthos was also sampled at different seasons from holes and cracks in the ice near the winter quarters at Hut Point; a useful summary of these positions has been given by Ehlers (1912). Most of these samples were taken in depths of less than 25 fm but there were a few samples from depths down to 180 fm and one north of Ross Island in 500 fm.

Little or no oceanographic work was carried out from the *Nimrod* during Sir Ernest Shackleton's first expedition – the British Antarctic Expedition of 1907–09. Several dredgings were made in Backdoor Bay, near their base at Cape Royds, in 6 to 20 fm and some in about 80 fm. The abundance in shallow water of yellow and orange animals, chiefly sponges and corals, was particularly noted compared with the predominantly white shells, sponges, and corals from deeper water. Current and tide observations were made in McMurdo Sound during 1908.

Scott's second expedition – the British Antarctic Expedition of 1910–13 – set up a base at Cape Evans in McMurdo Sound in January 1911 which was occupied until January 1913. During the third of her six voyages from New Zealand, *Terra Nova* spent some time north-east of Pennell Bank making regular soundings, collecting plankton, and trawling. South of 70° S in the Ross Sea area, plankton samples were collected at 59 stations and bottom samples at 18 stations. Plankton was also collected and tide observations made from the winter quarters (Brit. Mus. 1914).

There are no reports of oceanographic work from the Japanese Expedition under Lieutenant Shirase in the *Kainan Maru* in 1911 and again in 1912, nor from the Ross Sea party of Sir Ernest Shackleton's Imperial Trans-Antarctic Expedition who were trapped in pack ice in McMurdo Sound in May 1915, and who did not break loose until nine months and 1,191 miles later, having drifted north out of the Ross Sea and west along the coast of Oates Land.

Post Great War Expeditions

No further oceanographic work was carried out in the Ross Sea area until December 1923, when some natural history observations were made by a Norwegian whaling expedition led by Captain C. A. Larsen in the factory ship *Sir James Clark Ross*.

The Discovery Committee instigated oceanographic work for the Government of the Falkland Islands from s.s. *C. A. Larsen* south of 70° S in the vicinity of the Ross Sea in December 1928 and January 1929 (Anon, 1930). There were 21 stations in the northern Ross Sea; hydrology was carried out at 13, and plankton samples taken at 18. The RRS *Discovery II* took hydrology and plankton samples at a station in the western Ross Sea in February 1934 (Anon, 1942), and 23 stations were occupied in the Ross Sea during January 1936. Plankton samples were taken at 18 of these, benthos sampled at 15, and hydrological observations made at 17 (Anon, 1944).

Byrd's Expeditions

On Rear Admiral Richard E. Byrd's first expedition to Antarctica with the *Eleanor Bolling* and *City of New York*, few oceanographic observations were made (1928–30).

Early in 1934, Byrd returned to the Ross Sea with the *Jacob Rupert* and the *Bear of Oakland*. Plankton samples were obtained near the base; dredging was carried out near the Bay of Whales in January, 1935; and bottom samples were obtained along the Ross Ice Shelf. The *Bear of Oakland* ran eight echo-sounding traverses across the Ross Sea.

Increasing American interest in the Antarctic led to the U.S. Antarctic Service Expedition of 1939–41 under Admiral Byrd with the USS *Bear* and USNS *North Star*. Early in 1940, a base was established on the west coast of Graham Land and a second at Little America III in the Bay of Whales. The supply ship, *Bear of Oakland*, made several exploratory cruises including one from Cape Colbeck to 143° W, one to the Victoria Land coast, and one from the Ross Sea round to Graham Land. The biology of the birds and mammals was studied and small collections of marine invertebrates were made at each base. These bases were evacuated early in 1941.

After the Second World War, a large-scale U.S. Navy expedition under Admiral Byrd – Operation High Jump, 1946–47 – explored the coastline of the Antarctic Continent extensively, mainly from the air. Little America was re-established on the Ross Ice Shelf near the Bay of Whales and a party wintered there. Oceanographers from Woods Hole Oceanographic Institution and the U.S. Navy Electronics Laboratory accompanied the expedition, making a limited number of bathythermograph observations, taking sediment cores, plankton, and water samples in the vicinity of the Ross Sea. Ice observations and echo-soundings were also recorded.

I.G.Y. Preparations

In January 1955, USS *Atka* visited the Ross Sea on a reconnaissance survey to find suitable sites for bases for the United States International Geophysical Year programme. Seven hydrological stations were occupied and bathythermograph casts were made in the eastern Ross Sea. Plankton samples and 12 short cores were taken, ice conditions were recorded and echo-soundings made (U.S. Hydrogr. Office, 1956a).

The tempo of scientific research in the Antarctic increased sharply during the summer of 1956–57 during preparations for the International Geophysical Year which extended from 1 July 1957 to 31 December 1958. The operation of U.S. bases at Little America (eastern side of the Ross Ice Shelf), at Hut Point (McMurdo Sound), at Cape Hallett (a joint U.S.-N.Z. station), and the New Zealand station at Scott base (McMurdo Sound) meant the presence of numerous ships in the Ross Sea each year, greatly increasing the number of oceanographic observations made from icebreakers and support vessels. Cores, sediment and benthic samples have been obtained and temperature and salinity profiles recorded (U.S. Hydrogr. Office 1956b, 1957).

Finally, there has been the work of the New Zealand Oceanographic Institute, described here.

UNDERWAY OBSERVATIONS

Ross Sea Oceanographic Survey, 1958–59

The *Endeavour* left Wellington on the morning of 20 December 1958 on her third voyage to the Ross Sea. When weather permitted four-hourly bathythermograph dips were made and deck-hydrant samples of phytoplankton collected underway. Near the Antarctic Convergence bathythermograph observations were made two-hourly on 23 December and hourly on 24 December.

A westerly gale was encountered on 25 December, with winds up to 45 knots and seas up to 35 ft high, the ship rolling to 50°. Hourly bathythermograph observations were stopped until the following morning. The wind changed to the east during the next day while the ship was between 62° and 63°S. Cape pigeons, mollymawks, and prions were still about the ship and Wilson's storm petrel was observed. During the evening the first small icebergs were seen and some whales passed the ship.

On 27 December icebergs were fairly common about the ship; usually about five could be seen at any one time. The first Antarctic petrels and snow petrels made their appearance; Cape pigeons and mollymawks were still about and Scott Island was sighted.

On 28 December thick brash ice and rotten pack was encountered, and a bathythermograph lost. Seals, probably crab eaters, and Adelie penguins were seen on the ice, and pink euphausids, which appeared common in crevices in the pack, were often splashed up by the bow wave.

Bathythermograph dips were now only occasionally made when openings in the pack permitted, but phytoplankton samples were taken regularly. From 30 December the ship was working her way through belts of pack ice. The first Emperor penguins were seen, and a second bathythermograph was lost through brake failure.

The *Endeavour* was held up by heavy pack ice in the entrance to McMurdo Sound on 1 January, but later followed the icebreaker USS *Staten Island* to a position off Tent I.

On 9 January *Endeavour* proceeded out of McMurdo Sound to begin the planned oceanographic cruise in the Ross Sea, and the following day she was in clear water off Beaufort Island.

The enormous tabular berg which had been observed the previous year was still in position, jammed between the south-east corner of Beaufort Island and Cape Bird on Ross Island, a distance of about 11 miles, presumably having drifted along from the Ross Ice Shelf in the prevailing west-flowing current. Near Beaufort Island, the top of this berg was 30m a.s.l. Pack ice lay along the Victoria Land coast and surrounded Coulman Island so that original plans for working the area had to be modified. The programme was also disrupted on 18 and 20 January by strong SSW winds of up to 40 knots and the ship sailed south to a more sheltered position against the Ross Ice Shelf where surface carbon-14 samples were taken. At Station A 467, over the sloping bottom off Cape Crozier, the dredge brought up a large number of pectens (*Adamussium colbecki*)*.

In the evening of 26 January a search was made for a charted 45 fm patch east of Beaufort Island. This could not be found despite accurate bearings and radar ranges from Beaufort and Ross Islands. East of Beaufort Island, a flat-topped sea mount reaching up to 60 fm was found. Photographs taken with the bottom camera revealed an exceedingly rich growth of sessile animals on this sea mount, and samples were obtained with the trawl.

On the morning of 27 January, *Endeavour* returned to McMurdo Sound. The oceanographic cruise had lasted 18 days, during which 2,500 miles had been steamed and 22 stations occupied. (Positions are mapped on fig. 2.)

*They have a delicate, slightly sweet flavour, both raw and cooked.

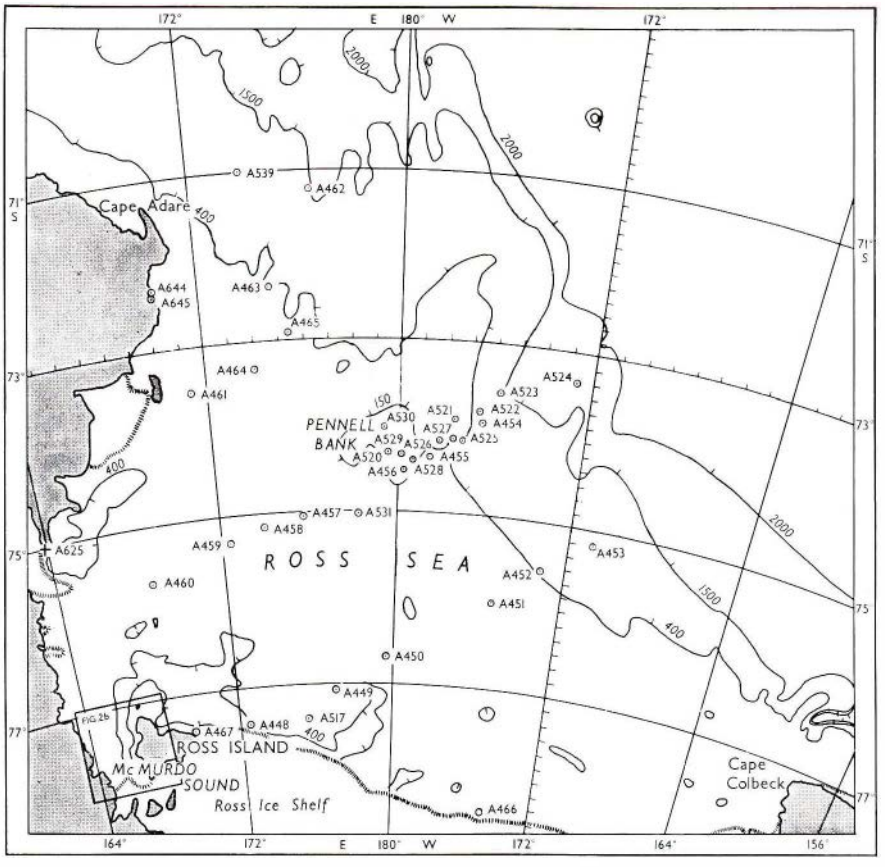


FIG. 2A. N.Z. Oceanographic Institute Stations occupied in the Ross Sea between 1958 and 1961. Depths in fm.

While moored against the ice in McMurdo Sound, a fish trap was lowered from the Kelvin sounding winch and several fish were captured. A few invertebrates were also brought up in the trap.

A station was worked from the ship on 29 January while she was moored against the ice, and bottom samples, plankton samples, and bottom photographs were obtained. Bulk water samples for carbon-14 data were taken from the surface and bottom in McMurdo Sound with a sampler improvised on board (Willis, 1959).

Endeavour left McMurdo Sound for New Zealand on 6 February. Near Cape Evans a trawl was made and bottom photographs that showed extraordinary masses of glass sponges were taken. Surface salinity samples were obtained at hourly intervals as the ship sailed out of McMurdo Sound.

The return voyage to New Zealand was uneventful. As before, bathythermograph dips were made and phytoplankton samples collected crossing the Convergence Zone, except during bad weather on 9 and 10 February.

Ross Sea Oceanographic Survey 1959–60

The *Endeavour* left Wellington on her fourth voyage to the Ross Sea on the afternoon of 27 December 1959.

Regular four-hourly bathythermograph casts began on the evening of 30 December and were increased to hourly across the Antarctic Convergence which lay between 62° and 63°S on 3 January. A proton magnetometer was towed.

On 4 January occasional bergs were passed, about three being in view at any one time, and the first lines of pack ice were encountered. Snow petrels, Antarctic petrels, fulmars, and 14 crabeater seals were seen.

Scott Island was reached that evening. The sea about the island was eight-tenths covered with pack ice, apart from a patch of open water against its south-west side. A successful haul of pebbles and benthos was made. An attempted landing on a boulder beach on the southern side of the island was unsuccessful because of swell.

About 200 miles of pack were passed before the

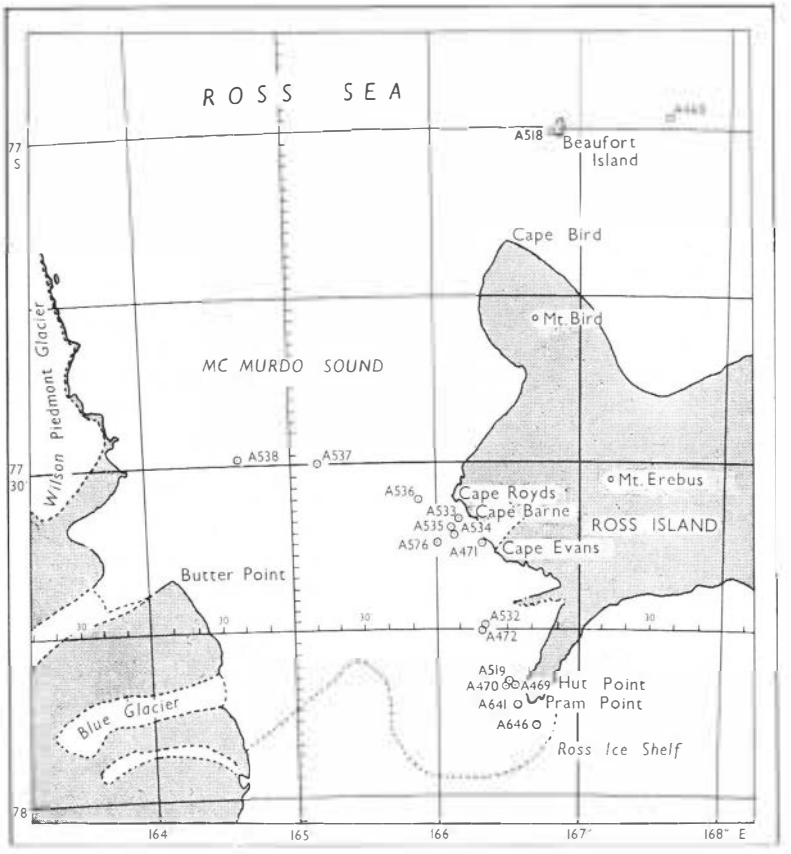


FIG. 2B. N.Z. Oceanographic Institute Stations occupied in McMurdo Sound between 1958 and 1961.

open waters of the Ross Sea were entered in clear sunny weather on the evening of 6 January. While crossing the Ross Sea, two large flocks of Antarctic petrels were seen. One flock of about 200 looked like a flock of starlings as it flew by several hundred feet up in the air. The other flock of about 100 birds were on the water and appeared to be actively feeding.

The open water extended south to Beaufort Island, which was sighted on 7 January. Ice pack was observed to the west of Beaufort and Franklin Islands. The 11-mile-long tabular berg, which had been jammed between Beaufort and Ross Islands the previous two seasons, was still in position. (It broke out the following summer.)

On the evening of 7 January, *Endeavour*, following USS *Atka* and USNS *Alatna* through the heavy broken pack in McMurdo Sound, proceeded into the icebreaker channel in the fast ice, and was finally moored against the ice about 4 miles north of Hut Point.

In the morning of 18 January equipment was made ready for the forthcoming combined seismic and oceanographic cruise, and at 4 p.m. *Endeavour* followed *Atka* through the icebreaker channel to open water.

The 19th day of January was spent in refraction seismic operations in the entrance to McMurdo Sound.

From 20 January, when Sta. A 517 off the Ross Ice Shelf was occupied, a steadily strengthening wind off the ice, with speeds of 40 to 50 knots, prevented work for the next two days.

Seismic operations were resumed in the entrance of McMurdo Sound from 23 to 26 January. The Adelie penguin colony on Beaufort Island, which had been visited the previous year from *Endeavour*, was examined on 25 January. An echo-sounding profile was made while approaching Cape Barne.

The *Endeavour* returned along the icebreaker channel to Hut Point on 27 January.

While against the ice in McMurdo Sound the fish trap was used successfully several times. On 29 January grab samples of benthos and sediment were obtained. On the 30th and 31st the underwater camera was tested.

In the afternoon of the 31st, *Endeavour* left for a second Ross Sea cruise. On the way out of

McMurdo Sound a party went ashore at Cape Royds to examine the Adelie penguin colony*.

Seismic operations were carried out east of Beaufort Island on 1 February, but on 2 February, because of high wind, a course was laid for Pennell Bank.

An oceanographic station was occupied there on 3 February and seismic work carried out.

Between 4 and 9 February nine oceanographic stations were occupied from Pennell Bank into deeper water to the north-east. On the ship's return to Pennell Bank a seismic refraction profile was shot on the evening of the 9th, and after a final dredge haul a course was laid for McMurdo Sound.

The ship moored in the icebreaker channel, about 3 miles north of Hut Point on 10 February. Two grab samples were obtained from the bottom at this position.

On the 14th, a strong south-easterly wind brought snow and temperatures of between 0° and 5°F and some of the salinity samples left on deck froze, the bottles cracking before the case was put down below.

On the morning of 16 February the ship cast off from the ice and with the help of USCGC *Eastwind*, steamed down the ice channel to open water in McMurdo Sound.

On 16 and 17 February the oceanographic team worked a line of six stations from Cape Royds towards Marble Point on the western coast of the Sound.

Below-zero southerly winds made conditions difficult. The trawl samples were sorted in the hold to prevent freezing.

During stations occupied near Marble Point, pack-ice formation was observed. An oily surface slick was encountered first, but nearer the coast a large area of pancake ice was met.

On 19 February a hydrology station was occupied north-east of Cape Adare to obtain bulk seawater samples for carbon-14 analysis.

Bathythermograph dips were made on either side of the Convergence Zone, but bad weather interrupted the series.

On 25 February *Endeavour* called in at Perseverance Harbour, Campbell Island. Near the meteorological station a series of bottom photographs and a small bottom sample were obtained. The photographs showed a small amount of weed, a few young flounder, and numerous specimens of the crustacean *Munida subrugosa*, some specimens of which were collected in the bottom sample.

On 27 February 1960 the *Endeavour* berthed at Bluff.

*Two Adelie penguins were taken on board the *Endeavour* for the New Zealand biologists E. C. Young and R. H. Taylor, and later released over Pennell Bank to test their homing ability, but were not seen again at Cape Royds that season.

EQUIPMENT AND SAMPLING TECHNIQUE

Ship

HMNZS *Endeavour* (frontispiece) was originally built in 1944 as a net layer, HMS *Pretext*. After the war her wooden hull was strengthened for ice, and she was operated by the Falkland Islands Dependencies Survey as the RRS *John Biscoe*. She was acquired by the New Zealand Government in 1956.

Endeavour displaces 1,015 tons, is 194½ ft long overall, and is powered by diesel-electric motors. In the summer of 1956–57 she was supply ship for the New Zealand IGY Expedition and for the Trans-Antarctic Expedition, and subsequently took part in the resupply of Scott Base each summer until February 1961.

Oceanographic work was normally carried out from the quarterdeck, where there were three winches. A small winch powered by a petrol motor was used with a boat davit to make water bottle casts and plankton hauls; a large 42 h.p. electric winch amidships handled heavier equipment from the main boom; and the bathythermograph was lowered from the electric Kelvin sounding winch on the starboard counter. Heavy dredging was carried out from the ship's main afterboom trained overside and topped to about 15 ft above water level.

Reversing bottle racks were secured to the after-deck house. Except when samples froze on deck, bottles were emptied and thermometers read in the open.

A space about 6 ft by 15 ft in the upper forward hold was partitioned off as an oceanographic laboratory and a similar adjoining space was used on the second oceanographic cruise for seismic operations.

Equipment

Hydrology

Knudsen reversing water bottles equipped with Negretti and Zambra protected and unprotected thermometers were used for serial temperature salinity observations on station. Bathythermographs with a 275 m depth range were used on station and underway. A continuously recording Negretti and Zambra thermograph mounted in the engineroom recorded the water temperature in the intake of the engine cooling system about 8 ft below the surface, and was operated almost continuously while the ship was away from New Zealand.

Bulk sea-water samples were collected for age determinations by the carbon-14 method. In the 1958–59 summer the special bulk sea-water sampler was lost and a replacement (type C, Willis, 1959) was constructed on board ship. The following summer Willis's type B sampler was used.

Geology

Sediment samples were obtained with grabs and trawls (see Biology below). Five short cores were obtained with a 1 m Phleger corer.

Biology (*Plankton*)

The various types of biological sampling equipment are referred to in the station list by the abbreviations given below.

Phytoplankton samples were collected with a nylon plankton net (N.P.) of 200 meshes per inch suspended beneath a sea-water hydrant for about 15 minutes. The sample was preserved in formalin. Plankton samples were taken at each station by a vertical haul with an N 70 plankton net (Kemp *et al.*, 1929) from near bottom to surface.

Biology (*Benthos*)

A remote underwater camera and several different types of trawls and grabs were used.

T.A.S. A small Agassiz trawl with a rectangular mouth 82 cm × 25 cm constructed of strap iron. The bag of the trawl was made of heavy double 3·8 cm mesh netting lined with light 1·3 cm mesh netting. At times chain was used in the first few metres of warp to add weight to the assembly.

T.P. An Agassiz trawl with a rectangular mouth 101 cm × 46 cm constructed of galvanised pipe. This trawl caught a higher proportion of bottom-living fish than the other trawls used, but was lost during the first cruise.

D.N. A naturalist's dredge with a rectangular mouth 51 cm × 18 cm made of heavy flat iron with bevelled leading edges. The bag of the dredge was heavy double 3·8 cm mesh netting lined with a hessian sack.

D.D. The Devonport dredge. This dredge was designed to slide over the substrate without penetrating. The dredge mouth was 15 cm × 66 cm and constructed of heavy flat iron. The "bag" was made of heavy-gauge galvanised wire (mesh diagonal, 1·3 cm) wired to a rectangular frame of angle iron. This dredge seemed efficient in skimming the surface but appeared to catch fewer mobile crustacea and fish than the T.P. or the T.A.S. types.

G.O.S. A small orange-peel grab with a bucket diameter of 31 cm. Washing of the sample on passage to the surface was prevented by a canvas hood (cf. Reish, 1959).

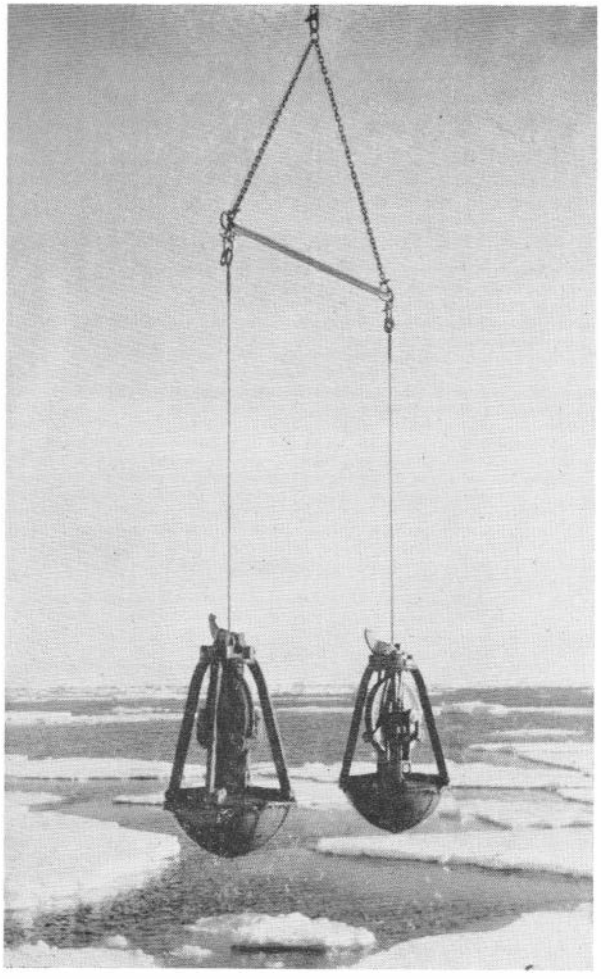
G.T.O.S. Two small orange-peel grabs suspended at either end of a 120 cm bar and lowered together. This contrivance saved time in obtaining multiple grab samples.

G.H.O. A four-blade Hayward orange-peel grab with a bucket capacity of 24·5 litres and diameter of 48 cm, modified by the addition of a triggering device and plates attached to the blades to form a lid to the bucket when closed.

G.T.H.O. Two four-blade Hayward orange-peel grabs suspended at either end of the 120 m bar. Care had to be exercised in lowering these grabs for if lowered too fast they would fall on their sides (plate 1).

G.D. Dietz - La Fond grab. This was normally used as a bottom weight for hydrology casts.

U.W.C. A remote underwater camera was used on both cruises. It consisted of camera and electronic flash units in pressure-resistant, watertight chambers with the camera



PL. 1. Twin orange-peel grab sampler. The grabs are closed and coming inboard.

mounted on a tripod above the flash. The camera chamber was mounted 165 cm above the bottom and directed downward at about 59° from the horizontal. The camera was a 35 mm Robot with a 40 mm focal-length lens fitted with supplementary lens to correct for chromatic aberration, and triggered by a magnet approaching the chamber when the tripod touched bottom. The field of the photographs was about 0·75 m wide in the foreground by 1 m deep. A series of shots could be taken at one lowering by raising the camera clear of the bottom between shots, allowing time for the flash unit to recharge.

Sieves. Grab samples were usually washed through a set of graduated sieves, the smallest mesh being 3·1 holes per cm. A piece of muslin (cheese cloth) with a mesh of about seven holes per cm was stretched over the last sieve to enable easy collection of small material without the wearisome difficulties of cleaning the fine mesh. The cloth and specimens were normally preserved intact.

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APPENDIX 1

Systematists Reporting on Material Collected During the Present Investigations

Foraminifera – Dr J. Kennett.
Arenaceous Foraminifera – Dr R. H. Hedley.
Sponges (Hexactinellida) – Mr R. E. H. Reid.
Sponges (Non-Hexactinellida) – Dr P. R. Bergquist.
Actinaria, Ceriantharia – Dr Cadet Hand.
*Scleractinia – Dr D. F. Squires.
*Stylasterina – Professor Dr H. Boschma.
Alcyonaria – Professor Dr Huzio Utinomi.
Nemertinea – Mr E. W. Dawson.
Polychaeta – Professor G. A. Knox.
Bryozoa – Mr J. S. Bullivant.
Nematoda – Mrs P. M. Thomas.
*Sipunculoidea – Dr S. J. Edmonds.
Pycnogonida – Dr J. W. Hedgpeth and Dr W. G. Fry.
Cumacea – Dr N. S. Jones.
Cirripedia – Dr W. Newman.
Amphipoda, Isopoda – Dr D. E. Hurley.
Decapoda – Dr J. C. Yaldwyn.
*Mysidacea – Dr Olive S. Tattersall.
Mollusca (except Opisthobranchia and Cephalopoda) – Dr R. K. Dell.
Opisthobranchia – Dr M. C. Miller.
Cephalopoda – Dr Gilbert L. Voss.
*Ophiuroidea, Echinoidea – Professor H. B. Fell.
*Asteroidea – Miss H. E. S. Clark.
Crinoidea – Dr J. H. Dearborn.
Ascidiacea – Dr B. I. Brewin.

*See list of published results (Appendix 2).

APPENDIX 2

Papers Published from the Observations and Collections of the N.Z. Oceanographic Institute Expeditions to the Ross Sea 1958–60

BOSCHMA, H. 1965: *Errina carnea*, a new Stylasterine coral from the Antarctic. *Proc. K. ned. Akad. Wet. Ser. C., 68 (1):* 19–24, pl. 1.

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EDMONDS, S. J. 1965: Sipunculoidea of the Ross Sea. The Fauna of the Ross Sea. Part 4. *N.Z. Dep. sci. industr. Res. Bull. 167:* 27–33.

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MILLER, R. G.; RESECK, JOHN Jnr. 1961: *Chionodraco markhami*, a new Antarctic fish of the family Chaenichthyidae. *Copeia, 1961 (1):* 50–3.

——— 1961: Notothenioid fishes collected at Cape Hallett, Ross Sea, Antarctica. *N.Z. J. Sci. 4 (3):* 664–8.

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Station List of New Zealand Oceanographic Institute Collections, 1959–61

Station No.	Locality	Date	Latitude	Longitude	Weather and State of Sea	Time Start	Time Finish	Depth, Metres	Sediment	Gear*
A 448	1 mile from Ross Ice Shelf	10/1/59	77° 27′S	172° 22′E	Calm and fine ..	1500	2400	752	Soft mud, coarse gravel, and stones	5 GTOS, TAS, NP N70, TS, BT
A 449	Ross Sea ..	11/1/59	77° 05′S	177° 12′E	Calm and fine, low swell	0630	1240	362	Soft gritty mud ..	5 GTOS, TAS, NP, N70, TS, BT
A 450	,, ..	,,	76° 42′S to 76° 36′S	179° 44′E to 179° 53′E	Southerly breeze ..	1645	2315	472–318	Muddy sand ..	2 GTOS, 2 GTHO, 2 TAS, NP, N70, TS, BT
A 451	,, ..	12/1/59	76° 00′S to 75° 50′S	175° 25′W to 175° 20′W	Sky overcast and snow flurries, southerly wind	0643	1315	523	Rocks and muddy sand	3 GTHO, TAS, NP, N70, TS, BT, GD
A 452	,, ..	,,	75° 35′S	173° 18′W	Sky overcast, snow flurries, moderate southerly wind, tight pack ice ahead	1725	0520	1280–1300	Yellow-brown mud, rock fragments, and gravel	2 GTHO, TAS, NP, N70, TS, BT
A 453	,, ..	13/1/59	75° 09′S	171° 00′W	Sky overcast, mild SE breeze, 6/10 pack ice, calm	1230	2109	2195	Yellow-brown mud with angular black gravel	1 GTHO, NP, N70, TS, BT
A 454	Pennell Bank ..	14/1/59	73° 56′S	176° 30′W	Sky overcast, strong SW wind	1900	0040	914-828	Rocks	GHO, 2 TAS, NP, N70
A 455	,, ..	15/1/59	74° 22′S	178° 35′W	Sky cloudy, moderate SW wind	0400	0920	322–340	Rocks, muddy sand	GTHO, GD, DN, NP, N70, TS, BT
A 456	,, ..	,,	74° 30′S	179° 40′W	Sky cloudy, steady SW breeze	1640	2100	238–301	Rocks, gritty mud	GTHO, TAS, NP, N70, fish line TS, BT
A 457	,, ..	16/1/59	75° 02′S	175° 50′E	Sky overcast, SW breeze	0600	1200	315–400	Sandy mud, gravel, pebbles	3 GTHO, TP, NP, N70, TS, BT
A 458	Ross Sea ..	,,	75° 10′S	174° 00′E	Sky overcast, steady southerly breeze	1545	2000	461–486	Muddy sand and pebbles	3 GTHO, TP, NP, N70, GD, Corer. TS, BT
A 459	,, ..	,,	75° 17′S	172° 20′E	Sky cloudy, southerly breeze	2350	0620	534-549	Soft mud ..	3 GTHO, TP, NP, N70, TS, BT Corer
A 460	,, ..	17/1/59	75° 38′S	168° 32′E	Sky overcast, moderate breeze	1430	1915	415–430	Gritty mud ..	3 GTHO, TP, NP, N70, GD, Corer, TS, BT
A 461	E. of Coulman Island	18/1/59	73° 32′S	171° 22′E	Misty, overcast weather, southerly breeze	1530	2120	578–567	Sandy mud and gravel	3 GTHO, TP, NP, N70, Corer TS, BT
A 462	Ross Sea ..	20/1/59	71° 15′S	176° 30′E	Sky overcast, strong SW wind	2030	0320	1831–2381	Gritty mud ..	GHO, DN, NP, N70
A 463	,, ..	21/1/59	72° 20′S	174° 50′E	Sky overcast, steady southerly wind	1100	2025	468–465	Barnacle plates and scattered rocks	3 GTHO, TP, TAS, NP, N70, TS, BT, GD
A 464	N.W. Ross Sea ..	22/1/59	73° 20′S	174° 00′E	Cloudy, intermittent rain, steady southerly wind	0330	0800	369–384	Sand and pebbles ..	2 GTHO, DN, NP, TS, BT
A 465	" ..	"	72° 55′S	175° 30′E	Sky overcast, snow squalls, steady southerly wind	1200	1600	399	Barnacle plates ..	DC, NP, GD

*For Gear Abbreviations, see p. 17; in addition, TS = Temperature Section; BT = Bathythermograph; NP = Phytoplankton Net; C = Carbon-14 Sampler; 70=70 cm diam. Plankton Net *(Discovery type)*.

Station List of New Zealand Oceanographic Institute Collections, 1959–61—*continued*

Hydrology Cast	Grab Haul	Dredge and Trawl Haul	Plankton Haul	Remarks
10 0–705 m	GTOS: 9 full. Few animals; tubicolous polychaetes, holothurians, 1 *Cerianthus*. 10 ophiuroids, 2 sipunculids, polyzoa, gorgonacean colonies, sponge fragments	TAS: 30 min. damaged, polychaetes, echinoids, sponges, asteroids, ophiuroids, papillate and rat-tailed holothurians, gorgonaceans (? *Thouarella* sp.), 3 fish	N 70V: 600–0 m. Copepods, pteropods, polychaete medusae, 1 ephausid	Penguins abundant
12 0–265 m	GTOS: 10 full. Frags. 3–4 species calcareous bryozoa, tubicolous polychaetes, ophiuroids, barnacle plates, crustacea, small molluscs, dead branches stylasterine coral	TAS: 20 min. holothurians, crinoids, bryozoan colonies	N 70V; touched bottom. Polychaetes, bryozoans, asteroids ophiuroids, sponge, flatworms, pycnogonids, tunicates, molluscs, brachiopods	"
12 0–275 m	GTHO: 4 full. Barnacle plates, holothurians, lamellibranchs, ophiuroids, sponges, crustacea, polychaetes, asteroids, bryozoans	TAS: 2 hauls, first fouled. Holothurians, pycnogonids, ophiuroids, worm tubes, alcyonarians, barnacle plates	N 70V; 256–0 m	½–1 knot drift on station
11 0–520 m	GTHO: 6 full. Amphipods, polychaetes, molluscs, sipunculids, bryozoans, gorgonaceans	TAS: fouled, small sample. Crinoids, pycnogonids, bryozoans, gorgonaceans	N 70V; touched bottom	Water froze in reversing bottles
15 0–1300 m (Wire angle 15°)	GTHO: 4 full. Small symmetrical echinoid, 2 ophiuroids, holothurian, worm tubes, small crustacea, bryozoans	"	N 70V; 1300–0 m. Sparse sample	Ship hove to
18 0–1400 m	GTHO: 2 full. Little animal life	"	N 70V: 1000–0 m. Copepods, 1 transparent fish, 6 cm. (*Pagetopsis macropterus*) (Reseck 1961)	"
5 0–255 m (Wire angle 20°)	GHO: empty	TAS: 2 hauls in 1,000 and 828 m, trawl damaged, small sample. Ophiuroids. *Serolis* sp. sponges, worm tubes, crinoids, 1 fish, molluscs, barnacle plates	N 70V: 700–0 m. Copepods	"
11 0–320 m	GTHO: 1 small sample: Sponges, bryozoans, 3 gorgonaceans	DN: Bryozoan, gorgonaceans, sponges, stylasterine corals, polychaetes, ophiuroids, and other echinoderms	N 70V: 300–0 m	"
10 0–180 m	GTHO: small sample. Bryozoan colonies, ophiuroids, asteroids. holothurians, barnacle plates, molluscs, gorgonacean colonies, (*Caligorgia* sp. *Thouarella* sp.) worm tubes, coral, fish	TAS: 2 hauls, only 2nd successful. Calcareous bryozoa, echinoderms, pycnogonids, polychaetes, octopi	N 70V: 200–0 m. Amphipods, isopods	Two soundings of 106 and 155 m (shown on chart) were not located. Minimum depth found, 183 m. Icebergs (presumably stranded on bank) in vicinity of station
12 0–312 m	GTHO: 6 full. Calcareous and chitinous bryozoans, ophiuroids, small molluscs, inc. scaphopods, polychaetes, gorgonaceans (*Thouarella* sp.)	TP: Bryozoans, gorgonaceans, *Cephalodiscus*, holothurians, asteroids, prawns, 6 fish, large polychaete (20 x 5 cm), small octopi	N 70V: 400–0 m. Touched bottom. Euphausids, chaetognaths, pteropods, frags. bryozoa, *Cephalodiscus*, much phytoplankton	"
12 0–436 m	GTHO: 6 full. Abundant polychaete tubes bryozoan colonies, sponge spicules, ophiuroids, gorgonacean	TP: failed to sample	N 70 V: 255 – 0 m. Abundant euphausids	Phleger corer recovered 10–15 cm core ending in gravel
12 0–510 m	GTHO: 6 full. Polychaetes with tubes, 2 sipunculids, 2 *Cerianthus* sp. tubes, small molluscs, 5 ophiuroids, 2 echinoids, holothurian, crinoid, sponge frags., calcareous bryozoans, sponge spicules	TP: 46 mins. 32 fish incl. 12 *Trematomus scotti*, asteroids, echinoids, calcareous bryozoans, pycnogonids, polychaetes. octopi, crinoids, sipunculids, prawns, alcyonarians	N 70V: 500–0 m. Rich in phytoplankton. Chaetognaths, copepods, euphausids, polychaetes, amphipods	Phleger corer: 46 cm core
11 0–395 m	GTHO: 6 full. Abundant worm tubes, 2 *Cerianthus* sp. tubes, 1 sipunculid, stem of pennatulacean, sponge spicules	TP: 30 mins. 22 fish, pennatulaceans (*Umbellula* sp.), prawns, crinoids, chitinous bryozoans, echinoids, octopi, sipunculids	N 70V: 400–0 m. Small sample rich in phytoplankton	Phleger corer–20 cm core
12 0–550 m	GTHO: 5 full. Polychaete tubes, ophiuroids, isopods, sponge spicules, part of large asteroid	TP: 7 fish, 3 octopi, holothurians, crinoids, ophiuroids, echinoids, pycnogonids, worm tubes with root-like projections	N 70V: 550–0 m	Ship drifted north at 1 knot
16 0–1750 m	GHO: small sample	DN: Failed	N 70V: 1000–0 m. Fair sample phytoplankton	Ship kept under way to maintain position. Bottom deeply shelving
11 0–453 m	GTHO: 6 full. Living barnacles and dead barnacle plates (*Hexelasma antarctica*), mollusc shells, amphipods, dead frags. of stylasterine coral	TP: Failed. TAS: 5 min, damaged but full. 100 lb barnacle plates	N 70V: 425–0 m. Phytoplankton	On shelf edge
10 0–345 m	GTHO: 4 Rock frags., and sand only	DN: damaged. Pink and white bryozoans, lamellibranchs, gastropods, gorgonaceans, holothurians, ophiuroids, other echinoderms, barnacle plates	Too windy to maintain station for vertical haul	"
10 0–375 m	GD: Barnacle plates, amphipods, ophiuroids	DC: damaged. Barnacle plates, ophiuroids	Too windy to maintain station for vertical haul	Weather conditions limited sampling

Station List of New Zealand Oceanographic Institute Collections, 1959–61—*continued*

Station No.	Locality	Date	Latitude	Longitude	Weather and State of Sea	Time Start	Time Finish	Depth, Metres	Sediment	Gear
A 466	Off Ross Ice Shelf	24/1/59	78° 26′S	174° 50′W	Cloudy, steady wind off Ice Shelf. Air temp. 12°F	1615	0130	569	Mud	3 GTHO, TAS, NP, N70, Corer
A 467	Off Cape Crozier	26/1/59	77° 25′S	169° 28′E	..	1040	1200	88–183	Rocks	N70, DN
A 468	Flat-topped seamount E. of Beaufort Island	,,	76° 59′S	167° 36′E	Bright with some cloud, strong westerly surface current 1½ knots. Surface slicks	2115	2245	110	..	TAS, UWC
A 469	McMurdo Sound near Hut Point	29/1/59	77° 50′S	166° 33′E	..	..	..	64	Gritty mud and sponge spicules	3 GTHO, NP, N70, UWC
A 470	,,	4/2/59	77° 50′S	166° 30′E	..	..	..	377	Muddy sand matted with sponge spicules	3 GTHO, N70
A 471	Off Cape Evans and Barne Glacier	6/2/59	77° 37′S	166° 20′E	Strong cold southerly wind	1500	1615	165–69	..	TAS, UWC
A 472	McMurdo Sound (moored against ice opposite Tent Island)	7/1/59	77° 45′S	166° 20′E	..	..	..	391	..	UWC
A 516	Scott Island ..	5/1/60	67° 25′S	179° 57′W	Clear patch of water surrounded by pack ice	0400	0600	457–183	Rock fragments ..	DN
A 517	Near Ross Ice Barrier	20/1/60	77° 24′S	175° 48′E	Sky cloudy, steady southerly wind, cold	1020	1730	688–640	..	TS, C^{14}
A 518	Beaufort I. ..	25/1/60	77° 0′ 30″S	166° 49′E	Fine, light winds ..	1830	2045	75	..	Camera
A 519	McMurdo Sound	29/1/60	77° 49′ 50″S	166° 30′ 45″E	..	1515	1600	479	Silty mud at top, volcanic sand and gravel	GHO
A 520	Pennell Bank ..	3/2/60	74° 20′ S	179° 30′E	10-knot wind ..	1130	1415	201–205	Pebbles and sandy mud	GHO, DN
A 521	,, ..	4/2/60	73° 54′S to 73° 52′ 36″S	177° 44′W to 177° 46′W	Sky cloudy, SW breeze	0854	1125	582–558	Gravel, cobbles, and mud	GHO, GTP, DD, TS, BT, GD
A 522	,, ..	,,	73° 48′S to 76° 50′S	176° 41′W to 176° 54′W	Sky cloudy, slight westerly breeze	1530	2045	1335	Muddy sand and pebbles	GHO, GTHO, DD, TS, BT, GD
A 523	,, ..	5/2/60	73° 34′S to 73° 31′S	175° 47′W to 175° 34′W	Partly cloudy sky, light breeze	0030	0830	2762–2804 2700 D 1375 I	..	BT, TS
A 524	,, ..	,,	73° 20′S to 73° 21′S	172° 48′W to 172° 48′W	Light cloud, breeze, thick pack ice	1815	2045	3566–3577	Yellow-grey gritty mud with a few pebbles	GTHO, BT
A 525	,, ..	7/2/60	74° 09′S to 74° 07′S	177° 16′W to 177° 09′W	Steady NE wind, snow flurries	0800	0855	591–583	Rocks	DD
A 526	,, ..	,,	74° 07′S	177° 41′W	..	1050	1215	461–465	Pebbles ..	GHO, DD, BT

Station List of New Zealand Oceanographic Institute Collections, 1959–61—*continued*

Hydrology Cast	Grab Haul	Dredge and Trawl Haul	Plankton Haul	Remarks
12 0–570 m	GTHO: 6 full. 15 rat-tailed holothurians, polychaete worms and tubes	TAS: 25 mins at dead slow ahead. Gelatinous holothurians, 7 fish, molluscs incl. 1 octopus, asteroids, ophiuroids	N 70V: 550–0 m. Fair sample	Bulk surface sample C^{14}
..	..	DN: 88–183 m down slope. 200 scallops (*Adamussium colbecki*), echinoids, ophiuroids, dendrochirate holothurians, sponges	N 70: Surface haul	Steep rugged bottom
..	..	TAS: 2 hauls, sampling top and part of western face of seamount. Crinoids, gorgonaceans, holothurians, bryozoans	..	Symmetrical, flat-topped, sea-mount rising from 350–110 m. 3 bottom photographs
..	GTHO: 6 full. Mud matted with sponge spicules, abundant lamellibranchs (*Limatula hodgsoni*), sponges, echinoids, asteroids, ophiuroids, other molluscs, polychaetes	..	..	Ship moored against ice. 3 bottom photos. In intact grab sample *L. hodgsoni* was found buried 1–2 cm below surface
12 0–365 m	GTHO: 4½ full. Sandy mud matted with sponge spicules, worm tubes, polychaete worms, molluscs, 2 crinoids, calcareous bryozoans, barnacle plates	..	..	Ship moored against ice W of Sta. 469. C^{14}, 80 gal at 366 m, 80 gal at surface
..	..	TAS: large sample. Massive sponges, asteroids, pycnogonids, worm tubes, polychaetes, hydroids, *L. hodgsoni*, embedded in sponges, 54 *Odontaster validus*	..	Ship drifted on station. 3 bottom photographs (colour) show abundant sponges
..	..	..	..	1 bottom photograph
..	..	DN: damaged. 4 orange-white pennatulaceans (*Umbellula* sp.), brittle stars, gorgonaceans, commensal polychaetes, holothurians, sipunculids, 1 small fish	..	..
12 0–644 m (C^{14} samples at 0, 376, 640 m)	..	..	..	C^{14}, 88 gal at 640 m, 88 gal at 376 m, 88 gal at surface
..	..	..	..	Shore collecting party to Beaufort Is. 1 bottom photo. Seismic observations
..	GHO: 3 full. Sediment matted with sponge spicules. Abundant animals including polychaetes (one with 8 mm diam. parchment tube and green-blue tentacles), crinoid, echinoid, asteroid, pycnogonids, bryozoans, gorgonaceans with polychaete commensals	..	..	Ship moored against fast ice N of Hut Point
..	GHO: 3 full sand and pebbles only	DN: 60 min. ⅓ full. Bryozoans, ophiuroids, pycnogonids, *Cerianthus*, holothurians, asteroids	..	2 Adelie penguins released. Least depth found on Pennell Bank = 194 m
11 0–545 m	..	DD: 15 min SW direction. Solitary corals (*Gardineria antarctica*) – flesh orange, ophiuroids, bryozoans, stylasterine corals	..	Depth decreased from 582–558 m during trawl
12 0–1,285 m (almost vertical wire)	GOS: Mud and rocks GTOS: Pebbles and a little mud	DD: 30 min. ¾ full. Brachiopods, ophiuroids, amphipods, live barnacles	..	..
13 1,500–2,700 m 0–1,350 m	..	..	..	C^{14}, 44 gal at 2700 m, 88 gal at 1375 m, 88 gal at 0 m
..	GTOS: Yellow-grey gritty mud. No macro-benthic organisms	..	..	..
..	..	DD: 10 min slow ahead, ⅙ full. Living solitary corals, large flaccid tunicates, ophiuroids, serolid, pycnogonids, holothurians, with hard brown dorsal surface (*Psolus* sp.), sea urchins, live barnacles and plates	..	..
..	GHO: Empty, suggesting rock bottom	DD: 30 min. Rock fragments, solitary corals, bryozoans, pink-red euphausids, crinoids, pink-purple urchins, ophiuroids, isopod (*Antarcticus* sp.), asteroids	..	..

Station List of New Zealand Oceanographic Institute Collections, 1959–61—*continued*

Station No.	Locality	Date	Latitude	Longitude	Weather and State of Sea	Time Start	Time Finish	Depth, Metres	Sediment	Gear
A 527	Pennell Bank ..	7/2/60	74° 10′S	178° 17′W	Sky cloudy, strong wind veering to S	1326	1430	358–337	Pebbles	GHO, DD, BT
A 528	,, ..	,,	74° 23′S	179° 26′W	Sky cloudy, 25-knot S wind	1725	1855	274–265	Patches mud and pebbles	Camera, DD
A 529	,, ..	8/2/60	74° 20′S	179° 55′W	Sky cloudy, 25-knot S wind	1403	1515	205–220	Photos show cobbles and coarse sandy mud	Camera, DD, BT
A 530	Pennell Bank (northern slope)	,,	74° 03′ 30″S to 74° 05′S	179° 21′E to 179° 19′E	Cloudy sky, light southerly breeze	1818	2000	271–267	Muddy sand ..	DD
A 531	Ross Sea (SW of Pennell Bank)	9/2/60	75° 02′S to 75° 12′S	178° 10′ E to 178° 14′E	..	0930	1030	358–357	Muddy sand (from photos)	Camera
A 531	..	,,	75° 02′S to 75° 12′S	178° 10′E to 178° 14′E	Flat calm ..	1740	1815	348	..	DD
A 532	McMurdo Sound (moored against ice 3 miles from Hut Point)	10/2/60	77° 44′ 30″S	166° 20′ 5″E	..	1045	1200	488	Muddy sand and rock fragments	GHO, BT
A 533	C. Barne ..	16/2/60	77° 35′S	166° 10′E	Snow flurries, 30-knot SE wind	1910 1955	1950 2010 ..	183–177 84–97	.. ..	DD DD
A 534	,, ..	,,	77° 36′ 42″S to 77° 36′S	166° 08′E to 166° 12′E	..	2305	2330	380–366	..	DD
A 535	,, ..	17/2/60	77° 36′S	166° 07′E	..	0045	0050	337–377	..	BT
A 536	McMurdo Sound	,,	77° 33′ 18″S to 77° 34′ 36″S	165° 53′E to 165° 50′E	Strong SE wind ..	0220	0350	794–790	Rocks and mud ..	TS, BT
A 537	,, ..	,,	77° 30′S to 77° 34′ 48″S	165° 12′E to 165° 19′E	..	0830 0945	0915 0925 1030	574–543	Mud and gravel ..	TS BT DD
A 538	McMurdo Sound	,,	77° 29′ 12″S to 77° 30′S	164° 39′E to 164° 38′E	Cold SE wind 30–40-knot, oily slick on sea, and pack ice forming	1500 ..	1545 1600	269–256	Sand and rocks, sandy mud	TS BT
			77° 30′S to 77° 30′ 12″S	164° 38′E to 164° 37′E		1645	1730	256–260		GD
			77° 30′ 36″S to 77° 31′ 12″S	164° 37′E to 164° 38′E		1740	1800	269–348 –256		Camera DD
A 539	Northern Ross Sea (NE of Cape Adare)	19/2/60	71° 00′S	173° 55′E	Sky partly cloudy, calm	1255	1915 1910	2249	..	TS, C^{14}, BT
A 540	Campbell Island (Perseverance Harbour)	25/2/60	52° 32′ 54″S	169° 7′ 48″E	..	0640	0710	18	Sandy mud ..	Camera, NS
A 576	McMurdo Sound	16/1/61	77° 37′ 6″S	166° 01′ 30″E	..	0830	1500	50	..	EW
A 625	Terra Nova Bay	5/2/61	75° 0′S	163° 58′ 42″E	..	1945	..	520	Pebbles and sandy mud	GHO
A 625	,,	,,	75° 0′S	163° 58′ 42″E	..	2000	2030	460	..	DD
A 641	McMurdo Sound Hut Point	9/2/61	77° 51′ 42″	166° 34′ 30″E	..	0900	0930	322	Rocks, gritty black sand	GHO
A 644	Moubray Bay ..	1/3/61	72° 18′ 8″S	170° 14′ 46″E	..	1710	1815	530	Sloppy black mud	GHO
A 645	,, ..	,,	72° 22′ 0″S	170° 9′ 6″E	..	1315	1420	220	Black-brown sandy mud, few stones	GHO
A 646	McMurdo Sound (first ice hole)	–/12/60	77° 53′ 32″	166° 42′ 00″E	..	..	..	..	..	Hand

Station List of New Zealand Oceanographic Institute Collections, 1959–61—*continued*

Hydrology Cast	Grab Haul	Dredge and Trawl Haul	Plankton Haul	Remarks
"	GOS: No sample	DD: 5 min. ¾ full. Gorgonaceans, stylasterine corals, large cidarids, small pale-pink echinoids, ophiuroids	"	"
"	"	DD: 30 min, ¾ full. Top part fragments of rock. Mud and bryozoans at bottom	"	3 black and white photographs
"	"	DD: 5 min slow ahead in 205 m. Bryozoans, abundant ophiuroids and asteroids	"	3 bottom colour photos taken in approx. 220 m.
"	"	DD: 30 min. Muddy worm tubes, echinoids, ophiuroids, bryozoans, 2 fish	"	"
"	"	"	"	8 colour bottom photos
"	"	DD: 5 min. Small sample. Bryozoans, yellow, orange-tinged crinoids, red echinoids, grey nemertean, ophiuroids, 2 ctenophores, round worm 18 cm long	"	The round worm formed a spiral in the sorting dish and cemented itself down
	GHO: 2 full. Live scaphopods, polychaetes, sponge spicules, gorgonaceans, ophiuroids, tunicates, sponges	"	"	2 close-up photos of live polychaetes. Amphipods taken on bait in fish trap
"	"	DD: 2 hauls. 20 min. 183–177 m, 15 min 84–97 m. Sponges, starfish, red specimens of *Odontaster validus*	"	Steeply shelving bottom off Cape Barne. Camera used without success at Sta. 533–4, 535
"	"	DD: 5 min. Sponges, bryozoans, ophiuroids	"	"
"	"	"	"	"
10 0–700 m (20–30° wire angle)	"	DD: small sample. Molluscs, pycnogonids	"	"
10 0–470 m (wire vertical)	"	DD: Abundant crinoids, ophiuroids, sponge (red), holothurians, bryozoans, polychaetes, prawns	"	Colour photos of fresh specimens
8 0–240 m (wire vertical)	"	DD: Sponges, bryozoans, gorgonaceans, fish, amphipods, worms, molluscs, and prawns	"	Station to windward, 800 yards from large iceberg. 9 bottom photos show rich benthos
6 1200–2200 m 9 0–1025 m	"	"	"	C^{14}. Deep 44 gal of 2,205 m. Intermediate 88 gla at 1,056 m. Surface 88 gal
				8 black and white photos. Small sample benthos
"	"	"	"	Polyzoa, Crinoidea, Gorgonacea, Mollusca
"	GHO: small sample. Sponge spicules brachiopod (live), coral (live), worm tubes, Polyzoa, echinoid spine	"	"	First cast with GHO failed to sample
"	"	DD: Crinoid, large pink and white anemone, prawns, sponge spicules, brittle stars, *Flabellum* sp., Polyzoa, echinoids, worm tubes, gorgonaceans, holothurians, fish, asteroids	"	"
"	GHO: Gorgonacea, brittle star, sponge spicules, Polyzoa, polychaetes, crinoids, brachiopods, amphipods, isopods algae, holothurian, barnacle plates	"	"	"
"	GHO: Large asteroid, 15 in. diameter, yellow-brown, brown tube feet, 1 brittle star	"	"	"
"	GHO: 2. Worm tubes, bare gorgonacean, sponge spicules	"	"	"
"	"	"	"	Dead half-fishes which floated through ice hole.? leavings from seal's meal

Station List of T.A.E. Collections

Marine collections (excluding plankton stations) during 1956–57 and 1957–58 seasons

Sta. No.	Latitude S, ° ′	Longitude E, ° ′	Locality	Depth (fm)	Ship	Dates	Equipment	Remarks	Collection No.
1	77 46·3	166 26·0	6½ miles north of Hut Point (ice edge)	..	*Glacier*	24/12/56	..	On B/T wire	153
	,,	,,	,,	..	,,	6/1/57	..	Floating dead	160–1, 191
	,,	,,	,,	280	,,	10/1/57	Fish trap	..	162–3
	,,	,,	,,	1	*Endeavour*	18/1/57	,,	..	164
	,,	,,	,,	308	,,	24/1/57	Mud snapper grab	..	165–6
	,,	,,	,,	324	,,	24/1/57	,,	..	170A–E
	,,	,,	,,	308	,,	24/1/57	Conical fish trap	..	167
	,,	,,	,,	324	,,	24/1/57	Fish trap	..	168A, B
	,,	,,	,,	308	,,	24/1/57	,,	..	169A, B
	,,	,,	,,	264	,,	26/1/57	Mud snapper grab	..	172–3
	,,	,,	,,	264	,,	27/1/57	,,	..	174–7
	,,	,,	,,	264	,,	28/1/57	Fish trap	..	178–9
	,,	,,	,,	312	,,	28/1/57	Mud snapper grab	..	180A, B
	,,	,,	,,	0	,,	28/1/57	Dip net	..	182
	,,	,,	,,	50–0	,,	29/1/57	Cone net (1 m)	"Midwater trawl"	181
	,,	,,	,,	1–2	,,	1/2/57	Gill net	..	183, 188
	,,	,,	Ice Harbour McMurdo Sound	..	,,	13/1/58	..	..	621
	,,	,,	,,	..	,,	18/1/58	..	Floating, damaged by explosion	870–2
	,,	,,	,,	..	,,	20/1/58	..	At surface	761
2	..	..	3 miles east of Butter Point (ice edge)	180	,,	5/1/57	Mud snapper grab	..	157A, B
3	..	..	7 miles east of Butter Point (ice edge)	..	,,	5/1/57	..	On line of grab	158
	..	..	,,	..	,,	5/1/57	Fish trap	..	159
	..	..	,,	..	,,	5/1/57	..	Floating at surface	156
4	..	..	Cape Armitage	67	..	19/3/57	Fish trap	Under bay ice	254–65
	..	..	,,	67	..	19/3/57	Mud snapper grab	,,	266–8
	..	..	,,	67	..	25/3/57	Fish trap	,,	275–9
	..	..	,,	67	..	14/4/57	,,	,,	282–6
	..	..	,,	67	..	17/4/57	,,	,,	287–97
	..	..	,,	67	..	20/4/57	,,	,,	298–304
	..	..	,,	67	..	22/4/57	,,	,,	308
	..	..	,,	67	..	26/4/57	,,	,,	309–15
	..	..	,,	67	..	3/5/57	,,	,,	320–9
	..	..	,,	67	..	3/5/57	Mud snapper grab	,,	318–9
	..	..	,,	67	..	20/4/57	,,	,,	305–6
	..	..	,,	80	..	6/2/57	Set line	,,	194

Marine collections (excluding plankton stations) during 1956–57 and 1957–58 seasons—*continued*

Sta. No.	Latitude S ° ′	Longitude E ° ′	Locality	Depth (fm)	Ship	Dates	Equipment	Remarks	Collection No.
5	"	"	Backdoor Bay, Cape Royds	2	*Endeavour*	8/2/57	Small Nat. dredge		199, 201
	"	"	"	3–5	"	20/2/58	"	On anchor chain	702
	"	"	"	12	"	23/2/58	Beam trawl	"	703–10, 882–3
6	"	"	Pram Pt	3½	"	17/2/57	Fish trap	Under pressure ice	203–4
	"	"	"	3½	"	18/2/57	"	"	205–8
	"	"	"	3½	"	18/2/57	Mud snapper grab	"	209
	"	"	"	3½	"	19/2/57	Fish trap	"	210
	"	"	"	3½	"	21/2/57	"	"	211
	"	"	"	3½	"	23/2/57	"	"	241–2
	"	"	"	3½	"	27/2/57	"	"	243–7
	"	"	"	3½	"	4/3/57	"	"	248
	"	"	"	3½	"	11/3/57	"	"	249–50
	"	"	"	3½	"	15/3/57	"	"	252–3
	"	"	"	3½	"	20/3/57	"	"	269–72
	"	"	"	3½	"	23/3/57	"	"	274
	"	"	"	2½	"	27/4/57	"	"	316–7
	"	"	"	2½	"	20/11/57	"	Dislodged by explosives through hole	368–74
8	"	"	Campbell I. – New Zealand	"	*Endeavour*	3/3/57	"	"	212
9	"	"	Cape Bernacchi 12 miles east	(307 m)	*Glacier*	13/12/57	"	At edge of fast ice	387
10 *	"	"	Cape Bernacchi 18 miles east	(304–0 m)	"	15/12/57	Crab net	30 minutes at 304 m, to surface	383–6
61	73 44	179 12	"	120	*Endeavour*	28/12/57	"	Caught on B/T	464, 758
74	"	"	Cape Armitage	7	"	17/1/58	Petersen grab	Under bay ice	869
	"	"	"	7	"	19/1/58	"	"	530–1, 544–9, 552, 559, 868
	"	"	"	0	"	19/1/58	"	Taken at surface	539–40
	"	"	"	7	"	23/1/58	Nat. dredge	Under bay ice	528–9, 532–8, 541–3, 550–1, 553–7, 562–93
	"	"	"	7	"	24/1/58	"	"	560–1
75	"	"	Cape Evans	0	*Endeavour*	22/1/58	"	Shore collections intertidal and foreshore	640, 637
	"	"	"	0	"	26/1/58	"	Foreshore and intertidal	614, 607
	"	"	"	0	"	27/1/58	Dip net	Foreshore	636
76	"	"	"	"	"	21/1/58	"	"	638
	"	"	"	23–30	"	27/1/58	Petersen grab	"	619–20
	"	"	"	23–30	"	28/1/58	"	"	641
	"	"	"	29	"	27/1/58	"	"	622–35
77	"	"	Cape Royds	0	"	23/1/58	"	Intertidal and foreshore (algae)	597–8, 604, 609

Station List of T.A.E. Collections—*continued*

Marine collections (excluding plankton stations) during 1956–57 and 1957–58 seasons—*continued*

Sta. No.	Latitude S	Longitude E	Locality	Depth (fm)	Ship	Dates	Equipment	Remarks	Collection No.
78	..	..	Turtle Rock	75–81	*Endeavour*	2/2/58	Petersen grab	..	643–56, 658
	..	..	„	0	„	3/2/58	Dip net	..	657
	..	..	„	1	„	5/2/58	„	From 6 ft below ice foot	660–1
79	77 51	166 34·0	Ice edge McMurdo Sound	68–90	„	5/2/58	Beam trawl	..	665–701, 762
	..	..	Hut Point Anchorage	95	„	6/2/58	„	¼ mile south of previous position	873, 662–4
	..	..	„	0	„	6/2/58	..	„	874
	..	..	„	0	„	6/2/58	Cone net, 1 metre	Beneath sea ice 16 ft thick	875
81	77 00	167 12	..	132	„	9/2/58	..	Caught on B/T	785–7
94	..	..	S.W. coast of Franklin Is.	..	„	11/2/58	..	Shore collection algae	727–8
95	..	..	„	40–60	„	11/2/58	Beam trawl	Ship slow ahead for 10 min	711–26, 879
98	76 07	168 10	Cape Roberts	103–106	„	12/2/58	„	„	731–52, 876–7, 880
99	77 01	162 38	Botany Bay, Granite Harbour	40	„	15/2/58	„	..	788–807
100	77 38	166 20	Cape Evans	60	„	23/2/58	„	..	816–67, 878, 881, 884–6
Misc.	..	..	Williams Field, McMurdo Sound	..	„	25/7/56	..	Taken in pump filter	154
Misc.	..	..	3 miles north of Hut Point	0	..	7/1/57	Dip net	Seal hole	155

*Sta. 11–72 (collections 1–63) were plankton stations taken on passage from New Zealand to the Ross Sea, 19–31 Dec 1957 (Cassie, 1963)

Plankton Stations T.A.E. Collections, 1957–58

(a) From HMNZS *Endeavour*, Franklin Island Cruise, 9/2/58–11/2/58

Sta. No.	Latitude S	Longitude E	Date	Method	Depth (m)	Time	Field Station No.	Collection No.
	° ′	° ′						
80	77 13	166 02	9/2/58	N 70, surface tow	0	1625–35 10 min	1	763
80	,,	,,	,,	Phyto net, surface tow	0	1630–35 5 min	1	764
81	77 00	167 12	9/2/58	N 70, surface	0	2020–30 10 min	2	765
82	77 16·5	169 35	10/2/58	,,	0	0009–25 16 min	3	766
83	76 54	171 20	10/2/58	,,	0	0415–25 10 min	4	767
84	76 27·5	172 45	10/2/58	N 70 Surface tow	0	15 min	5	729
85	76 00	174 00	10/2/58	Phyto net, surface tow	0	1225–30 5 min	6	771
85	,,	,,	10/2/58	Surface tow	0	1210–25 15 min	6	768
86	75 42	172 00	10/2/58	N 70, vertical	400–0	2025–40 15 min	7	769
87	75 22	170 00	10/2/58	Phyto net, surface tow	0	2040–45 5 min	8	770
88	75 04	168 10	11/2/58	N 70, vertical	350–0	0018–27 9 min	9	772
,,	,,	,,	11/2/58	Phyto net, surface tow	0	0030–35 5 min	9	773
89	74 48	167 00	11/2/58	N 70, vertical	500–0	0423–35 12 min	10	774
,,	,,	,,	11/2/58	Phyto net, surface tow	0	0435–40 5 min	10	775
90	75 14	167 15	11/2/58	N 70, vertical	300–0	0813–25 12 min	11	776
,,	,,	,,	,,	Phyto net, surface tow	0	0825–30 5 min	11	777
91	75 46	167 30	11/2/58	N 70, vertical	300–0	1210–20 10 min	12	778
92	76 18·5	167 24	11/2/58	N 70, vertical	650–0	2025–43 18 min	13	779
,,	,,	,,	,,	Phyto net, surface	0	2043–53 10 min	13	780
93	Franklin Is. off beach	W.	11/2/58	Phyto net, surface	0	1600–10 10 min	..	784
96	76 32	165 48	12/2/58	Phyto net, surface	0	0038–48 10 min	14	781
97	76 46·5	165 48	12/2/58	N 70, vertical 500 m to surface	500–0	0420–35 15 min	15	782
,,	,,	,,	,,	Phyto net, surface	0	0437–47 10 min	15	783

(b) Miscellaneous Collections

Sta.	Locality	Date	Ship	Depth (fm)	Equipment	Remarks	Collection No.
1	6–7 miles north of Hut Point (ice edge)	3/2/57	*Endeavour*	6–0	N 70	Vertical haul	184–7
	,,	3/2/57	,,	0		Surface planktonic polychaetes	189
	Ice harbour, McMurdo Sound	19/1/58	,,	300–0	N 70		756
	,,	20/1/58	,,	0		Polychaetes at surface	759
	,,	21/1/58	,,	300–0	N 70	At anchorage 1400 h	617
	,,	29/1/58	,,	300–0	N 70	At anchorage	642
4	Cape Armitage	11/4/57				On bay ice in 67 fm vert. haul	280–1
	,,	20/4/57		67–0	N 70		307
6	Pram Point	20/3/57		3½–0		Vert. haul	273
73	3 miles south of Tent Island	15/1/58	*Endeavour*	0	Phyto net	Surface tow	757
74	Cape Armitage	20/1/58		0	,,	Net suspended in tidal current through ice hole for 30 min	558

Stanford University Invertebrate Studies in the Ross Sea 1958–61: General Account and Station List†

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Abstract

The objectives and results of Stanford University Benthic Invertebrate Studies in Antarctica are summarised. A Station List is presented.

INTRODUCTION

Stanford University has conducted marine biological research in Antarctica since the southern summer of 1958–59, mostly near the U.S. Naval Air Facility at McMurdo Sound (77° 51′S, 166° 39′E). Under the project leadership of Donald E. Wohlschlag,* studies of metabolism, growth, composition of blood, and systematics of Antarctic fishes, ecology and distribution of zooplankton and benthic invertebrates, and biochemical aspects of reproduction in selected invertebrates have been undertaken. This marks the first time a land-based group has been in the Ross Sea area specifically to carry out a marine biological project throughout the year.

Since 1958, as project assistant, the author has been engaged in a study of benthic invertebrate communities at McMurdo Sound. This has involved 25 months of fieldwork in Antarctica including two winter seasons, 1959 and 1961.

This report, completed for publication in 1962, describes the invertebrate programme and provides station data.

*Financial support has been provided by the following U.S. National Science Foundation grants to Stanford University: NSF-G6328, NSF-G9190, NSF-GI3209, NSF-G18021 and NSF-G23210.

Objectives

The programme was organised to study the ecology and distribution of marine benthic invertebrates at McMurdo Sound (plate 2). Emphasis was placed on collecting in shallow water since little of this work has been done. Feeding habits and reproduction were of particular interest. The original objectives of the programme were outlined as follows:

1. To determine, by intensive collecting, the composition and characteristics of the benthic invertebrate fauna near the U.S. Naval Air Facility.
2. To obtain, by quantitative sampling, an indication of the relative abundance of various animals on differing substrates and at various depths.
3. To obtain specific data on feeding habits and reproduction of the most common species.
4. To gather physical data (temperature, salinity, oxygen) to determine the environmental conditions under which these benthic communities exist.

Several general accounts are available of recent marine investigations that include the Ross Sea. Oceanographic work by New Zealand is described by Bullivant (1959a), and Burling (1960). Tressler

†THE FAUNA OF THE ROSS SEA. Part 5. 1967. General Accounts, Station Lists, and Benthic Ecology. By John S. Bullivant and John H. Dearborn. *N.Z. Dep. sci. industr. Res. Bull. 176.*

(1961) reviews the work of the U.S. Navy Hydrographic Office in the Antarctic. Bayer (1961) provides an excellent summary of marine invertebrate work in the Antarctic, indicates the present state of reference collections in the United States, and emphasises the need for systematic investigations.

A short general account of previous oceanographic work carried out in the Ross Sea is given by John S. Bullivant in the N.Z.O.I. General Account preceding this section of "Fauna of the Ross Sea".

Stanford University biological personnel in the Antarctic, 1958–62, comprised:

Summer, 1958–59: John H. Dearborn, Hugh H. DeWitt, James C. Tyler, Donald E. Wohlschlag.

Winter, 1959: John H. Dearborn.

Summer, 1959–60: John H. Dearborn, Stoner B. Haven, Jack L. Littlepage.

Winter, 1960: Stoner B. Haven.

Summer, 1960–61: John H. Dearborn*, Jack L. Littlepage, John S. Pearse, Karl E. Ricker, Bruce L. Wing, Donald E. Wohlschlag.

Winter, 1961: John H. Dearborn, Jack L. Littlepage, John S. Pearse, Karl E. Ricker.

Summer, 1961–62: John H. Dearborn*, Arthur L. DeVries, Gerald L. Kooyman, Jack L. Littlepage, John S. Pearse, Donald E. Wohlschlag*.

*Part of Season only.

AREA STUDIED

Major collections were made between Arrival Heights and Pram Point on the Hut Point Peninsula of Ross Island, South-west Ross Sea, in depths from 0 to 585 m. Additional material was obtained along the north shore of Cape Evans, Ross Island, and along the Victoria Land coast between McMurdo Sound and Coulman Island (figs. 3 a–c).

At N.A.F. McMurdo the shoreline and bottom out to a depth of 15–20 m is composed of cobble, gravels, and sand of volcanic origin. Between 20 and 50–60 m the bottom usually consists of a volcanic substrate overlain with silt, debris from diatoms, siliceous sponges and ectoprocts, and dead bivalve shells (mostly *Limatula hodgsoni*) (plate 3). In deeper water a rich fauna exists comprising mainly thick mats of siliceous sponges, alcyonarians, tubicolous polychaetes, and ectoprocts (plates 4–5). Rocky or mud bottoms occur locally at various depths.

Subsurface water temperatures at McMurdo Sound vary less than 1·0°C around a mean of −1·86°C (pers. comm., J. L. Littlepage). The salinities of subsurface water vary from 34 to 35°/oo.

METHODS

Collecting Techniques

A variety of gear was used in making collections (see Station Details). The Foerst grab and wire traps were used most often and were the most successful, particularly in working through the ice. When open cracks appeared in the sea ice the small Blake trawl, pulled by hand, was used with great success.

In summer it was possible to maintain unsheltered stations on the ice which merely required periodic clearing of ice from the holes.

During the first winter (1959), the maintenance of three unheated stations was attempted. Shacks of plywood were built over two of the holes. The third was used without protection until late July when it had to be abandoned. With air temperatures down to − 60° F a great deal of ice accumulated at these stations between visits and clearing involved manual work. Although the shacks provided some escape from the wind, working conditions were at times difficult since the gear was set and pulled by hand (plate 6). Valuable material was, however, obtained during the first winter.

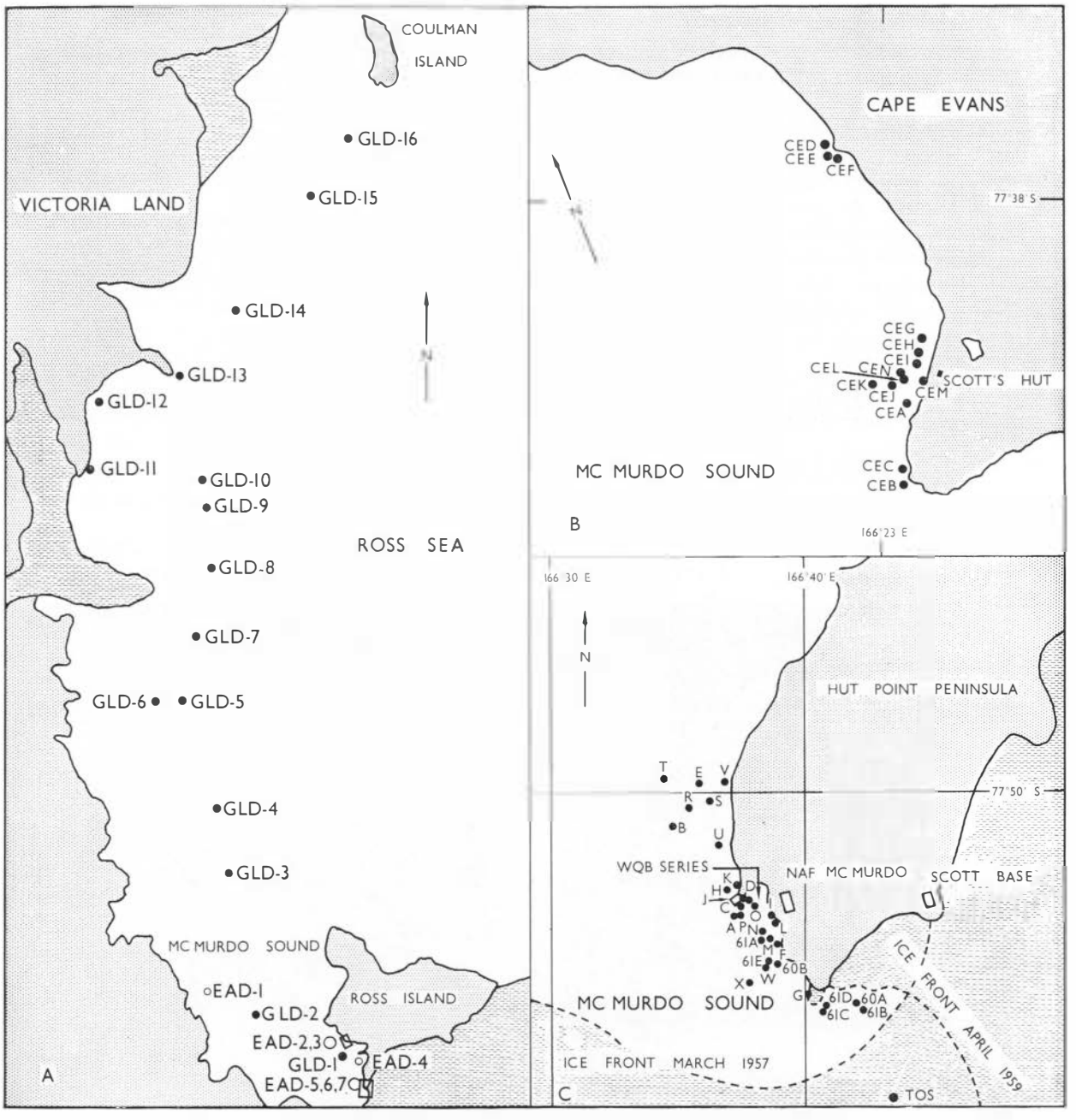


FIG. 3A. Victoria Land coast at the SW corner of the Ross Sea. Stations shown are those made aboard the USS *Glacier* (AGB-4) in 1958, and aboard the USCGC *Eastwind* (WAGB-279) in 1960. Locations of fig. 3b, c are outlined on Ross Island.

3B. Collecting stations at Cape Evans, McMurdo Sound.

3C. Collecting stations at Hut Point, SW Ross Island, McMurdo Sound.

In 1961 sampling in winter was carried out in relative luxury through the use of prefabricated, insulated buildings, complete with heaters, power winches, generators, work tables, and other refinements (plate 7). Minor problems arose, but for the most part the operation went smoothly and large quantities of biological material were collected throughout the year

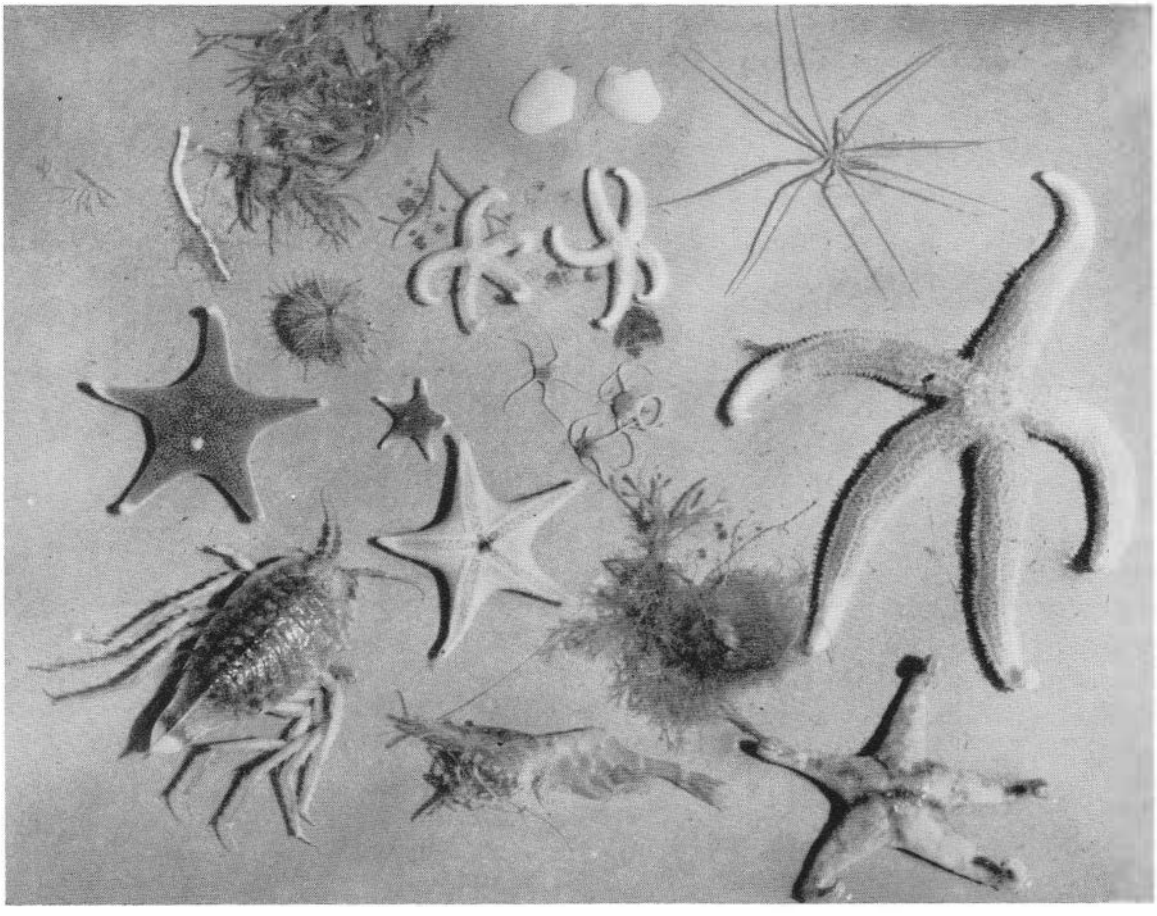
Animals were transported to the Biological Laboratory at the Base in insulated containers or in open buckets or jars quickly placed in a warm vehicle. Most specimens arrived at the laboratory alive and in good condition considering that the temperature difference between the water and the inside of the station building was usually between 40 and 60° F.

Laboratory Work

Emphasis was placed on collecting during the first year of field work. After a reference collection had been built up more time was spent examining and observing living material. With an increase in laboratory space and facilities after the first year it was possible to carry out more detailed work with individual animals, particularly in regard to feeding habits and reproduction. Constant-temperature equipment made it possible to keep material alive for several weeks or more. Much time was spent with photography, particularly during the second winter when dark-room facilities were available.

Abbreviations for Gear (Plates 9, 10)

AT	Alaska fish trap, netting over a heavy rectangular metal frame (plate 6)
BT2	Two foot Blake (Agassiz) trawl
BT4	Four foot Blake (Agassiz) trawl.
DN	Dip net, long handled
DRN	Small draw net on light wire frame
DT	Drum trap, net bag attached to one end of a small open metal drum or barrel.
EPD	Emery Pattern dredge (bottom snapper grab – a small modified Petersen-type grab designated "dredge" by the manufacturer.)
FG	Foerst grab, maximum volume of 5 litres, surface area 0·07 m^2 (plate 9a).
GN	Gill net, variable mesh
HL	Hook and line
LPG	Large Petersen grab, surface area 0·2 m^2
MPG	Modified Petersen grab, surface area 0·1 m^2
NT	Net trap, constructed of fine netting placed over a frame of wire or wood.
OP	Orange-peel grab (plate 9a)
PC	Phleger core
PN12	Plankton net, diam. 12 in
PN5	Plankton net, diam. 0·5 m, coarse mesh
PN1	Plankton net, diam. 1 m, coarse mesh
RN	Ring net, diam. 28 in., netting 1 in. stretch mesh
RT	Ring trap
SDD	Sand dollar dredge (plate 9b)
ST	Small tangle of net or rope
TD	Small triangular dredge, all metal (plate 9c)
UL	Underwater light
WT	Wi traps, various sizes (plate 10) re-mesh



PL.2. Invertebrates from McMurdo Sound. The asteroids are *Diplasterias brucei* (top and right), *Perknaster fuscus antarcticus* (lower right), and *Odontaster validus* (left). The urchin (upper left) is *Sterechinus neumayeri*. An isopod, *Glyptonotus antarcticus*, is at lower left. A calcareous worm tube, ectoprocts, a pycnogonid, several ophiuroids, and a shrimp are shown.

Official U.S. Navy photograph

STATION DETAILS*

The following list includes all localities where benthic invertebrates have been collected during the present study. Original letter and number designations used in the field are retained. Times (h or hours) listed are local and 12 hours ahead of Greenwich Mean Time. Station locations are shown in fig. 3.

(1) Sta. Occupied from the USS *Glacier* (AGB–4), 1958

Collectors John H. Dearborn, Hugh H. DeWitt, and the USS *Glacier* Oceanographic Team (Oceanographer in charge, James Q. Tierney, U.S. Navy Hydrographic Office). Stations correspond to the "GL" series listed by DeWitt and Tyler (1960).

Sta. GLD–1. West of Tent Island, McMurdo Sound; 77° 42′S, 166° 12′E; 11–14 November 1958; 384 m; no bottom data; HL, RT.

Remarks: Nine separate ring-trap sets of varying duration made during the period; 99% ice cover.

Sta. GLD–2. East of Marble Point, McMurdo Sound; 77° 27′S, 164° 41′E; 17 November 1958; 0915–1100 h; 320 m; no bottom data; WT.

Remarks: 99% ice cover.

Sta. GLD–3. South-west Ross Sea; 76° 50′S, 165° 07′E; 27 November 1958; 0000–0045 h; 549 m; no bottom data; PC, PN12.

Remarks: Vertical tow from about 300 m to surface; equals USS *Glacier* Deep Freeze (D.F) IV Ocean. Sta. GL–4.

Sta. GLD–4. South-west Ross Sea; 76° 31·8′S, 164° 55′E; 27 November 1958; 0615–0700 h; 587 m; sponge – coelenterate complex; BT4.

Remarks: Speed of ship 1–2 knots; equals USS *Glacier* D.F. IV Ocean. Sta. GL–5.

Sta. GLD–5. South-west Ross Sea; 76° 11·6′S, 164° 46′E; 27 November 1958; 1400–1500 h; 695 m; sponge – gorgonacean complex; TD.

Remarks: Equals USS *Glacier* D.F. IV Ocean. Sta. GL–6.

Sta. GLD–6. South-west Ross Sea; 76° 04′S, 164° 18′ E; 27 November 1958; 2100 h; 695 m; no bottom data; RN.

Remarks: Vertical haul from about 365 m; equals USS *Glacier* D.F. IV Ocean. Sta. GL–7.

Sta. GLD–7. South-west Ross Sea; 75° 46·4′S, 165° 15′E; 29 November 1958; 0230–0430 h; 860 m; sponge – coelenterate complex; BT4.

Remarks: Speed of ship 1–2 knots; equals USS *Glacier* D.F. IV Ocean. Sta. GL–8.

Sta. GLD–8. Off South Terra Nova Bay, Ross Sea; 75° 30′S, 165° 44′E; 29 November 1958; 0945–1045 h; 631 m; sponge – gorgonacean complex; BT4.

Remarks: Speed of ship 1–2 knots; equals USS *Glacier* D.F. IV Ocean. Sta. GL–9.

Sta. GLD–9. Off Terra Nova Bay, Ross Sea; 75° 15′S, 165° 55′E; 29 November 1958; 1500–1545 h; 808 m; no bottom data; RN.

Remarks: Vertical tow, bottom to surface; equals USS *Glacier* D.F. IV Ocean. Sta. GL–10.

Sta. GLD–10. Off Terra Nova Bay, Ross Sea; 75° 06′S, 165° 52′E; 29 November 1958; 1545–1700 h; 832 m; rocky with sponges; BT4.

Remarks: Speed of ship 1–2 knots.

Sta. GLD–11. Terra Nova Bay, Ross Sea; 74° 58′S, 164° 04′E; 30 November 1958; 0030–0630 h; 860 m; no bottom data; RT.

Sta. GLD–12. Terra Nova Bay, Ross Sea; 74° 41·5′S, 164° 37′E; 30 November 1958; 1500–1700 h; 15–30 m; rocky with red algae; HL, TD.

Remarks: Collecting area from one-half to 1 mile from the ship's position listed; one ring trap and one circular trap with funnel openings were set off the ship, 1500–1800 h, caught nothing.

Sta. GLD–13. Off Cape Washington, Ross Sea; 74° 39′S, 165° 52′E; 30 November 1958; 2300–2330 h; 165 m; sponge – coelenterate complex; BT4.

Remarks: Equals USS *Glacier* D.F. IV Ocean. Sta. GL–13.

Sta. GLD–14. North of Cape Washington, Ross Sea; 74° 25·1′S, 167° 00·3′E; 1 December 1958; 0400–0945 h; 732 m; no bottom data; AT.

Remarks: Trap dragged on the bottom as ship drifted.

Sta. GLD–15. South-west of Coulman Island, Ross Sea; 73° 58·5′S, 168° 29′E; 1 December 1958; 1930–2000 h; 366 m; gravel and pebbles, some mud; TD.

Remarks: Equals USS *Glacier* D.F. IV Ocean. Sta. GL–16.

Sta. GLD–16. Off Coulman Island, Ross Sea; 73° 46·7′S, 169° 09′E; 2 December 1958; 0130–0215 h; 836 m; gravel and pebbles; TD.

Remarks: Equals USS *Glacier* D.F. IV Ocean. GL–17.

*Sta. 79, 98, 100, 258, 285, 293, 300, 313, 317, and 377 in "The Fauna of the Ross Sea, Pt. 4" by Olive S. Tattersall, pp. 11, 14, were erroneously referred to as Stanford University Stations. These "Station" numbers are T. A. E. Collection Numbers (see p. 26, this Memoir). The Stanford University Station List begins with "Tressler . . ." (p. 14, Tattersall).

(2) McMurdo Sound, 1958–61

Positions of stations plotted from U.S. Navy Hydrographic Chart H.O. 6712, revised edition 21 August 1961, using data from aerial photographs, field sketches, and limited ground surveys.

Sta. A. Off Hut Point, McMurdo Sound; 77° 51′ 03″S, 166° 37′ 19″E; 19 November 1958–5 January 1959; 51 m; sponge – coelenterate complex; MPG, NT, PN5, RN, WT.

Remarks: Coll. J. H. Dearborn, H. H. DeWitt, and others; seal hole enlarged by hand; equals DeWitt and Tyler (1960) Sta. MM–20.

Sta. B. North of Hut Point, McMurdo Sound; 77° 50′ 14·8″S, 166° 35′ 05″E; 19 November 1958–5 January 1959; 115 m; sponge – coelenterate complex; MPG, WT.

Remarks: Coll. J. H. Dearborn, H. H. DeWitt, and others; seal hole enlarged by hand; equals DeWitt and Tyler (1960) Sta. MM–18.

Sta. C. Off Hut Point, McMurdo Sound; 77° 50′ 56·9″S, 166° 37′ 43″E; 22 November 1958–5 January 1959; 25 m; volcanic gravel and sandy mud; GN, HL, MPG, WT.

Remarks: Coll. J. H. Dearborn, H. H. DeWitt, D. E. Wohlschlag, and others; hole in ice cut by hand; equals DeWitt and Tyler (1960) Sta. MM–19.

Sta. D. Off Hut Point, McMurdo Sound; 77° 50′ 55·7″S, 166° 37′ 51″E; 18 December 1958–5 January 1959; est. 25 m; volcanic gravel and sandy mud; HL.

Remarks: Coll. J. H. Dearborn, J. Reseck, and others; hole in ice cut by hand.

Sta. E. Off Arrival Heights, McMurdo Sound; 77° 49′ 58·9″S, 166° 36′ 07″E; 26 December 1958–6 January 1959 8–87 m; volcanic gravel (8 m) – sponge complex (87 m); AT, HL, MPG, NT, PN5, RN, WT.

PL. 3. Bottom sample from Station 61E, 20 m. Substrate, mostly organic debris consisting in part of siliceous sponge spicules, ectoprocts, and bivalve shells (mostly *Limatula hodgsoni*). The gastropod in the centre is probably *Trophon longstaffi*.

Official U.S. Navy photograph

Remarks: Coll. J. H. Dearborn, H. H. DeWitt, and others; open crack in sea ice, crack extended out at right angles to the shoreline, collections from several points along the crack; position indicates deepest site where the majority of samples were taken; equals DeWitt and Tyler (1960) Sta. MM–21.

Sta. F. North-west shore of Cape Armitage, McMurdo Sound; 77° 51′ 16·3″S, 166° 39′ 16″E; 9 January 1959–22 February 1959; 7–15 m; volcanic gravel and sandy mud; HL, MPG, WT.

Remarks: Coll. J. H. Dearborn, H. H. De Witt, D. E. Wohlschlag, and others; tidal crack along ice foot, several areas sampled along a 15–20 m stretch; equals DeWitt and Tyler (1960) Sta. MM–25.

Sta. G. Near tip of Cape Armitage, McMurdo Sound; 77° 51′ 42·7″S, 166° 40′ 21″E; 11 January – 22 February 1959; 5·5 m; volcanic gravel and sandy mud; HL, MPG, WT.

Remarks: Coll. J. H. Dearborn, H. H. DeWitt, D. E. Wohlschlag, and others; open crack in the ice, area further enlarged by hand; equals DeWitt and Tyler (1960) Sta. MM–26.

Sta. G–1. Near tip of Cape Armitage, McMurdo Sound; 77° 51′ 43·4″S, 166° 40′ 22″E; 11 January – 22 February 1959; 4·6 m; volcanic gravel and sandy mud; MPG.

Remarks: Coll. J. H. Dearborn, H. H. DeWitt, D. E. Wohlschlag, and others; open crack in the ice, area further enlarged by hand.

Sta. G–2. Near tip of Cape Armitage, McMurdo Sound; 77° 51′ 44″S, 166° 40′ 22″E; 11 January – 22 February 1959; 4·4 m; volcanic gravel and sandy mud; MPG, WT.

Remarks: Coll. J. H. Dearborn, H. H. DeWitt, D. E. Wohlschlag, and others; open crack in the ice, area further enlarged by hand.

Sta. G–3. Near tip of Cape Armitage, McMurdo Sound; 77° 51′ 44·5″S, 166° 40′ 22″E; 11 January – 22 February 1959; 5 m; volcanic gravel and sandy mud; DRN, DT, MPG, PN5, RN, TD, WT.

Remarks: Coll. J. H. Dearborn, H. H. DeWitt, D. E. Wohlschlag, and others; open crack in the ice, area further enlarged by hand; equals DeWitt and Tyler (1960) Sta. MM–28.

Sta. H. North of Hut Point, McMurdo Sound; 77° 50′ 48·7″S, 166° 37′E; 29 January – 1 February 1959; 54 m; no bottom data; DN, HL, WT.

Remarks: Coll. J. H. Dearborn, H. H. DeWitt; along ice edge in ship channel; equals DeWitt and Tyler (1960) Sta. MM–29.

Sta. I. Along shore line in front of the U.S. Base, McMurdo Sound; 77° 51′ 6·3″S, 166° 39′ 05″E; 23 February – 27 March 1959, 14 – 21 March 1961; 4 m; volcanic gravel and sand; DT, WT.

Remarks: Coll. J. H. Dearborn, J. S. Pearse, and others; gear set in open water off ice foot, or through holes in newly formed ice.

Sta. J. Hut Point, McMurdo Sound; 77° 50′ 54·9″S, 166° 37′ 43″E; 8 March – 5 April 1959; 4 m; rocky with volcanic gravel; WT.

Remarks: Coll. J. H. Dearborn and U.S. Navy personnel; gear set in open water off ice foot, or through holes in newly formed ice.

Sta. K. Off north shore Hut Point, McMurdo Sound; 77° 50′ 48″S, 166° 37′ 38″E; 6 – 16 April 1959; 3·3 m; volcanic gravel and sand; DN, UL, WT.

Remarks: Coll. J. H. Dearborn and U.S. Navy personnel; gear set from ice edge, hole kept open by hand.

Sta. L. Just off shore in front of the U.S. N.A.F., McMurdo Sound; 77° 51′ 8·6″S, 166° 39′ 08″E; 21 – 25 April 1959; 6·1 m; volcanic gravel and sand; DN, UL, WT.

Remarks: Coll. J. H. Dearborn and U.S. Navy personnel; hole cut in ice by hand.

Sta. M. South of Hut Point, McMurdo Sound; 77° 51′ 14·2″S, 166° 39′ 01″E; 22 April – 24 October, and 18 November 1959; 38 m; greyish-brown gravelly mud with sponge spicules and *Limatula* valves; FG, HL, OP, PN5, ST, WT.

Remarks: Coll. J. H. Dearborn, U.S. Navy personnel, and others; hole blasted in the ice, kept open by hand; unheated shack built over hole during winter; two 55 gal steel drums, welded end to end, used to line hole; station turned over to W. Stanley Wilson, Virginia Fisheries Laboratory, on 24 October 1959.

Sta. N. South of Hut Point, McMurdo Sound; 77° 51′ 11·2″S, 166° 38′ 46″E; 22 April – 21 November 1959; 43 m; greyish-brown gravelly mud with sponge debris and *Limatula* valves; DT, FG, GN, HL, OP, PN5, ST, WT.

Remarks: Coll. J. H. Dearborn, S. B. Haven, J. L. Littlepage, U.S. Navy personnel, and others; hole blasted in the ice, kept open by hand; unheated shack built over hole during winter; two 55 gal steel drums, welded end to end, used to line hole.

Sta. O. South of Hut Point, McMurdo Sound; 77° 51′ 01·8″S, 166° 38′ 09″E; 15 June – 25 July 1959; 43 m; no bottom data; PN5, WT.

Remarks: Coll. J. H. Dearborn and U.S. Navy personnel; hole in ice partially cut by hand, then blasted.

Sta. P. Off Hut Point, McMurdo Sound; 77° 51′ 03″S, 166° 37′ 30″E; 8 September – 17 December 1959; 57 m; sponge complex; AT, FG, OP, PN5, PN1, RN, WT, LPG.

Remarks: Coll. J. H. Dearborn, S. B. Haven, J. L. Littlepage, and others; seal hole enlarged and kept open by hand; equals DeWitt and Tyler (1960) Sta. MM–30.

Sta. R. Off Arrival Heights, McMurdo Sound; 77° 50′ 06″S, 166° 35′ 55″E; 5 – 17 December 1959; 71 m; sponge – bivalve complex with many polychaete tubes; FG, WT.

Remarks: Coll. J. H. Dearborn, S. B. Haven, J. L. Littlepage; hole blasted in ice.

Sta. S. Off Arrival Heights, McMurdo Sound; 77° 50′ 05·1″S, 166° 36′ 26″E; 25 November – 24 December 1959; 64·5 m; sponge – coelenterate complex; FG, OP, PN5, PN1, WT.

Remarks: Coll. J. H. Dearborn, J. L. Littlepage, and others; hole blasted in ice.

Sta. T. Off Arrival Heights, McMurdo Sound; 77° 49′ 55·5″S, 166° 34′ 37″E; 6–28 December 1959; 103 m; sponge – bivalve complex; AT, FG, PN5, PN1.

Remarks: Coll. J. H. Dearborn, J. L. Littlepage, and others; hole blasted in ice.

Sta. U. North of Hut Point, McMurdo Sound; 77° 50′ 30·8″S, 166° 36′ 48″E; 6–17 December 1959; 55·5 m; sponge – bivalve complex; FG, LPG.

Remarks: Coll. J. H. Dearborn, J. L. Littlepage; hole blasted in ice.

Sta. V (series). Off Arrival Heights, McMurdo Sound; 77° 49′ 58·2″S, 166° 36′ 50″E (V); 16 December 1959–3 January 1960 (V,V–1, V–2, V–3), 20 December 1959–3 January 1960 (V–4, V–5), 22 December 1959–3 January 1960 (V–6);

PL. 4. Bottom sample from Station 61D, 136 m. A large pycnogonid (upper left), several worm tubes, and a number of valves of the mollusc, *Limatula hodgsoni*, are visible. The majority of the mat is composed of siliceous sponges and ectoprocts.

Official U.S. Navy photograph

8·5 m (V), 15·5 m (V–1), 19 m (V–2), 23 m (V–3), 29 m (V–4), 31 m (V–5), 33 m (V–6); volcanic gravel to sponge complex as depths increase along ice crack; AT, BT2, FG, OP, SDD, TD, WT.

Remarks: Coll. J. H. Dearborn, J. L. Littlepage, and others; open crack in the sea ice; crack ran at right angles to the shore line, seven separate depths sampled plus trawls by hand along crack from deepest (V–6) to most shallow (V) station.

Sta. W. Off north-west shore of Cape Armitage, McMurdo Sound; 77° 51′ 25″S, 166° 38′ 44″E; 24 December 1959–13 January 1960; 53 m; sponge complex; FG, PN5, PN1, WT, HL.

Remarks: Coll. J. H. Dearborn, J. L. Littlepage, and others; hole blasted in ice.

Sta. X. West of Cape Armitage, McMurdo Sound; 77° 51′ 43·1″S, 166° 37′ 24″E; 24 December 1959–21 February 1960; 135 m; sponge – shell complex; FG, PN5, PN1, WT.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole blasted in ice.

Sta. TOS (Tressler Oceanographic Station). South of Cape Armitage, McMurdo Sound; 77° 53′S, 166° 44′E; April 1960–10 March 1961; 565–585 m; gravel, small rocks, ectoproct and sponge debris; FG, OP, ST, WT.

Remarks: Coll. S. B. Haven, A. M. Ommundsen, W. L. Tressler, and others; station established and operated by Dr Willis L. Tressler, U.S. Navy Hydrographic Office, and Audun M. Ommundsen for obtaining physical data; turned over to Stanford personnel in February 1961; hole cut in ice by hand; over hole was set up insulated, prefabricated building, 20 × 24 ft, with heating, power winch, and generator; station moved with the ice over 300 ft during the year; station and much gear lost on 10 March 1961 when the ice went out rapidly.

Sta. 60A. South-east of Cape Armitage, McMurdo Sound; 77° 51′ 56·8″S, 166° 43′ 05″E; 5 December 1960–26 February 1961; 234–240 m; sponge – coelenterate complex; PN1, WT, FG.

Remarks: Coll. J. L. Littlepage, and others; hole blasted in ice; over hole was built uninsulated, heated shack, 8 × 12 ft, with power winch and generator; station primarily used for Littlepage plankton studies.

Sta. 60B. North-west of Cape Armitage, McMurdo Sound; 77° 51′ 25·3″S, 166° 39′ 12·5″E; 15 December 1960–25 February 1961; 19 m; no bottom data; WT.

Remarks: Coll. J. S. Pearse, and others; hole in ice cut with chain saw; station used mainly by Pearse to collect asteroids and amphipods for biochemical studies.

Sta. WQB–1. Winter Quarters Bay, McMurdo Sound; 77° 50′ 55·9″S, 166° 38′ 26″E; 1 April 1961; 19·5 m; volcanic gravel and sandy mud FG.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole in ice cut with chain saw.

Sta. WQB–2. Winter Quarters Bay, McMurdo Sound; 77° 50′ 54·9″S, 166° 38′ 20″E; 1 April 1961; 16 m; volcanic gravel and sandy mud; FG.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole in ice cut with chain saw.

Sta. WQB–3. Winter Quarters Bay, McMurdo Sound; 77° 50′ 54″S, 166° 38′ 14″E; 1 April 1961; 23·5 m; volcanic gravel and sandy mud; FG.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole in ice cut with chain saw.

Sta. WQB–4. Winter Quarters Bay, McMurdo 1961; 18·5 m; volcanic gravel and sandy mud; Sound; 77° 50′ 53″S, 166° 38′ 08″E; 1 April FG.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole in ice cut with chain saw.

Sta. WQB–5. Winter Quarters Bay, McMurdo Sound; 77° 50′ 52·1″S, 166° 38′ 02″E; 1 April 1961; 15 m; volcanic gravel and rocks; FG.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole in ice cut with chain saw.

Sta. WQB–6. Winter Quarters Bay, McMurdo Sound; 77° 50′ 51·3″S, 166° 38′ 12″E; 1 April 1961; 23 m; volcanic gravel and sandy mud; FG.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole in ice cut with chain saw.

Sta. WQB–7. Winter Quarters Bay, McMurdo Sound; 77° 50′ 52·7″S, 166° 38′ 20″E; 1 April 1961; 28 m; volcanic gravel and sandy mud; FG.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole in ice cut with chain saw.

Sta. WQB–8. Winter Quarters Bay, McMurdo Sound; 77° 50′ 53·5″S, 166° 38′ 27″E; 1 April 1961; 27 m; volcanic gravel and sandy mud; FG.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole in ice cut with chain saw.

Sta. 61A. South of Hut Point, McMurdo Sound; 77° 51′ 14·2″S, 166° 38′ 44·9″E; 25 March–1 April 1961; 38 m; no bottom data; WT.

Remarks: Coll. J. H. Dearborn, J. L. Littlepage, and J. S. Pearse; hole cut in ice with chain saw.

Sta. 61B. South-east of Cape Armitage, McMurdo Sound; 77° 51′ 59·6″S, 166° 43′ 14″E; 9 April 1961–3 January 1962; 278–290 m; sponge – coel-

enterate complex; FG, HL, LPG, OP, PN5, PN1, SDD, WT.

Remarks: Coll. J. H. Dearborn, J. L. Littlepage, J. S. Pearse, and others; station used mainly by Littlepage for plankton studies; no sampling of benthic invertebrates was carried out after 3 November 1961; hole in ice cut with chain saw; over hole was built insulated, heated shack, 8 × 16 ft with power winch and generator; station moved with the ice several hundred feet during the year.

Sta. 61C. South of Cape Armitage, McMurdo Sound; 77° 52′ 3·8″S, 166° 41′ 10″E; 14 April 1961; 190 m; sponge – coelenterate complex; FG.

Remarks: Coll. J. H. Dearborn and J. S. Pearse; hole in ice cut with chain saw.

Sta. 61D. South of Cape Armitage, McMurdo Sound; 77° 51′ 57·3″S, 166° 41′ 17″E; 10 May – 3 November 1961; 128–136 m; sponge – coelenterate complex; BT2, FG, HL, OP, PN5, PN1, TD, UL, WT.

Remarks: Coll. J. H. Dearborn, J. S. Pearse, and others; station primarily for collecting of benthic invertebrates, used by Stanford personnel for other projects after 3 November 1961; hole in ice cut with chain saw; over hole was built insulated, heated shack, 8 × 16 ft, with power winch and generator; station moved with the ice several hundred feet during the year.

Sta. 61E. North-west of Cape Armitage, McMurdo Sound; 77° 51′ 24″S, 166° 38′ 50″E, 3 May – 18 December 1961; 19–23 m; volcanic gravel, mud, sponge and ectoproct debris; FG, HL, WT.

Remarks: Coll. J. H. Dearborn, J. S. Pearse, and others; station used primarily by Pearse for collecting asteroids and amphipods for biochemical studies; no general sampling of benthic invertebrates after 31 October 1961; hole in ice cut with chain saw; over hole was built insulated, heated shack, 8 × 16 ft, immersion heater periodically used in hole.

PL. 5. Siliceous sponge spicules, ectoproct debris, and valves of the mollusc *Limatula hodgsoni* (right) from Station 61D, 136 m.

Official U.S. Navy photograph

(3) Stations from USCGC *Eastwind* (WAGB–279), 1960

Collectors John H. Dearborn, Jack L. Littlepage, and the USCGC *Eastwind* Oceanographic Team (Oceanographer in charge, Lloyd W. Wilson, U.S. Navy Hydrographic Office).

Sta. EAD–1. Off Marble Point, McMurdo Sound; 77° 26′S, 164° 03′E; 19 February 1960; 1730 h; 181 m; mud; FG.

Sta. EAD–2. Off Inaccessible Island, McMurdo Sound; Start 77° 39·4′S, 166° 16′E; Stop 77° 40·8′S, 166° 16·5′E; 19 February 1960; 1945–2040 h; 315 m; sponge – coelenterate complex; BT2.

Sta. EAD–3. Off Inaccessible Island, McMurdo Sound; Start 77° 42·1′S, 166° 19·5′E; Stop 77° 43·1′S, 166° 19·1′E; 19 February 1960; 2149–2300 h; 351–432 m; sponge complex with some rocks; BT2.

Sta. EAD–4. Off Erebus Bay, McMurdo Sound; 77° 47′ 30″S, 166° 27′E; 20 February 1960; 0030 h; 587 m; mud; FG.

Sta. EAD–5. Near Hut Point, McMurdo Sound; 77° 50·7′S, 166° 36′E; 20 February 1960; 0230 h; 85 m; sponge – coelenterate complex; FG.

Sta. EAD–6. Near Hut Point, McMurdo Sound; 77° 50·5′S, 166° 34·5′E; 20 February 1960; 0308 h; 101 m; sponge – coelenterate complex, FG.

Sta. EAD–7. Near Hut Point, McMurdo Sound; 77° 50·2′S, 166° 33·9′E; 20 February 1960; 0325 h; 205 m; sponge debris and mud; FG.

Pl. 6. John H. Dearborn (left), and Jack L. Littlepage pulling an Alaska trap from a hole in the ice near Hut Point, Ross Island (Station T), December 1959.

Official U.S. Navy photograph

(4) Cape Evans, 1960–61

Positions of stations plotted from U.S. Navy Hydrographic Chart H.O. 6667 (2nd Ed.), revised 28 September 1959, and the British Antarctic Expedition 1910–13 (*Terra Nova*) map of Cape Evans (Report on Surveys VIII), corrected through Notice to Mariners, 18 July 1959, using data from aerial photographs and field sketches.

Sta. CEA, CEA–1. North shore of Cape Evans, McMurdo Sound; 77° 38′ 21″S, 166° 24′E; 17–22 January 1960 (CEA), 18 January 1960 (CEA–1); 4·3 m; volcanic gravel and sand; EPD, WT.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; holes cut in ice by hand along natural crack; CEA–1 about 40 ft east of CEA.

Sta. CEB. Off the tip of North Cape, Cape Evans, McMurdo Sound; 77° 38′ 32″S, 166° 23·5′E; 19 January 1960; 0600–0700 h; 4·6 m; coarse volcanic gravel; EPD.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; eight grab samples taken through natural holes and cracks in ice.

Sta. CEC. North-east side of North Cape, Cape Evans, McMurdo Sound; 77° 38′ 30″S, 166° 23·6′E; 19–29 January 1960; 1–3·5 m; volcanic gravel and sand, some rocks with red algae; DN, EPD, GN, TD, WT.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; some gear set using a rubber boat.

Sta. CED. Off north-east shore of Cape Evans, near south edge of the Barne Glacier, McMurdo Sound; 77° 37′ 47″S, 166° 24·6′E; 23 January 1960; 2200–2245 h; 3·4 m; volcanic gravel; EPD.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole cut in thin ice along pressure crack.

Sta. CEE. Off north-east shore of Cape Evans, near south edge of the Barne Glacier, McMurdo Sound; 77° 37′ 48″S, 166° 24·5′E; 23 January 1960; 2245–2330 h; 3 m; volcanic gravel and sand; EPD, OP.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole cut in thin ice along pressure crack.

Sta. CEF. Off north-east shore of Cape Evans, near south edge of the Barne Glacier, McMurdo Sound; 77° 37′ 49″S, 166° 24·5′E; 23 January 1960; 2330–2400 h; 4·3 m; volcanic gravel; OP.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole cut in thin ice along pressure crack.

Sta. CEG. Off beach in front of Scott's Hut, north shore of Cape Evans, McMurdo Sound; 77° 38′ 15″S, 166° 24·5′E; 25 January 1960; 1530–1615 h; 13·7 m; black sandy mud; FG.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole cut in thin ice along pressure crack.

Sta. CEH. Off beach in front of Scott's Hut, north shore of Cape Evans, McMurdo Sound; 77° 38′ 16″S, 166° 24·4′E; 25 January 1960; 1615–1700 h; 15·2 m; rocky with gravel; FG.

PL. 7. Interior of Station 61D, McMurdo Sound. The orange-peel grab is shown in open position over the hole.
Official U.S. Navy photograph

PL. 8. Interior of Station 61B, McMurdo Sound, showing a 1 m plankton net, Nansen bottles, and winch.
Official U.S. Navy photograph

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole cut in thin ice along pressure crack.

Sta. CEI. Off beach in front of Scott's Hut, north shore of Cape Evans, McMurdo Sound; 77° 38′ 18″S, 166° 24·2′E; 25 January 1960; 1700–1730 h; 10 m; volcanic gravel and mud; FG.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole cut in thin ice along pressure crack.

Sta. CEJ. Off north shore of Cape Evans, McMurdo Sound; 77° 38′ 21″S, 166° 24′E; 26–30 January 1960; 12 m; volcanic gravel and small rocks; EPD, FG, WT.

Remarks: Coll. J. H. Dearborn, and J. L. Littlepage; hole in ice, 3 × 4 ft, cut by hand; some gear lost when ice broke up quickly.

Sta. CEK. Off north shore of Cape Evans, McMurdo Sound; 77° 38′ 18″S, 166° 23·8′E; 29–30 January 1960; 30 m; volcanic gravel and mud; FG, WT.

Remarks: Coll. J. H. Dearborn and J. L. Littlepage; hole in ice, 3 × 4 ft, cut by hand; some gear lost when ice broke up quickly.

Sta. CEL. Off north shore of Cape Evans, McMurdo Sound; 77° 38′ 20″S, 166° 24·2′E; 24 January 1960; 1230–1330 h; 5–6·5 m; volcanic gravel and cobble, some red algae; SDD, TD.

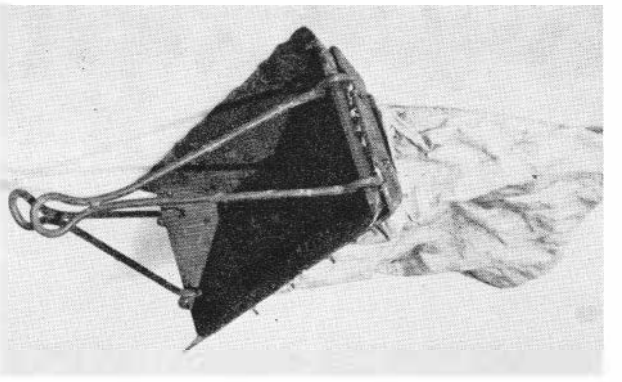
Remarks: Coll. J. H. Dearborn and J. L. Littlepage; seven short dredge hauls by hand along crack in ice.

Sta. CEM. Northern shore of Cape Evans, McMurdo Sound; 77° 38′ 21″S, 166° 24·1′E; 15 January – 4 February 1960, 4 January, 7 February, 6 March, 5 and 20–21 April, and 5 May 1961; 0–3 m; volcanic gravel and sand; AT, BT2, DN, GN, TD, WT.

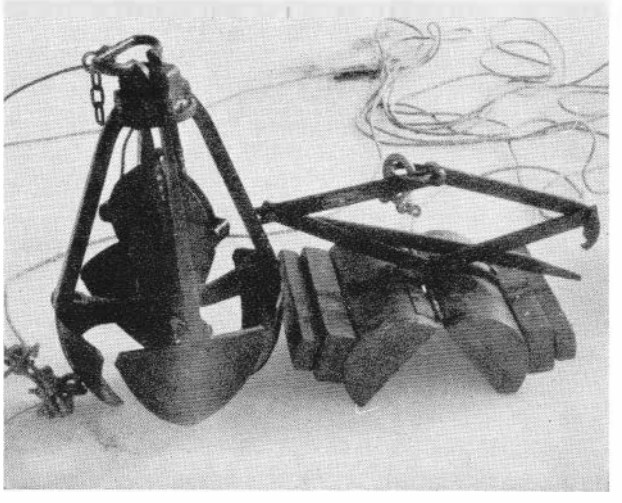
Remarks: Coll. J. H. Dearborn, J. L. Littlepage, J. S. Pearse, and others; collecting along ice foot and beach; some gear set using a rubber boat.

Sta. CEN. Off beach in front of Scott's Hut, northern shore of Cape Evans, McMurdo Sound; 77° 38′ 18″S, 166° 24·1′E; 31 August – 4 September, 25–29 September, 31 October – 4 November 1961; 14–16 m; volcanic gravel and cobble; FG, WT.

Remarks: Coll. J. H. Dearborn, J. L. Littlepage, J. S. Pearse, and others; two separate holes, 25 ft apart, cut in ice with chain saw and by hand; Pearse continued occasional work at this station until 7 December 1961.



PL. 9 (b) Sand Dollar type dredge (SDD) with mouth width of 18 in.
Photograph by John H. Dearborn



PL. 9 (a). Orange-peel grab (OP) and the Foerst grab (FG).
Photograph by John H. Dearborn

PL. 9 (c) Small triangular metal dredge (TD) with 1 ft sides.
Photograph by John H. Dearborn

RESULTS

Scope of Faunal Survey

During the 25 months of field work in Antarctica between 1958 and 1961, collections were made at 79 localities in the Ross Sea. Of these stations, 65 were at McMurdo Sound, and 14 along the Victoria Land coast. Collecting was done from the shore line to a depth of 860 m on a variety of substrates.

Of the McMurdo Sound stations, 41 were 50 m or less in depth, eight between 50 and 100 m, seven between 100 and 200 m, seven between 200 and 400 m, and two deeper than 400 m. Off the Victoria Land coast, one station was less than 50 m, one 100–200 m, one 200–400 m, and 11 at depths exceeding 400 m.

Hydrological Data

Tressler and Ommundsen (1962) provide considerable physical oceanographic data for a station 585 m deep south of Cape Armitage, McMurdo Sound, referred to by them as the "ice hole" (see station list, Tressler Oceanographic Station). The following comments on temperature, salinity, and oxygen values are based on their work.

Sea temperatures at McMurdo Sound were very constant throughout the year. Tressler's data indicated a yearly mean of −1·83°C (extreme 0·56°) at 100 m, and for bottom water (585 m) −1·89°C (extreme 0·07°). Mean summer temperature (November to March) on the bottom was −1·88°C (range 0·04°), and in winter (May to October) was −1·90°C (range 0·07°).

Over 11 months of regular sampling of the water column (surface to 585 m) salinity at the ice hole varied from 34·00–34·96‰. From October to March the salinity of the bottom water varied from 34·72–34·96‰.

Dissolved oxygen values ranged from 4·89–8·40 ml/l. Values for bottom water, October to March, ranged from 5·58–6·71 ml/l. In winter there was very little variation in dissolved oxygen concentrations throughout the water column. Data from May to September indicated a range of 5·51–6·19 ml/l for depths below 200 m.

Physical data recorded by Jack L. Littlepage at Station 61B agree closely with these findings (Littlepage 1965).

Effects of Ice on Marine Ecology

The scouring action of ice along the shore line effectively eliminates an intertidal fauna. In winter, ice accumulated along the shore may grind against the bottom to depths of 5 m or more. Grounded icebergs and floes may disturb the substrate at much greater depths. Shallow waters adjacent to ice foot formations are by no means devoid of benthic inhabitants, but the larger invertebrates are mostly found in summer after some melting has occurred (e.g., *Lineus corrugatus*, *Glyptonotus antarcticus*, *Odontaster validus*, and *Perknaster fuscus*. Anchor ice may form directly on the bottom.

Pearse (1962b) has noted large patches of ice crystals on the bottom at Cape Evans in April 1961 in water 1–2 m deep. He has also found sea urchins, clam shells, and pebbles embedded in two-year-old sea ice 2 m thick over water 19 m deep. On this evidence, he has suggested that the presence of benthic invertebrates and fish remains in floating sea ice and shelf ice is due to animals becoming entrapped in ice which under certain conditions can form on the bottom and subsequently rise.

More recent evidence supports Pearse's view. Underwater photographs taken near Cape Armitage by Verne Peckham* clearly indicate large ice crystals attached to the substrate in about 12 m. The photographs show several invertebrates clearly entangled in ice crystals or with ice attached to them. Species include an unidentified actiniarian; a nemertean, *Lineus corrugatus*; an isopod, *Glyptonotus antarcticus*; an asteroid, *Odontaster validus*; and an echinoid, *Sterechinus neumayeri*. Thus anchor ice may have pronounced effects on benthic invertebrates in shallow water. The limit of depth at which ice may form on the bottom, if indeed there is one, is not known. Evidence of anchor ice forming on thick sponge-coelenterate mats would be of particular interest.

The physiological response of marine animals to temperature in nearly constant physical conditions appears to be very sensitive, and the variation in McMurdo Sound water is less than 1°C. In temperate and tropical seas such physiological processes as initiation of gametogenesis, spawning, or deposition of lipids may require a temperature stimulus of much greater magnitude than in the Antarctic. This is supported by work on invertebrates and fish at McMurdo Sound by Stanford University workers (unpublished).

*Laboratory technician in 1962 at the U.S. Antarctic Research Program Biological Laboratory at McMurdo Base.

GENERAL SURVEY OF MATERIAL COLLECTED IN McMURDO SOUND

McMurdo Sound collections indicate a rich and varied benthic invertebrate fauna, with filter-feeding and predaceous forms predominating. The relative paucity of species associated with the volcanic gravel and sand substrate of shallow water is compensated for by a large assemblage of species inhabiting the complex of siliceous sponges, alcyonarians, and ectoprocts overlying the volcanic gravel and rocks in deeper water. Hydroids, polychaetes, small crustaceans, brachiopods, pterobranchs, and ascidians are commonly found in the sponge mats. The following brief outline of species taken is in no way a complete faunal list but it does indicate the more abundant or representative invertebrate animals within groups for which identifications were available.

Near the McMurdo base, on the volcanic gravel and debris in depths less than about 50–60 m, the most conspicuous benthic invertebrates include an unidentified actiniarian; a large nemertean, *Lineus corrugatus*; a large sluggish isopod, *Glyptonotus antarcticus*; a bivalve mollusc, *Limatula hodgsoni*; the ophiuroids, *Ophiurolepis gelida* and *Ophiacantha antarctica*; and the asteroids, *Odontaster validus* and *Diplasterias brucei*.

The extensive mats of sponges found on the bottom in much of McMurdo Sound, usually below 50 m, are formed largely of siliceous species, especially the hexactinellid genus *Rossella*. Associated with the sponge mats are many alcyonarians (e.g., *Primnoisis*, *Primnoella*, *Thouarella*, *Umbellula*) and ectoprocts.

Two species of scleractinian corals, *Caryophyllia antarctica*, and *Gardineria antarctica*, were taken on rocky bottoms or on mixed rock, gravel, and shell debris.

Two species of sipunculids, *Golfingia margaritacea capsiformis* and *G. ohlini*, have been identified.

There were few species of Malacostraca in the McMurdo Sound collections, although there were many individuals, particularly tanaidaceans and amphipods. Only a single leptostracan, *Nebaliopsis* (?) sp., was found but the mysids included *Hansenomysis antarctica*, *Pseudomma belgicae*, *P. armatum*, *Amblyops tattersalli*, *Mysidetes posthon*, *Antarctomysis maxima*, and *A. ohlinii*. Four species of cumaceans were identified, *Cyclaspis gigas*, *Campylaspis antarctica*, *Paralamprops* (?) sp., and *Diastylis* sp., and a single species of tanaidacean, *Nototanais antarcticus*, was found to be extremely common to depths of about 100 m. Common isopods in deeper water included *Cirolana intermedia*, *C. albinota*, *Aega glacialis*, and several species of *Antarcturus*. Species of the amphipod genus *Orchomenella* were taken at McMurdo Sound in great numbers, *O. pinguides* being often collected in shallow water along the ice edge, while *O. plebs* (with *O. rossi*) was taken in baited wire traps literally by the bucketful. Amphipods regularly collected below 100 m included *Epimeria macrodonta*, *Epimeriella macronyx*, *Eusirus microps*, *Maxilliphimedia longipes*, and *Orchomenella* sp. Several specimens of *Eusirus perdentatus*, a large amphipod brilliantly marked with crimson, were taken at depths exceeding 500 m.

PL. 10 Dr Donald Wohlschlag mending a wire trap at McMurdo Sound.

Official U.S. Nat. Sci. Foundation photograph

Molluscs are an important element in McMurdo Sound, both in number of species and of individuals. One of the most abundant in shallow and intermediate depths is the bivalve, *Limatula hodgsoni*, usually associated with sponge debris or living mats of sponge in which it burrows. Other common bivalves include *Laternula elliptica*, *Thracia meridionalis*, *Yoldia* (*Aequiyoldia*) *eightsii*, and *Philobrya sublaevis*. Gastropods most frequently encountered are *Margarella refulgens*, *Trophon longstaffi*, *Antimargarita crebrilirulata*, *Subonoba fraudulenta*, and *Neobuccinum eatoni*. *N. eatoni* is especially abundant off the north shore of Cape Evans.

Except for the vast numbers of sponges and alcyonarians on the sea floor at McMurdo Sound, the echinoderms were the most conspicuous and perhaps spectacular animals present. Four species of crinoids were noted: *Promachocrinus kerguelensis* and *Anthometra adriani*, being common from depths below about 50 m. Four species of echinoids were taken, three of them belonging to the *Abatus* complex. The only sea urchin taken regularly near McMurdo Base was *Sterechinus neumayeri*. Of nine species of ophiuroids, the most common were *Ophiacantha vivipara*, *O. antarctica*, *Amphiodia joubini** and *Ophiurolepis gelida*. The three most common shallow-water asteroids were *Odontaster validus*, *Diplasterias brucei*, and *Porania antarctica glabra*. *Odontaster meridionalis* also occurred but much less frequently. Common asteroids taken mostly below 300 m included *Psilaster charcoti*, *Notasterias armata*, *Luidiaster gerlachei*, *Bathybiaster loripes obesus*, and *Macroptychaster accrescens*. Along the north shore of Cape Evans, as well as the shallow-water asteroids mentioned above, several specimens of *Perknaster fuscus antarcticus* were obtained.

*Transferred to *Hemilepis* by Fell (1962, p. 5).

Collections

Collections made during this study have been sorted and, through the courtesy of the N.Z. Oceanographic Institute, and in particular John S. Bullivant, specialists have accepted and begun work on these and N.Z. collections from the Ross Sea. (List in Bullivant, App. 1.)

Bulk material will remain at Stanford University until the completion of the present ecological project. It will then be deposited, with all type material, in the U.S. National Museum, although in some instances paratypes and duplicate material may be retained by individual specialists.

Reports

Systematic accounts are being published in the N.Z. Oceanographic Institute series *The Fauna of the Ross Sea*, and in various journals. (See Appendices 2, 3).

ACKNOWLEDGMENTS

A programme involving several seasons of field collecting in Antarctica is necessarily dependent for its success on many people and organisations. I gratefully acknowledge the logistic support of U.S. Navy Task Force 43 and, in particular, the officers and men of Operation Deep Freeze IV and 61. Personnel of the Antarctic Programmes Office of the National Science Foundation have cooperated in all aspects of this study.

It is impossible to thank individually all those who have aided in this work. The following persons and organisations have been especially helpful: Thomas E. Berg, Hugh H. DeWitt, William G. Fry, Galen Howard Hilgard, Robin Leech, and George H. Meyer; the New Zealand Oceanographic Institute, particularly J. W. Brodie and John S. Bullivant; New Zealand Scott Base personnel, particularly Vincent E. Donnelly and the late Rodney Hewitt; Jack L. Littlepage, Audun Ommundsen, John S. Pearse, Madison E. Pryor, John Reseck, John Russell, James Q. Tierney, Willis L. Tressler, Lloyd W. Wilson, and W. Stanley Wilson. Donald P. Abbott, my graduate advisor and major professor, has made many helpful suggestions throughout the programme.

The encouragement and assistance offered by Donald E. Wohlschlag, Stanford Biological Projects Leader for Antarctica, are acknowledged with thanks.

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TRESSLER, W. L. 1961: The Hydrographic Office in the Antarctic. *Bull. U.S. Antarctic Proj. Officer 3 (2)*: 2–5.

APPENDIX 3

List of Antarctic Biological Papers Entirely or in Part by Stanford University Personnel

1. DEARBORN, J. H. 1962: An unusual occurrence of the leopard seal at McMurdo Sound, Antarctica. *J. Mammal. 43 (2)*: 273–5.
2. ——— 1962: Food habits of the isopod *Glyptonotus antarcticus* Eights at McMurdo Sound, Antarctica. (Abstr.) *Bull. ecol. Soc. Amer. 43 (3)*: 86.
3. ——— 1963: Marine benthos at McMurdo Sound, Antarctica. (Abstr.) *Bull. ecol. Soc. Amer. 44 (2)*: 41–2.
4. ——— 1967: Stanford University invertebrate studies in the Ross Sea 1958-61: General account and station list. *In* The Fauna of the Ross Sea. Part 5. By J. S. Bullivant and J. H. Dearborn. *N.Z. Dep. sci. industr. Res. Bull. 176*.
5. ——— 1965: Reproduction in the notothenid fish *Trematomus bernacchii* Boulenger at McMurdo Sound, Antarctica. *Copeia, (3)*: 302–8.
6. ——— 196–: Food habits of Weddell seals at McMurdo Sound, Antarctica. *J. Mammal.* In press.
7. DEVRIES, A. L. 1964: Diving depths of the Weddell seal. *Science, 145 (3629)*: 292.
8. DEWITT, H. H. 1962: On the probable identity of *Macrias amissus*, a deep-water notothenioid fish from the Chilean coast. *Copeia, (3)*: 657–9.
9. ——— 1962: A new genus and species of zoarcid fish from McMurdo Sound, Antarctica. *Copeia, (4)*: 819–26.
10. ——— 1962: A new Antarctic notothenid fish with notes on two recently described Notothenioforms. *Copeia, (4)*: 826–33.
11. DEWITT, H. H., and TYLER, J. C. 1960: Fishes of the Stanford Antarctic Biological Research Program, 1958–59. *Stanford ichthyol. Bull. 7 (4)*: 162–99.
12. KOOYMAN, G. L. 1963: Erythrocyte analysis of some Antarctic fishes. *Copeia, 1963*: 457–8.
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15. ——— 1962: Diving behavior of a Weddell seal wintering in McMurdo Sound, Antarctica. (Abstr.) *Bull. ecol. Soc. Amer. 43 (3)*: 69.
16. ——— 1963: Seasonal variation of the plankton of McMurdo Sound, Antarctica and its relationship to the marine physical environment. (Abstr.) *Bull. ecol. Soc. Amer. 44 (2)*: 42.
17. ——— 1963: Diving behavior of a Weddell seal wintering in McMurdo Sound, Antarctica. *Ecology 44 (4)*: 775–7.
18. ———1964: Seasonal variation in lipid content of two Antarctic marine crustacea. *In* R. Carrick *et al*, eds;, "Biologie Antarctique". *C.r. 1er Symp. S.C.A.R., Paris, 1962*: 463–470.
19. ——— 1965: Oceanographic Observations in McMurdo Sound, Antarctica. *Antarct. Res. Ser. 5, Am. Geophys. Union Publ. 1297*: 1–37.
20. LITTLEPAGE, J. L., and J. S. PEARSE. 1962: Biological and oceanographic observations under an antarctic ice shelf. *Science 137 (3531)*: 679–81.
21. MEYER, G. H., et al. 1962: Antarctica: the microbiology of an unfrozen saline pond. *Science 138 (3545)*: 1103–4.
22. PEARSE, J. S. 1962a: Gametogenic and spawning periods in the Antarctic asteroid, *Odontaster validus* Koehler. (Abstr.) *Bull. ecol. Soc. Amer. 43 (3)*: 99.
23. ——— 1962b: Early development of the Antarctic asteroid, *Odontaster validus* Koehler. (Abstr.) *Amer. Zool. 2 (3)*: 436.
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33. ——— 1961: Sexual differences in metabolism of an Antarctic fish. (Abstr.) *Bull. ecol. Soc. Amer. 42 (2)*: 59.
34. ——— 1961: Activity and metabolism of Antarctic fishes. (Abstr.) *Bull. ecol. Soc. Amer. 42 (3)*: 81.
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39. ——— 1962: Antarctic fish growth and metabolic differences related to sex. *Ecology 43 (4)*: 589–97.
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45. ——— 1963: Research program on the ecological and physiological characteristics of McMurdo Sound animals. *Bull. U.S. Antarct. Proj. Officer 5 (1)*: 12–16.
46. ——— 1963: Biological research facilities at McMurdo Station. *Bull. U.S. Antarct. Proj. Officer 5 (1)*: 17–21.
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Ecology of the Ross Sea Benthos*

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Abstract

A general commentary on the Ross Sea benthic fauna establishes a basis for dividing the fauna sampled into three major assemblages and a number of minor assemblages, linked with substrate characteristics. These major groups are the Deep Shelf Mixed Assemblage, the Deep Shelf Mud Bottom Assemblage, and the Pennell Bank Assemblage.

The Ross Sea benthos is dominantly sessile in character and associated with the availability of hard substrate. The unique character of the antarctic benthos is discussed.

INTRODUCTION

Much of the Ross Sea floor lies in depths between 200 and 400 fm (fig. 4). The coasts plunge steeply down to this deep shelf that extends over the whole ice-free area of the Ross Sea. This wide shelf in turn drops rapidly, especially to the north, to abyssal depths. The surface of the deep undulating shelf is typically covered with a glacial sediment of silt, sand, gravel, and scattered erratic boulders.

The coast of Antarctica is for most of its length protected from wave erosion by glaciers or pack ice and, because the surface of the continent is almost entirely covered by ice, there is no river or windborne organic and inorganic sediment to contribute to continental shelf deposits and to the food of the organisms of that shelf.

The present description of the unusual benthos found in the Ross Sea is based on field notes, on photographs of trawl samples and on examination of the sorted material. The benthos found at each station is described and the distributions of similar faunas are mapped. (The report was completed, 1964.)

*THE FAUNA OF THE ROSS SEA. Part 5. 1967. General Accounts, Station Lists, and Benthic Ecology. By John S. Bullivant and John H. Dearborn. *N.Z. Dep. sci. industr. Res. Bull.* 176

FAUNAL GROUPINGS REFERRED TO SUBSTRATE

Coarse and Fine Sediment Areas

Coarse Sediment Stations

Sta. A 449 was worked on a small rise on the deep shelf floor. The sediments obtained were coarse and the fauna of stylasterine coral, barnacle plates, and bryozoa suggest that the substrate was dominated by ice-rafted erratics. The benthos was rich and included tubicolous polychaetes (plate 11).

Sta. A 450 resembled A 449 in the mixture of epifauna and infauna. Nine species of ophiuroids are recorded from Sta. A 449 and 10 from Sta. A 450. Seven of these species are common to the two stations. *Amphiodia joubini*, the only ophiuroid recorded from both Antarctic and New Zealand waters, occurs at both stations (Fell, 1961): from its distribution Fell concludes that this species "is an indicator of soft bottom".

Sta. A 451 resembled the previous station, in the sparse fauna of polychaetes and molluscs, also scattered bryozoans, gorgonaceans, and crinoids.

The benthos at Sta. A 457, which was on the deep shelf south-west of Pennell Bank, resembled that found at Sta. A 449 and A 450 – a mixture of bryozoans, polychaetes, sponges, echinoderms, and molluscs. Of the 11 species of ophiuroids recorded from Sta. A 457, six also occur at Sta. A 449 and six at Sta. A 450. Like Sta. A 449 the bathymetry of the area reveals that this station lies on a slight rise on the shelf.

Fine sediment stations

In contrast with the above stations are those characterised by animals requiring a soft substrate (plate 12). Sta. A 448 is situated in a relative depression on the shelf floor, the sediment is fine, a tubicolous polychaete is characteristic and animals requiring a hard substrate are generally lacking.

Grab samples from Sta. A 452 and A 453 yielded yellow-brown, stiff, muddy clay, with a few animals which probably lived on top of the mud. These samples were from well down the shelf slope, south-east of Pennell Bank.

At Sta. A 458 there were large numbers of tubicolous polychaetes and the bryozoans were of varieties equipped with chitinous roots for anchoring in a soft substrate.

Sta. A 459 (plate 13) resembles A 448 even more closely than does the previous station. The 10 species of ophiuroids reported from this station all occur at Sta. A 448 and a similar fauna of polychaetes, echinoderms, sipunculids, cerianthids, and gorgonaceans occurs at both stations.

The bulk of the specimens taken in the grabs at Sta. A 460 were polychaete tubes. The benthos from this station (north of Franklin I.) resembled that from Sta. A 448 and A 459. Six of the seven species of ophiuroids also occurred at Sta. A 448.

Another station resembling A 448 was Sta. A 461, just east of Coulman Island. The nine species of ophiuroids at Sta. A 461 all occurred at Sta. A 448 and polychaete worm tubes were abundant.

Sta. A 466 was notable for the abundance of burrowing rat-tailed holothurians; otherwise the benthos resembled that at Sta. A 448.

The light brown cylindrical arenaceous tests (about 5 mm × 1 mm) of a benthic foram *(Rhabdammina* sp. possibly *discreta)* were common in the sediments from this station and from Sta. A 448, A 458, A 459, A 460, A 461, all stations at which the sessile fauna was sparse and the sediment fine.

Stations on Barnacle-plate Bottom

A most unusual bottom, which can only be described as a barnacle bank, was found at Sta. A 463 on the northern edge of the deep shelf. Here, evidently, the barnacle *Hexelasma antarcticum* (plate 14) covers exposed erratics thickly and the dead plates have built up a deposit comprised of very little else, with almost no fine sediment. The depth at this station was 468 m, and a similar deposit was recovered from Sta. A 465 at 399 m.

On 10 November 1956 the USS *Glacier* occupied a station (No. 7) at 72° 25′ 06″S, 174° 09′ 30″E, about 18 miles west of Sta. A 463. An orange-peel-grab sample was taken in 521 m, barnacle plates, bryozoans, and corals forming almost all of the sample (U.S. Hydrographic Office, 1957). The author comments: "Fragments generally 1 cm or longer in size. Some gastropods and a few sea urchin spines are also present." This is evidently the same type of deposit. Hence a fairly extensive bed of barnacles on the northern edge of the deep shelf exists from 400–550 m and, from the extremely coarse nature of the sediment in comparison with the sediment elsewhere in the Ross Sea, it is reasonable to assume that in this area there are strong bottom currents which prevent deposition of finer sediment grades.

A related barnacle, *Hexelasma hirsutum*, has been found associated with the barnacle *Verruca recta* in depths between 500 and 1,000 fm (900–1,800 m) on the continental slope to the south-west of the British Isles (Southward and Southward, 1958). In the laboratory *H. hirsutum* did not sweep the water with its cirri, as barnacles normally do, but simply extended them into a current of water of a suitable

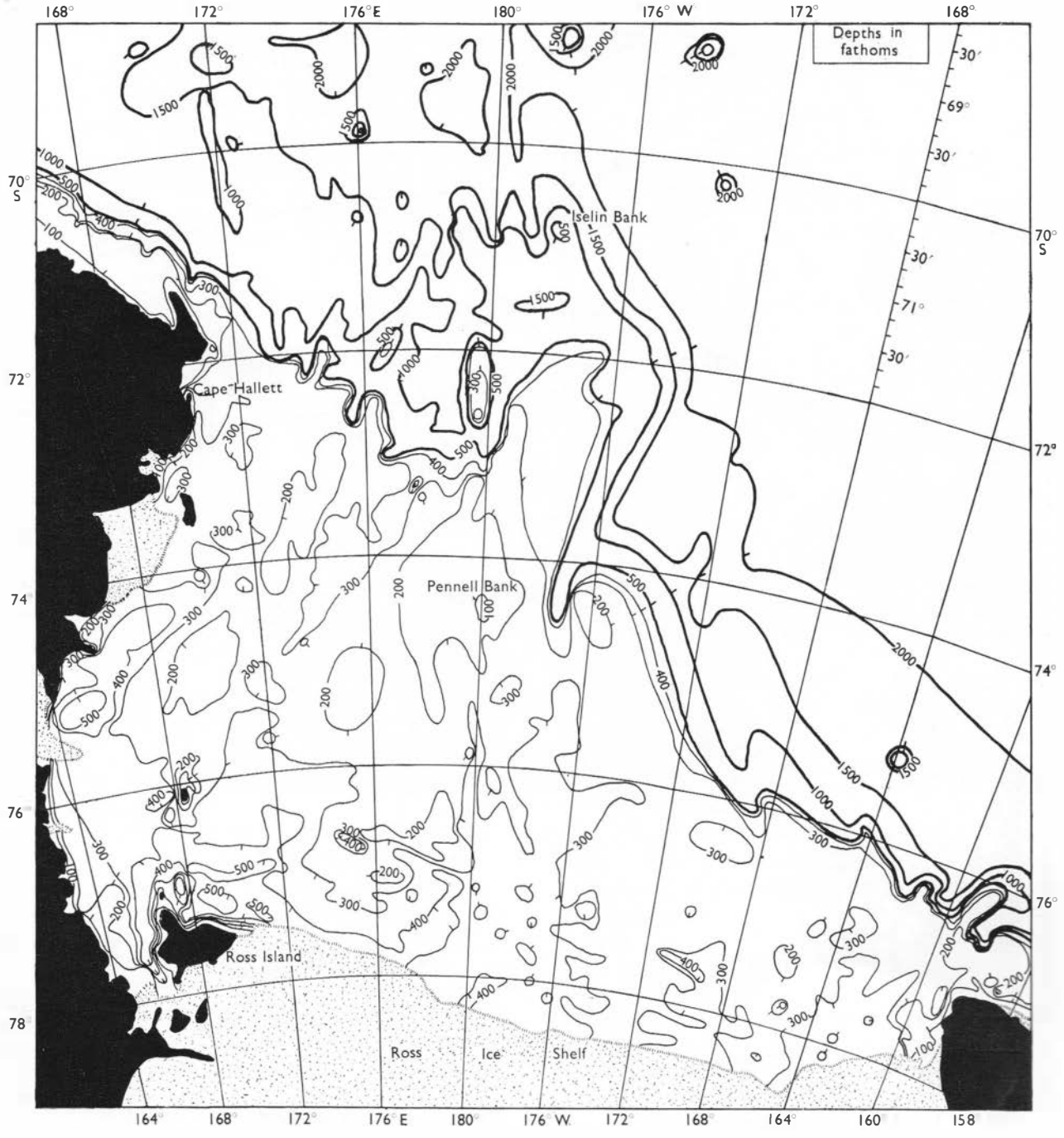


FIG. 4. Bathymetric chart of the Ross Sea.

strength. The nature of the substrate and the behaviour of *H. hirsutum* and *V. recta* indicate that they are accustomed to considerable water movement. Perhaps *H. antarcticum* behaves similarly.

Southward and Southward (1958) remark: "Barnacle communities of shallow water areas are best developed on wave-beaten rocky coasts or in estuaries with strong tidal currents, and it is a general rule that most species need water movement in their habitat to succeed in competition with other sessile organisms."

Other groups of animals which feed as do barnacles on plankton and drifting particulate organic matter just above the bottom are sponges, various coelenterates, sessile polychaetes, molluscs, bryozoans, brachiopods, and tunicates. Of these

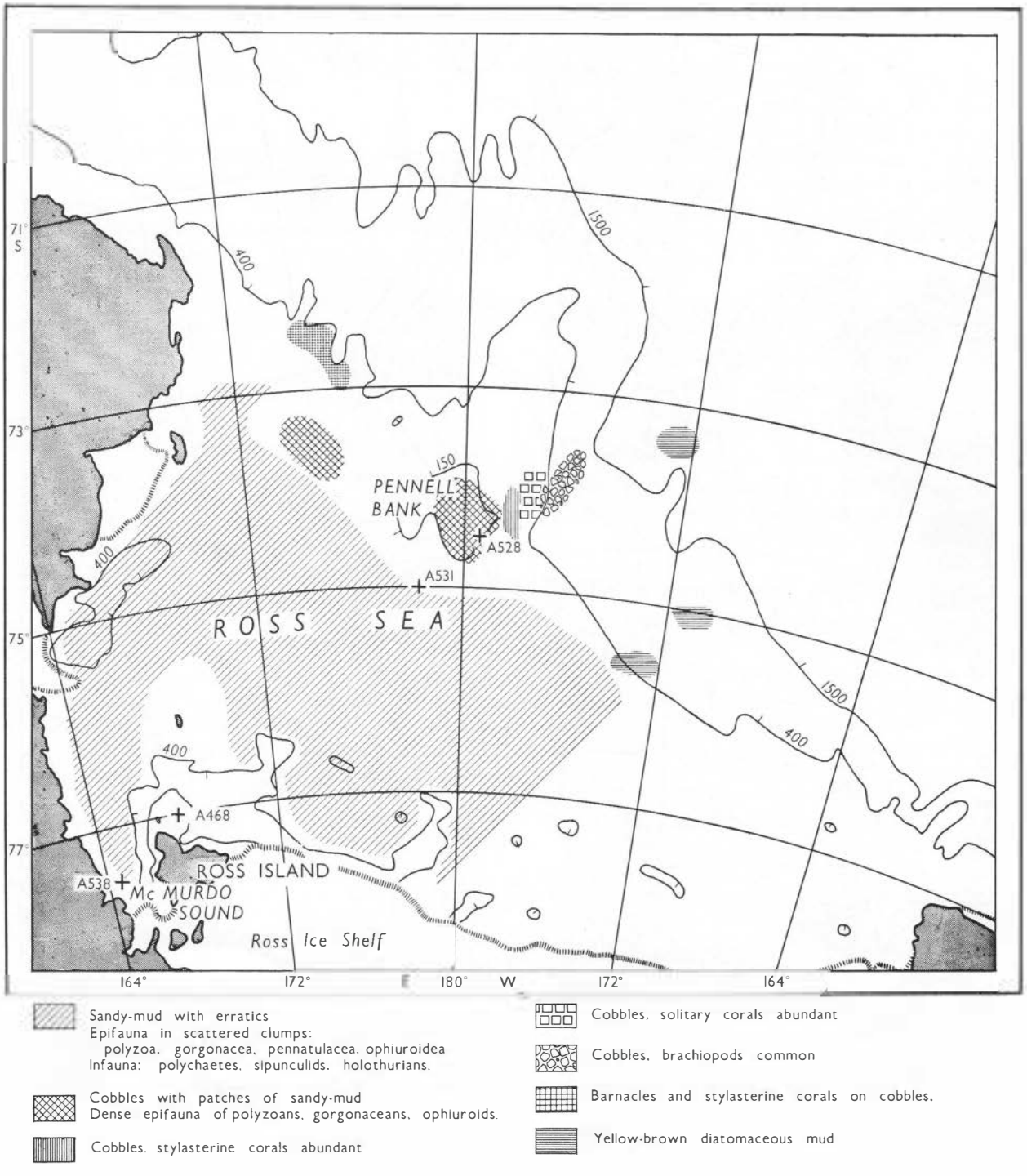
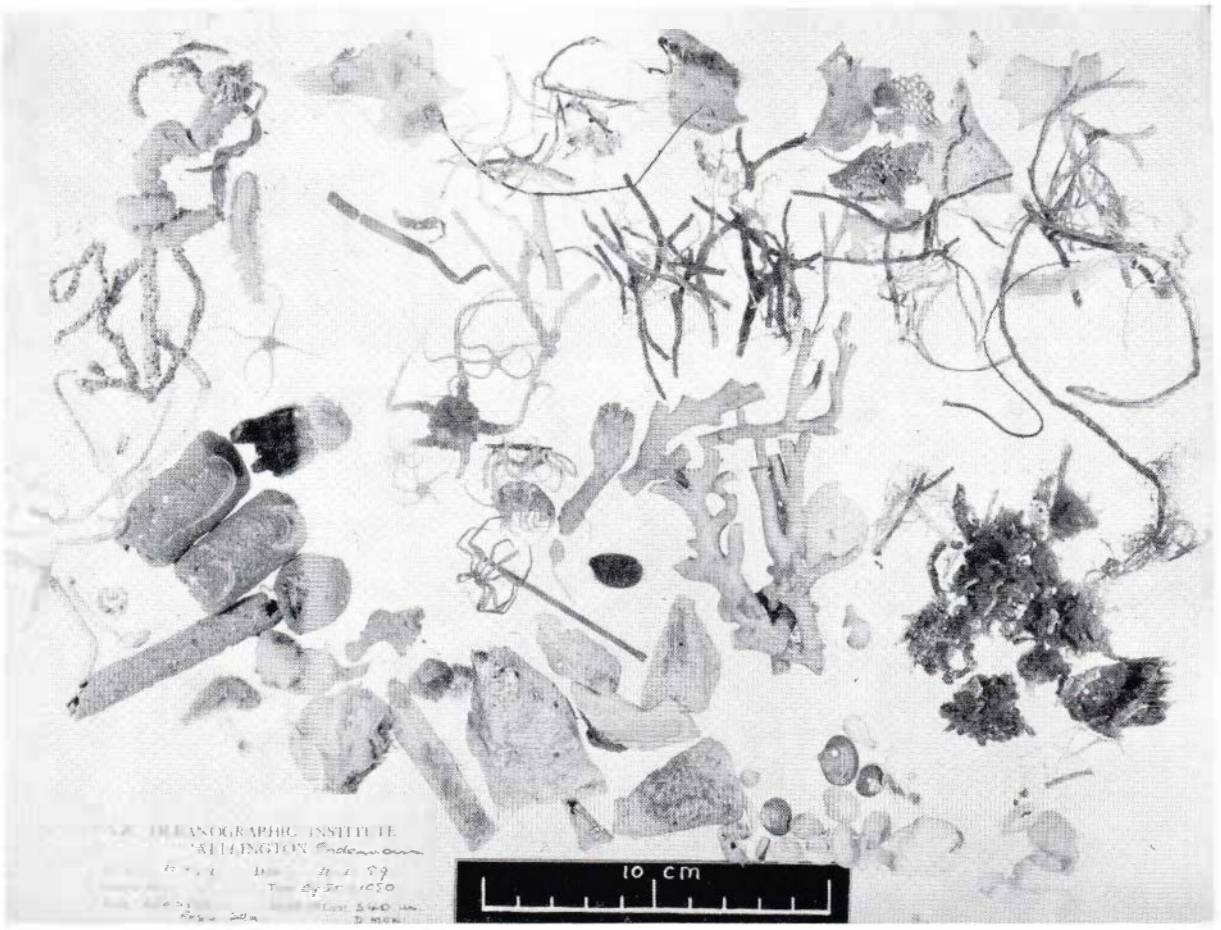


FIG. 5. Sediment groupings and associated fauna in the Ross Sea. Depths in fm.



PL. 11. Combined grab samples from the Deep Shelf Mixed Assemblage at Sta. A 449 (340 m).

groups probably all, save the coelenterates, may be described as filter feeders. With cilia or flagella they generate a current of water trapping the food particles carried by the current in a mesh of mucus-coated tissue. The coelenterates are carnivorous, capturing minute organisms with their delicate extended tentacles which are armed with stinging cells.

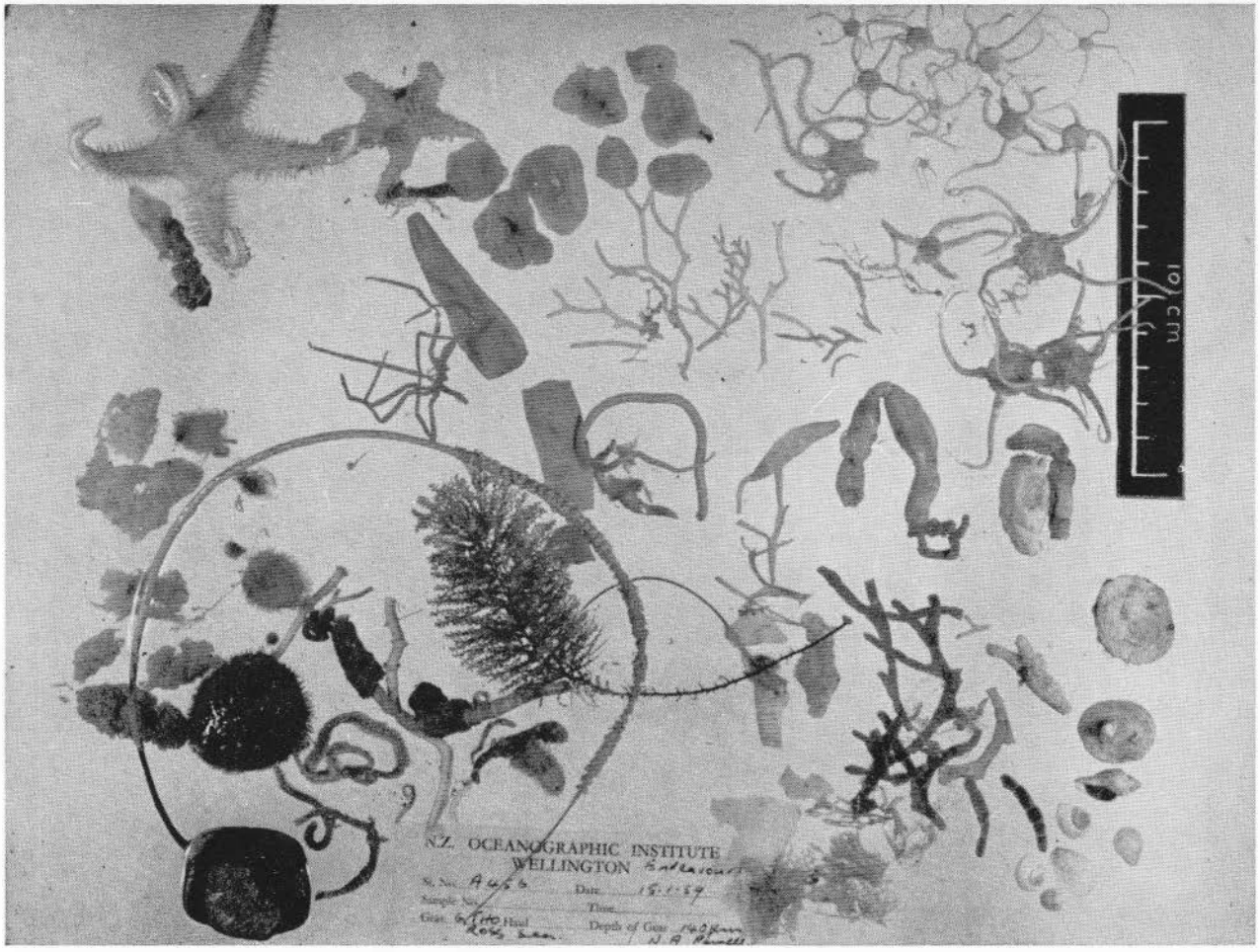
Of the groups mentioned, none appear to have a feeding mechanism which would benefit directly were the animal exposed to a strong current of water. Many, being fragile, would not withstand much water movement. Barnacles, on the other hand, are generally robustly constructed and should, within limits, filter more water the faster it moves.

There is then, in the abundance of barnacles and absence of other organisms apart from strongly constructed stylasterine corals, further evidence that unusually strong currents are to be found in the vicinity of Sta. A 463 on the northern edge of the deep shelf.

Barnacle plates (probably *H. antarcticum*) were found in small numbers at many of the stations throughout the Ross Sea and in McMurdo Sound. Only at one other station (A 522) were three small live individuals of this type of barnacle found. The reason for this distribution is not immediately obvious, though settlement on freshly deposited erratics is probable. It is not inconceivable that they may settle on the rocks still embedded in the bottom of icebergs, but this would require a fairly long larval life.

Shelf-edge Stations

At Sta. A 468 (110 m) the development of sessile, filter-feeding organisms reaches a very high density. The three bottom photographs taken at regular intervals across the top of the seamount indicate that the bottom here is covered with a dense carpet of sponges, gorgonaceans, and bryozoans (plate 15a). Evidently conditions here are particularly suitable for the development of these



PL. 12. Grab sample from the Pennell Bank Assemblage at Sta. A 456.

three groups. At the surface at this locality there is a strong current from the east but, from the attitude of the organisms in the photographs, it would seem that there was very little current on the bottom.

Corals, sponges, and bryozoans do not flourish where there is much inorganic sediment suspended in the water. Tropical corals flourish best under oceanic conditions. Presumably the supply of food to this seamount is high but the rate of sediment deposition is low.

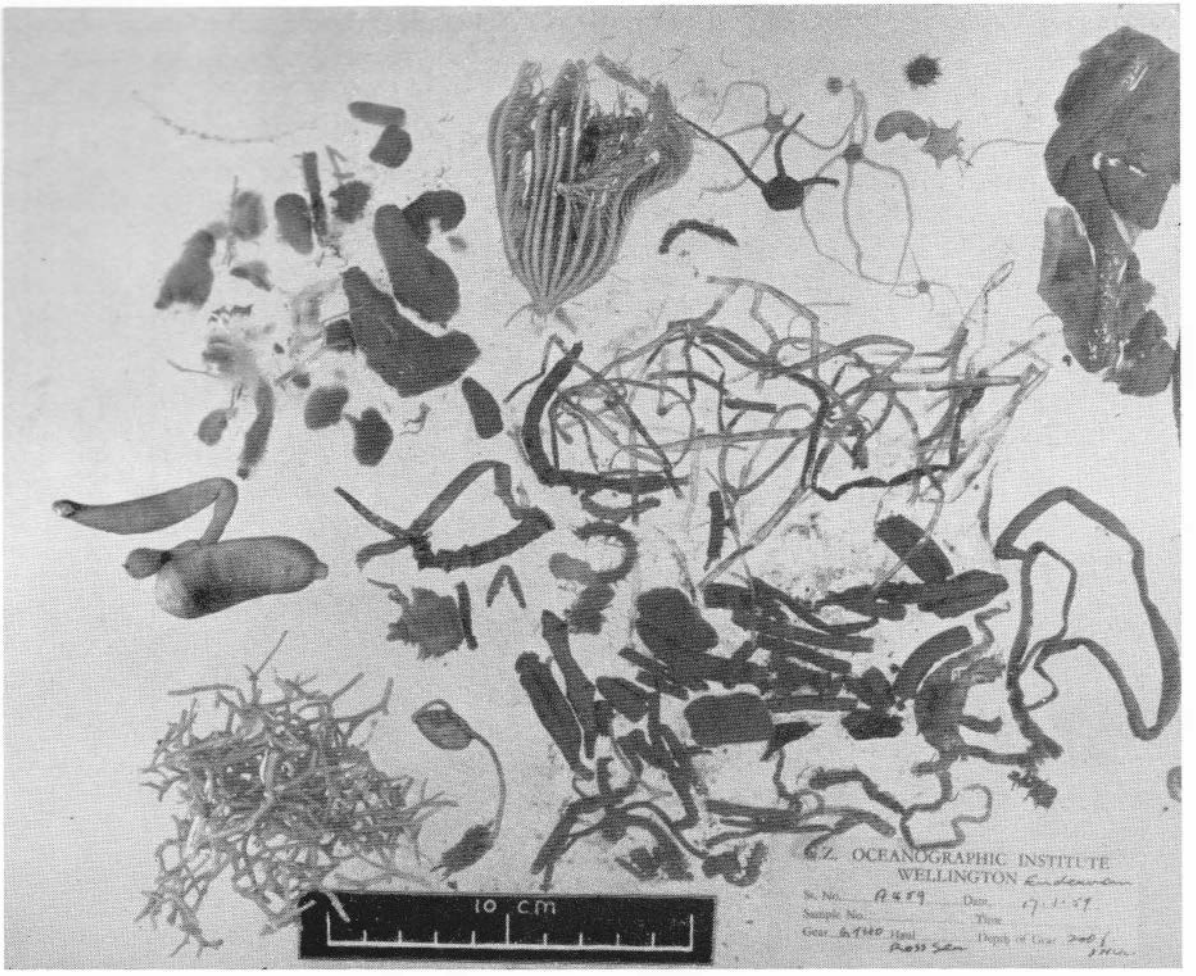
At Sta. A 469 (64 m) on the other hand, where three bottom photographs were also taken (plate 15b), there was a rather different benthos. The most abundant animal was probably the lamellibranch *Limatula hodgsoni* which occurred burrowing in the upper centimetre or two of the sediment of sand and grit, matted with sponge spicules (Bullivant, 1959).

Concerning this lamellibranch, J. Murray, in a letter quoted by Hedley (1911), remarks: "The Lima is constantly present at depths of twenty-five to eighty fathoms. Very commonly the animal is embedded in a sponge usually one of the softer, horny kinds." He refers to the area about Cape Royds, McMurdo Sound.

At Sta. A 471 (69–165 m) off Cape Evans and at Sta. A 533 (183–84 m) off Cape Barne, both just south of Cape Royds, the dredge came up packed with marine siliceous sponges in which *L. hodgsoni* was embedded. Three bottom photographs taken at Sta. A 471 show these sponges forming a thick carpet on the bottom (plate 16).

The sediment in McMurdo Sound near Ross Island is a mixture of volcanic rock fragments, grit, and mud. It is probably derived from Ross Island, where similar material was observed on exposed rock surfaces and where streams of melt water were seen which would carry the material down to the sea.

If the area photographed (off Cape Royds, Sta. A 471) were to receive a heavy coat of sediment,



PL. 13. Combined grab samples from the Deep Shelf Mud Bottom Assemblage at Sta. A 459.

during an unusually warm summer with prolonged run-off, then probably the sponges would perish, and only the motile organisms such as *L. hodgsoni* would survive. It is suggested that this has indeed happened to the bottom at Sta. A 469, accounting for the dense mat of sponge spicules in the sediment. The *L. hodgsoni* abundant at this station either survived the event or recolonised later.

Pennell Bank and Slope Areas

The following stations were occupied in less than 275 m. on Pennell Bank – A 456, A 520, A 528, A 529, A 530. Bottom photographs were taken at Sta. A 528 and A 529 (plates 17, 18). Sta. A 530 is exceptional in this group, the dredge haul – to the north of Pennell Bank in 267 m – indicating a sandy bottom and a sparse fauna. At the other four stations grab samples, dredge samples, and bottom photographs indicate a sessile fauna dominated by various calcareous bryozoans, with associated ascidians, sponges, and gorgonaceans (plates 12, 17, 18.)

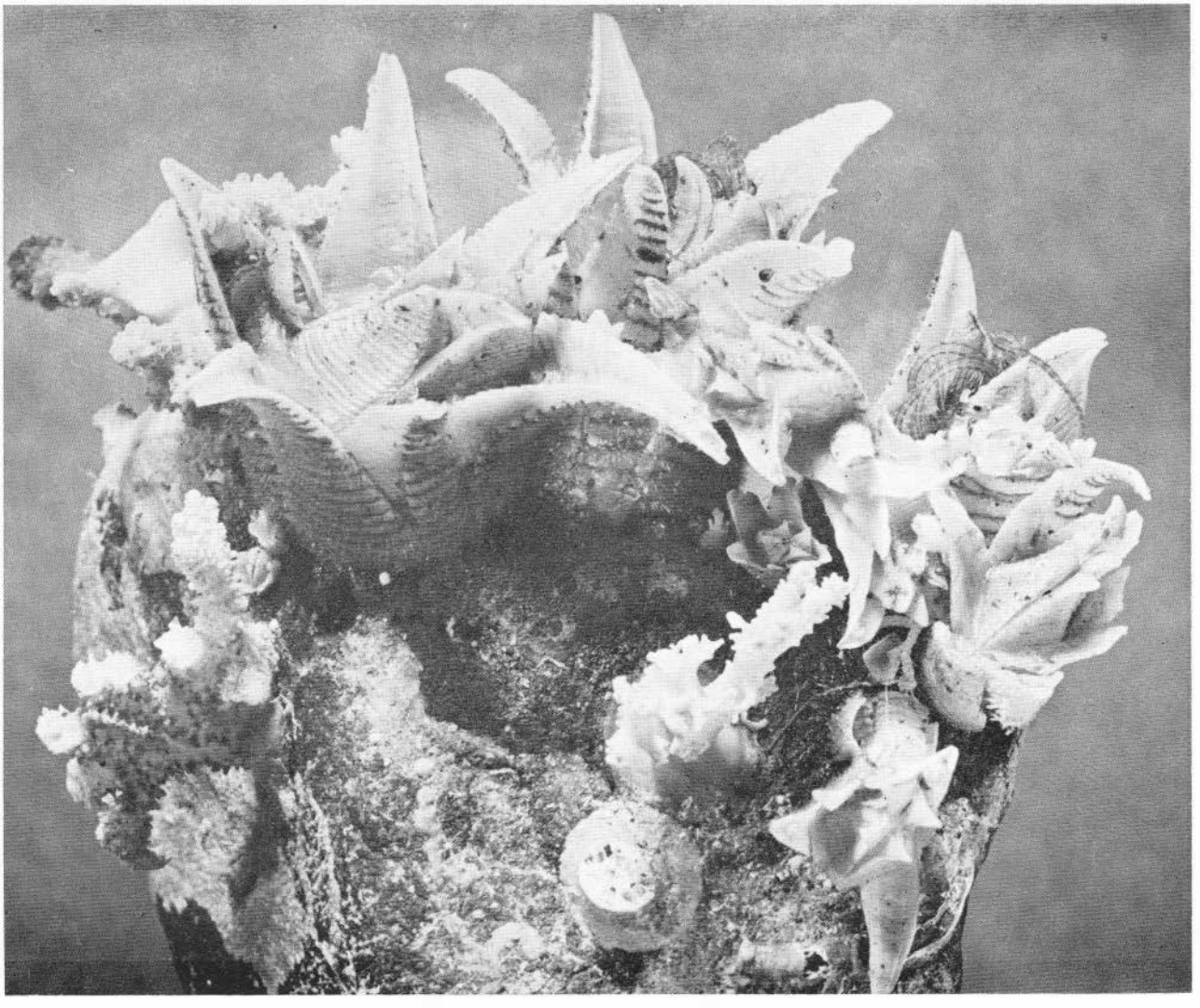
Ophiuroids are particularly abundant in this assemblage. *Ophiacantha antarctica*, Fell (1961) points out, is the most abundant Ross Sea echinoderm, being especially common on Pennell Bank and at other localities where there are many sessile animals. Another common ophiuroid particuarly plentiful on Pennell Bank is *Ophiurolepis gelida*. Fell suggests that this species is a selective deposit feeder, underwater photographs showing it with an arm buried in the substrate. If this is so, presumably fine deposits exist wherever it is found.

The ophiuroid *Ophioceres incipiens* occurred commonly on Pennell Bank and in other areas with a hard or mixed substrate. After examining underwater photographs taken on Pennell Bank and in McMurdo Sound, Fell suggests that this species climbs up worm tubes, sponges, or other sessile organisms and, extending some of its arms with tentacles protruded, "fishes" in the surrounding water for food particles. It is suprising that this species was not taken at Sta. A 468 where a very extensively developed sessile fauna was found.

Also common on Pennell Bank were asteroids, echinoids, crinoids, holothurians, pycnogonids, cerianthids, molluscs, polychaetes, and crustaceans.

At Sta. A 464 (369–384 m), on a rise on the north-eastern edge of the deep shelf, the fauna was like that on Pennell Bank. Bryozoans and other sessile animals were abundant and, of the 12 species of ophiuroids, there were six which occurred at Sta. A 456 on Pennell Bank but only three which occurred at Sta. A 448. The latter is taken as an example of a benthic assemblage living on sandy mud, the finest sediments on the deep shelf.

Nine stations were occupied on the slope to the north-east of Pennell Bank. The shallowest of these were Sta. A 455 and A 527 in 330–366m. At both stations there was a substrate of cobbles embedded in muddy sand. The most conspicuous organism was a bright orange stylasterine coral of the genus *Errina* (cf. Boschma, 1965), but at both stations bryozoans, gorgonaceans, sponges, and a variety of echinoderms were present. There were 12 species of ophiuroids at each station, eight species being common to both.



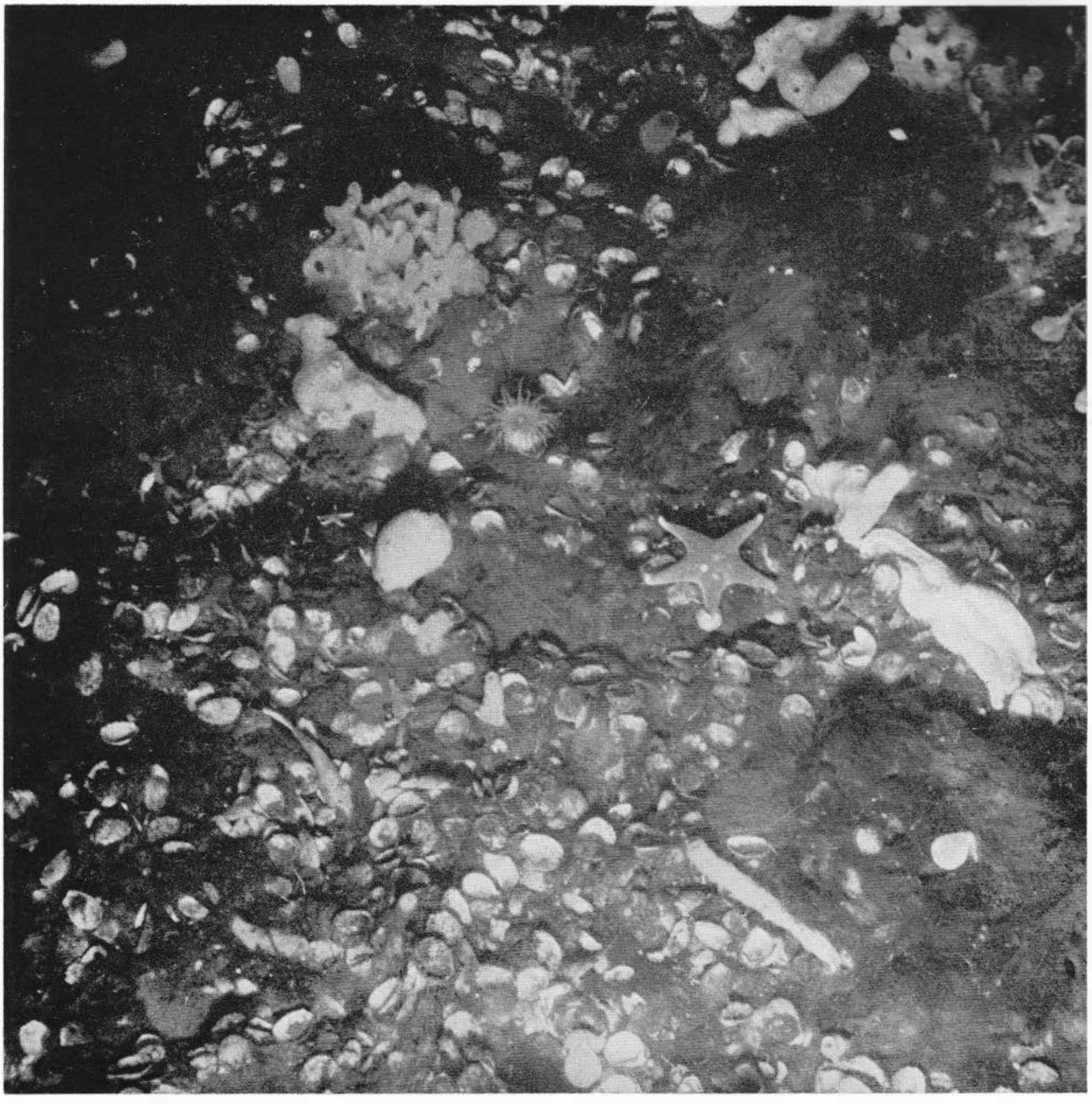
PL. 14. Barnacles *(Hexelasma antarctica)* from Sta. A 463.

PL.15a. Bottom photograph from Sta. A 468 (110 m). Note the prolific growth of sessile sponges, bryozoans, and gorgonaceans.

The sediment of cobbles in sandy mud continued down the north-east slope, at Sta. A 526 (461 m), Sta. A 521 (558 m), and Sta. A 525 (583 m). These stations were the only three at which the solitary coral *Gardineria antarctica* was at all abundant. Sta. A 521 yielded 141 living and dead specimens; Sta. A 526, eight living specimens; and Sta. A 525, five living and dead specimens. Various echinoderms, sponges, bryozoans, and stylasterine corals were also present.

Echinoderm Distribution on Pennell Bank and Slope

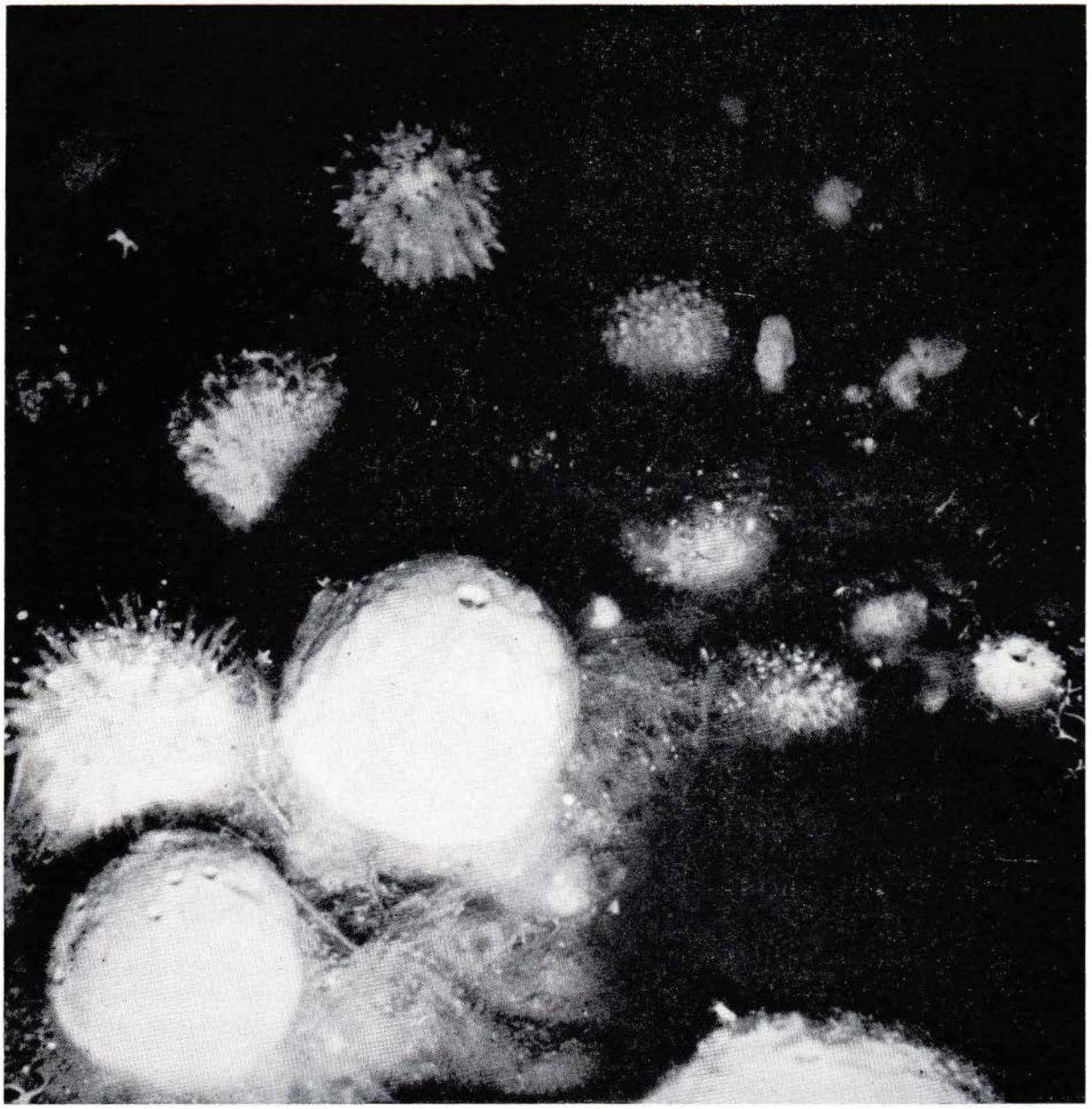
Two species of starfish taken at Sta. A 525 are of interest. Twenty-two specimens of the new species *Peribolaster powelli* H. E. S. Clark were taken from 10 stations, A 456, A 457, A 461, A 464, A 520, A 521, A 522, A 525, A 527, and A 529, and 12 specimens of *Pteraster stellifer* were found at eight stations, A 461, A 464, A 521, A 522, A 523, A 425, A 526, and A 527. These stations are all towards the outer or northern region of the deep shelf near Pennell Bank or towards Coulman Island.



PL. 15b. Bottom photograph from Sta. A 469. The dominant mollusc is *Limatula hodgsoni*, the starfish *Odontaster validus*.

A similar distribution is shown by some of the ophiuroids. *Ophiura ambigua* occurred at Sta. A 454, A 464, A 521, A 523, and A 527, *Astrochlamys bruneus* at A 454, A 461, and A 521, *Ophiopyren regularis* at A 454, A 521, and A 527, and *Ophiacantha pentactis* at A 455, A 464, A 516, A 523, and A 527. This distribution suggests there is an outer shelf edge fauna containing species which have not penetrated far over the shelf to the south.

The substrate of cobbles and muddy sand continued down the slope and was found again at Sta. A 454 in 828m and at Sta. A 522 in 1335 m. The fauna at these two stations was sparser than at the stations further up the slope. There was a notable lack of gorgonaceans and bryozoans despite the stone substrate. A few ophiuroids were taken, some sponge, and three live barnacles from Sta. A 522 (*Hexelasma* sp.). Brachiopods were conspicuously abundant at Sta. A 522 and they also occurred at Sta. A 454.



PL. 16. Bottom photograph from the McMurdo Sound Glass Sponge Assemblage at Sta. A 471 (165–69 m) showing siliceous sponges.

Sta. A 522 is the only station from which the new species of ophiuroid *Euvondrea floretta* Fell 1961 has been taken. A starfish, *Paralophaster lorioli*, previously known only from the Weddell Sea in 750 to 4,570 m, was also taken at this station*.

Sta. A 524 (3,566 m) yielded the deepest bottom samples taken during the present investigations. A stiff yellow-brown diatomaceous mud was found similar to that obtained at Sta. A 452 and A 453 to the south-east of Pennell Bank. No macrobenthic animals were obtained at this station.

*Records of biological material from Sta. A 523 are due to an error in labelling and should apparently all be referred to Sta. A 522. Only hydrological observations were made at A 523. Thus, the type locality for *Euvondrea floretta*, given in Fell (1961) as A 523 should be A 522, and the record of *Paralophaster lorioli* in Clark (1963) should similarly be corrected.

PL.17. Bottom photograph of the Pennell Bank Assemblage from Sta. A 528 (274–265 m). Bryozoan colonies on cobble bottom.

McMurdo Sound Stations

Several stations in McMurdo Sound present a unique type of substrate meriting further comment. At Sta. A 538 nine bottom photographs in colour were taken. These show a rich benthos on a hummocky sediment of sand or sandy mud (plate 19). Bryozoans and sponges are abundant and there are many sabellid polychaetes and some gorgonaceans and cerianthids. The type of bryozoans present and the appearance of the substrate suggests a relatively high rate of sedimentation. Fell (1961) has remarked on the abundance of ophiuroids shown in these photographs and from the attitudes of certain species (*Astrotoma agassiz*, *Ophioceres incipiens*, and *Ophiurolepis gelida*) has

PL. 18. Bottom photograph of the Pennell Bank Assemblage from Sta. A 529 (205–220 m). The fine sediment is scattered with a variety of bryozoans.

made deductions about their feeding mechanisms.

At the deeper stations in McMurdo Sound – A 472 (plate 20), A 536, A 537 – there is evidently a fauna rather similar to that at Sta. A 538 (plate 19) but less dense.

The abundance of certain free-living crinoids, particularly *Promachocrinus kerguelensis*, is worthy of comment. A provisional list of crinoids taken during the first summer lists this species from 11 of the 25 stations from which bottom samples or bottom photographs were obtained. Evidently widespread in the area, these motile filter feeders usually show in the photographs clinging to sessile fauna.

THE ROSS SEA FAUNAL ASSEMBLAGES

Certain assemblages of Ross Sea animals recur at more than one station and these may be grouped accordingly.

Thus, the benthos may be divided into three major assemblages, the distribution of which is correlated with the type of substrate. These assemblages are listed below, together with several minor assemblages with a more restricted distribution (fig. 6).

1. Deep Shelf Mixed Assemblage

This assemblage is widely distributed in the Ross Sea and on the western side of McMurdo Sound. It is associated with a fine sediment on which erratic boulders are scattered, providing a substrate for various sessile animals requiring a solid anchorage.

The common animals are tubicolous polychaetes, bryozoans (mostly rooted varieties), various ophiuroids, occasional gorgonaceans, crinoids, and other echinoderms and molluscs.

This assemblage occurred at Sta. A 449 (plate 11), A 450, A 451, A 457, A 531 (plate 21), and A 538 (plate 19). The underwater photographs from Sta. A 531 (plate 21) indicate the overall appearance of this assemblage.

2. Deep Shelf Mud Bottom Assemblage

This assemblage was found particularly at the deeper stations on the shelf where the sediment was mud, or sandy mud and where there were erratic boulders.

Tubicolous polychaetes are abundant and a species of sipunculid and an arenaceous foraminifer (*Rhabdammina* sp.) are common. Also present were various ophiuroids, in particular *Amphiodia joubini*, holothurians, mainly a rat-tailed species, *Umbellula* sp., and occasional crustaceans, molluscs, asteroids, echinoids, and crinoids.

This assemblage occurred at Sta. A 448, A 458, A 459 (plate 13), A 460, A 461, A 466, and possibly A 530.

3. Pennell Bank Assemblage

On Pennell Bank and at Sta. A 464 to the west a substrate of cobbles up to several centimetres in size occurred embedded in a muddy sand, with patches of muddy sand among the cobbles.

Common animals were calcareous bryozoans, gorgonaceans, stylasterine corals and tunicates (i.e. organisms attaching to a solid substrate) with various echinoderms, notably *Ophiacantha antarctica*, *Ophioceres incipiens*, *Ophiurolepis gelida*, polychaetes, and pycnogonids.

This assemblage occurred at Sta. A 456 (plate 12), A 464, A 520, A 528 (plate 17), and A 529 (plate 18); the bottom photograph from Sta. A 528 gives some idea of its appearance.

4. Minor Assemblages

There are several smaller groups of stations, mostly about the periphery of the deep shelf against the land and on the slope, which do not fit into the major divisions above. These are:

(a) *Shelf Edge Barnacle Assemblage*

This was found on a rocky bottom between 350–500 m deep, on the outer edge of the deep shelf where strong bottom currents may be inferred. The characteristic animal is *Hexelasma antarcticum* (plate 14). This assemblage was found at Sta. A 463 and A 465.

(b) *Deep Ooze Assemblage*

This assemblage occurs in deep water (1,200–2,200 m) on the slope at Sta. A 452, A 453. A sparse fauna on a diatomaceous ooze, possibly extending as deep as Sta. A 524 (3,566–3,577 m).

(c) *Deep Slope Cobble Assemblages*

(a) Stylasterine Coral Assemblage: Sta. A 455 and A 527 (322–358 m).

(b) *Gardineria antarctica* Assemblage: Sta. A 521, A 525, and A 526 (461–591 m).

(c) Brachiopod Assemblage: Sta. A 454 and A 522. (828–1,335 m).

(d) *McMurdo Sound Glass Sponge Assemblage*

This is a substrate of unsorted rock debris on which siliceous sponges, e.g., species of *Rosella* and *Cinachyra*, are especially well developed. Other common animals are the lamellibranch *Limatula hodgsoni*, and the starfish, *Odontaster meridionalis*. Various molluscs, echinoderms, polychaetes, and pycnogonids are also present.

The assemblage was found at Sta. A 471 (pl. 16) and A 533 (69–183 m).

(e) *McMurdo Sound Mixed Assemblage*

This assemblage may simply be a variant of the Deep Shelf Mixed Assemblage, but there are certain features which suggest that the stations concerned form a separate group.

Polychaete worms, cellularine bryozoans, sponges and various echinoderms, including numerous crinoids, occur on a mixed sediment containing a higher proportion of coarse rock particles than the sediments with which the Deep Shelf Mixed Assemblage are associated.

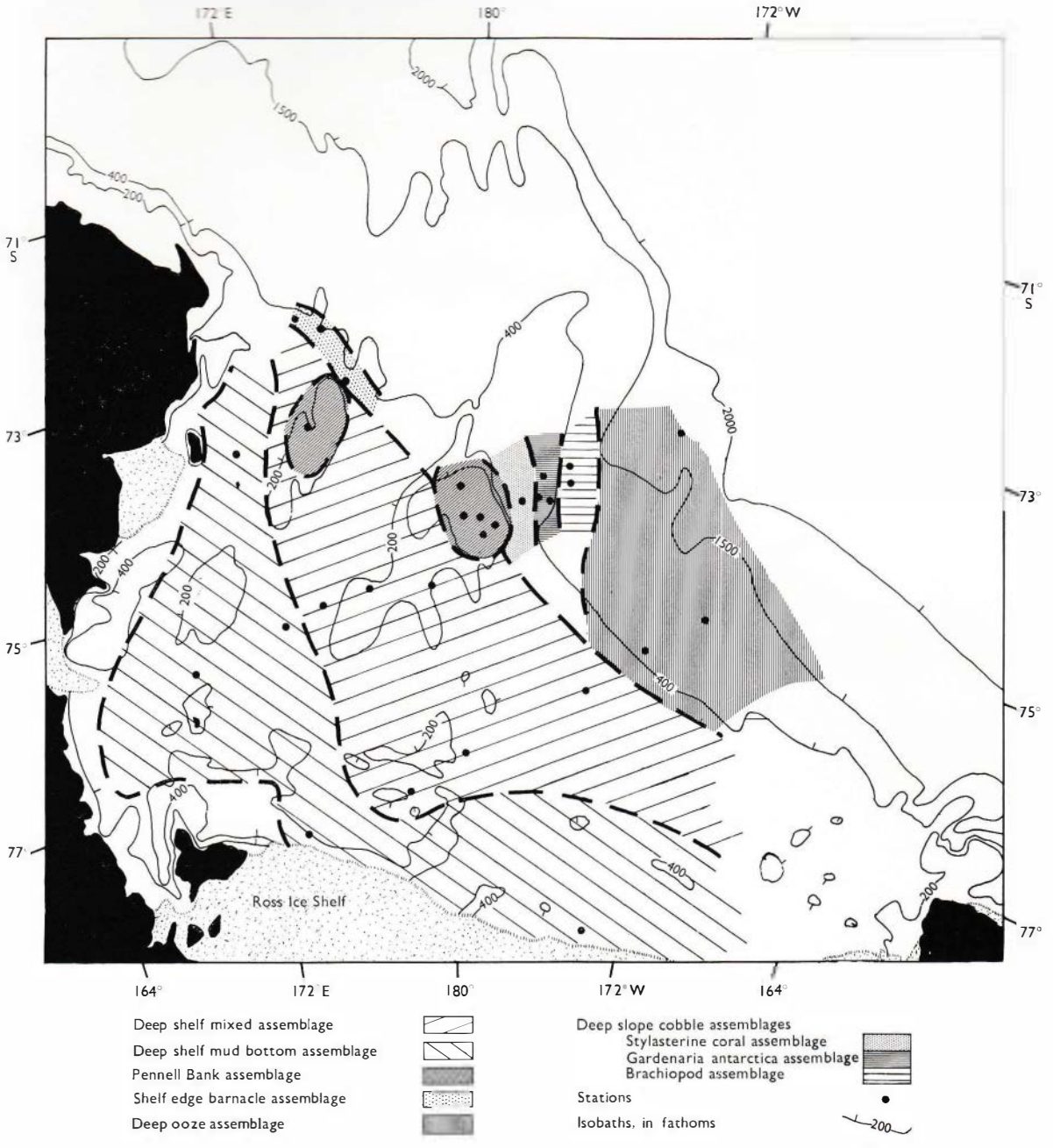


FIG. 6. Ross Sea faunal assemblages.

PL. 19. Bottom photograph of the McMurdo Sound Mixed Assemblage from Sta. A 538 (256–260 m) showing bryozoans, gorgonaceans, sponges, echinoderms, and polychaete worms.

Siliceous sponges are particularly abundant at the shallowest stations (A 538, pl. 19).

The assemblage was found at stations A 470, A 472 (plate 20), A 519, A 532,A 534, A 536, A 537, and A 538 (plate 19) in 256–794 m. The dredge hauls revealed a decrease in density of benthos with depth and this is also shown by the underwater photographs from the shallow stations A 538 (256 m), and A 472, (391 m).

In the report of the oceanographic survey of Operation Deep Freeze II (U.S. Hydrographic Office, 1957), there is a bottom photograph (plate

PL. 20. Bottom photograph of the McMurdo Sound Mixed Assemblage from Sta. A 472 (391 m) showing bryozoans, ophiuroids, and polychaetes.

XV) taken in 448 m in McMurdo Sound which shows crinoids, sponges, bryozoans, and worm tubes referrable to this assemblage.

A dredge haul obtained at Sta. A 625 in Terra Nova Bay in 460 m by G. A. Harlen held a mass of sponge material (plate 22) as well as crinoids, a large pink and white anemone, prawns, brittle stars, echinoids, asteroids, some 50–60 living and dead *Flabellum antarcticum*, worm tubes, gorgonaceans, holothurians, and molluscs. This station is tentatively placed with the McMurdo Sound Mixed Assemblage.

PL. 21a. Bottom photograph of the Deep Shelf Mixed Assemblage from Sta. A 531 (358 m) showing echinoderms with colonies of bryozoans and gorgonaceans.

(f) *Ross Sea Bathyal Assemblage*

Just north of Ross Island and in Terra Nova Bay against the Victoria Land coast are two basins exceeding 1,000 m. The basin north of Ross Island was sampled by the National Antarctic Expedition on 21 January 1902. The trawl included a polychaete, three species of sponge, a crinoid, a prawn, and a mollusc.

During the present investigations these basins were not sampled but it is suggested that the benthos in them will resemble the Deep Shelf Mud Bottom Assemblage with a reduction in density of organisms and with some deeper living animals normally found in the bathyal assemblage.

PL. 21 b. Bottom photograph of the Deep Shelf Mixed Assemblage from Sta. A 531 (358 m) showing clumps of bryozoans on a fine sediment.

Miscellaneous Groupings

The benthos at the following stations does not conform to any of the assemblages already outlined:

Sta. A 469 (64 m) (McMurdo Sound): *Limatula hodgsoni* and *Odontaster validus* abundant on a substrate of matted sponge spicules and coarse sediment.

Sta. A 467 (88–183 m) (off Cape Crozier): A mixed fauna of sponges, coelenterates and pterobranchs on an extremely rocky bottom. The pecten *Adamussium colbecki* is particularly abundant.

Sta. A 468 (110 m) (on a seamount east of Beaufort Island): A dense fauna of sponges, coelenterates, and bryozoans (plate 15a). Substrate unknown, probably rocky with a layer of fine mud trapped by the sessile benthos.

PL. 22. Dredge sample from Sta. A 625. Note mass of sponges, polychaete tubes, crinoids, and solitary corals.

This assemblage is comparable with the dense glass-sponge assemblage found at Sta. A 471 (plate 16), but is presumably not subject to the deposition of rocky debris from the adjacent land that apparently occurs at the latter station.

Sta. 518 (75 m) (off the raised beach at the south-west corner of Beaufort Island): A single bottom photograph (plate 23) shows a relatively sparse fauna on a mixed mud and gravel bottom. Included in the photograph is a large single barnacle plate, three gorgonaceans, seven asteroids, two dendrochirote holothurians with tentacles extended, tube worms, algae, and cellularine bryozoans (Bullivant, 1961). No dredge sample was obtained.

Sta. A 516 (457–183 m) (off Scott Island): A mixed fauna (see station details) from a mixed rock and mud substrate.

Relation of Previous Dredgings to the Present Classification

The published results of previous expeditions in the Ross Sea have been examined to see whether they fitted the faunal-sediment classification developed as a result of the present investigation.

Not all material collected in the past has been reported on and not many published reports list the material in a manner that would facilitate listing of animals taken at each station. As well, name changes have occurred that prevent direct comparisons at the specific level of some of the earlier station material with the present collections.

However, comments on the present collections have been based on the groups of animals represented, so that a similar approach to past dredge hauls makes useful supplementary data available. As a basis for the following remarks, lists were prepared of the species in each dredge haul. One or two groups, such as amphipods and isopods, were not included.

Shallow Water Stations

At different times dredgings have been made about Cape Adare, Coulman Island, Franklin Island, and the winter quarters in McMurdo Sound. The shallow dredgings at the first three localities were in depths down to 30 fm with generally a stony bottom. The benthos sampled appears to have been

PL. 23. Bottom photograph from Sta. A 518 (75 m) showing ophiuroids, starfish, polyzoa and several tube worms. There are three gorgonaceans looking like bottle-brushes and, part of the way up the stem of one of these, a dendrochirote holothurian with tentacles extended is visible.

of mobile echinoderms, molluscs, and polychaetes, rather than sessile sponges, coelenterates, and bryozoans. The pecten *Adamussium colbecki* was taken for the first time by men of the *Southern Cross* expedition off Franklin Island in 10 fm.

Collecting near winter quarters in McMurdo Sound was generally carried on through the ice from shallow depths to depths of several hundred fathoms, and often only one or two species were taken.

Deep Water Stations

The RRS *Discovery* made six dredge hauls in the Ross Sea during the 1930s. Only a few animal groups taken have been described so far: crinoids, molluscs, cellularine bryozoans, and pennatulaceans. These reports are not sufficient to allow a comparative review of the fauna sampled.

Some 22 dredge hauls, in depths of over 30 fm (55 m) have been made in the Ross Sea by earlier expeditions. Examples of these follow.

On 19 January 1841 off Coulman Island in 370 fm (677 m), Sir James Clark Ross dredged up stones, bryozoans, molluscs, small crustaceans, and serpulids.

On 27 January 1902 at the eastern end of the Ross Ice Shelf Scott's first expedition dredged up a pycnogonid; a gorgonacean colony; two species of hydroids; two tunicates: a singie species each of asteroid, crinoid, and ophiuroid; three species of sponge; several pterobranch colonies; and five species of cellularine bryozoans from "rough ground".

On 15 January 1913 at Sta. 294 in 158 fm (289 m) on Pennell Bank the *Terra Nova* dredged up five species of sponges, two of actinarians, three of nemertines, eight of polychaetes, a species of cellularine bryozoan, four of molluscs, 12 of pycnogonids, two of decapods, a species of brachiopod, two of starfish, two of echinoids, and seven of fish.

On 24 January 1912 at Sta. 339 in 140 fm in McMurdo Sound the *Terra Nova* expedition dredged up 31 species of sponges, an actinarian, four of nemertines, 11 of polychaetes, 14 of cellularine bryozoans, eight of molluscs, a pycnogonid, two of decapods, three of brachiopods, an ophiuroid, four of starfish, three of echinoids, and two of pterobranchs.

Comparison with Ross Sea Assemblages

The first three of these four dredge hauls yielded samples such as would be expected from the Deep Shelf Mixed Assemblage. They contain a mixture of sessile and motile animals, sponges, actinarians, bryozoans, and pterobranchs, as well as echinoderms and polychaetes.

The *Terra Nova* Expedition made several dredge hauls in McMurdo Sound; the last of the four detailed above is one of these. Like Sta. A 538 in the recent investigations these *Terra Nova* stations are notable for the large number of species of sponges taken. There were many other groups also present at these stations, however, so they are tentatively grouped with the McMurdo Sound Mixed Assemblage rather than with the Siliceous Sponge Assemblage in which the bottom is covered with a dense mat of sponge.

A "large catch of glassy sponge" was dredged up at *Terra Nova* Sta. 349, off Butter Point in McMurdo Sound in 80 fm (146 m). Presumably this station sampled the Siliceous Sponge Assemblage.

It is suggested that the Deep Shelf Mixed Assemblage was sampled by earlier expeditions at the following stations.

Sir James Clark Ross, 1841–42

(1) 18/1/41. 230 fm (421 m).
(2) 19/1/41. 370 fm (677 m).

National Antarctic Expedition Brit. Mus. (Nat. Hist.), 1907–12

(1) 13/1/02. 100 fm (183 m).
(2) 27/1/02. 100 fm (183 m).
(3) 4/3/04. 67° 21′ 46″S, 155° 21′ 10″E. 254 fm (465 m), west of Balleny Island.

Terra Nova Expedition

Sta. 194; 22/2/11. 69° 43′S, 143° 24′E. 180–200 fm (329–366 m), off Oates Land.
Sta. 294. 158 fm (289 m), Pennell Bank.
Sta. 295. 190 fm (348 m), off Coulman Island.

The McMurdo Sound Mixed Assemblage was sampled at the following stations:

National Antarctic Expedition

Sta. 21/2/02 just north of Ross Island, 500 fm (914 m).

Terra Nova Expeditions

Sta. 314, 316, 331, 338, 339, 340, 348, 355, 356. These stations are all in McMurdo Sound in 50 to 300 fm (91–549 m).

At a station in 300 fm (549 m) off the Ross Ice Shelf the National Antarctic Expedition took a dredge sample containing several pycnogonids, a hydroid, a cellularine bryozoan, four ophiuroids, a holothurian, a prawn, a brachiopod, a pterobranch colony, and an *Umbellula* from a mud bottom. The absence of sponges and the presence of the pennatulacean suggest this came from the Deep Shelf Mud Bottom Assemblage.

These earlier dredgings support the rather loose classification of the Ross Sea benthos devised for the present collections. A detailed analysis of communities must wait until fuller consideration can be given to the fauna at specific levels.

Features of the Ross Sea Benthos

The ecological study of the marine benthos owes much to the work during the early part of this century of C. J. Petersen, who first clearly recognised the existence of communities which recur at different localities where the conditions of depth and sediment are similar.

Groupings of the Benthos

Thorson (1957) defines the terms infauna and epifauna (first introduced by Petersen in 1913) as follows:

The Epifauna, comprising all animals living upon or associated with rocks, stones, shells, piling and vegetation – i.e., sitting or crawling on a substratum – *The Infauna*, comprising all animals inhabiting the sandy or muddy surface layers of the sea bottom – i.e., living buried or digging in a substratum.

These terms epifauna and infauna have been avoided in the preceding discussion. Instead the benthic animals have been grouped according to whether they are *sessile* or *motile*. Sessile animals

such as sponges and tunicates form a natural group in that they are attached and therefore develop in areas where they will not be smothered with sediment. Unable to move, they must feed on the plankton and suspended particulate matter which drifts past them.

The remainder of the benthos, the motile organisms, form a heterogeneous group, which may be divided according to the feeding habits of the species. These include animals which feed on plankton and suspended particles, animals taking their food from the bottom deposits, and predatory animals. Motility serves these animals in a variety of ways. It enables the deposit feeders and predators to hunt for their food and the filter feeders to maintain themselves in a suitable position to feed whether climbing on the substrate or lying in the surface layer of sediment.

Level Bottom Communities

The animals of Petersen's level bottom communities are generally infaunal animals which either feed on suspended particles or selectively on the surface scum of sediment.

Longhurst (1958) divides the benthos on the continental shelf and slope off Sierra Leone into 12 communities determined by depth and type of substrate at any one locality. A typical shelf community which occurred on shelly sands in depths down to 40 m was the *Venus declivis* community, characterised by a variety of lamellibranchs, two crustaceans, and a lancelet. In deeper water, on mud or sandy mud, this community gave way to a community dominated by *Amphioplus congensis*, an ophiuroid which occurred with two molluscs, three crustaceans, and two gephyreans.

Longhurst describes three shallow hard-substrate communities in which molluscs, barnacles, and coelenterates were abundant. He also describes two deep hard-substrate communities from outcrops of rock at the shelf edge. One of the latter, dominated by a yellow coral *Dendrophyllia* sp., resembles closely a community of deep water corals found on outcropping igneous rocks in the eastern north Atlantic (Le Danois 1948).

Thorson in 1957 reviewed investigations into level bottom shelf communities. Communities made up of motile infaunal animals (such as those described by Petersen and Longhurst) have been found extensively on deposits of mud or sand about Europe, on both coasts of North America, about Japan, around New Zealand, through the Arctic, and off the west coast of Africa. Often communities many thousands of miles apart are made up of related species; for example, the *Amphiura rosea* community found in New Zealand waters (Powell, 1937) is comparable with *Amphiura* communities in several other parts of the world.

Generalising, it may be said that on the continental shelf, areas of level bottom with sandy or muddy sediments are inhabited by a motile infauna of molluscs, polychaetes, echinoderms, and crustacea, but where a hard substrate is exposed in areas of strong bottom currents or low sedimentation a fauna of sessile animals, coelenterates, sponges, bryozoans, and barnacles dominates.

Summary – Ross Sea Benthic Assemblages

Faunal analyses of the present collections show that the Ross Sea benthos may be grouped into the following assemblages:

1. Deep Shelf Mixed Assemblage

Found on a coarse sediment with scattered erratic boulders in depths between 256 and 523 m. Polychaete worms, bryozoans, gorgonaceans, and echinoderms are common.

2. Deep Shelf Mud Bottom Assemblage

On sandy mud away from the coast, in depths between 415–752 m. Polychaete worms and echinoderms are common.

3. Pennell Bank Assemblage

On a substrate of cobbles with patches of muddy sand, in depths between 201–384 m. Bryozoans, gorgonaceans, sponges, tunicates, stylasterine corals, and echinoderms are common.

4. Minor Assemblages

(a) *Deep Slope Cobble Assemblages:*

(i) Stylasterine Coral Assemblage: On cobbles, between 322 and 358 m.

(ii) *Gardineria antarctica* Assemblage: On cobbles, between 461 and 591 m.

(iii) Brachiopod Assemblage: On cobbles, between 828 and 1,335 m.

(b) *Shelf-edge Barnacle Assemblage:* On rocky current-swept bottom at outer edge of shelf, between 399 and 521 m.

(c) *Deep Ooze Assemblage:* Sparse fauna of echinoderms and polychaetes on sandy diatomaceous ooze in 1,280–2,195 m.

(d) *McMurdo Sound Glass Sponge Assemblage:* From shelving sides of McMurdo Sound in 68–183 m.

(e) *McMurdo Sound Mixed Assemblage:* On coarse glacial sediments between 377 and 794 m about McMurdo Sound. Polychaete worms, cellularine bryozoans, sponges and echinoderms are common.

(f) *Ross Sea Bathyal Assemblage:* In deep basins on shelf below 800 m. Reduced Mud Bottom Assemblage with bathyal elements.

DISCUSSION

It is clear that in types of animals not one of the Ross Sea assemblages resembles the usual level-bottom benthic fauna of continental shelves elsewhere in the world.

Similarities might be expected between the ecology of the benthos of the Antarctic and of the Arctic; however, the two environments are dissimilar in several major aspects.

The Benthos in Other Regions of the Antarctic

It is now recognised that there is a circumpolar Antarctic benthic fauna which is distinct from neighbouring faunas and which shows a high degree of endemism (Broch, 1961).

Squires (1962) points out that the Antarctic Scleractinian fauna is a homogeneous circumpolar fauna of which five out of six species are endemic.

Burton (1932) found that in the collection of non-calcareous sponges made by the Australasian Antarctic Expedition 1911–14, near the Shackleton Ice Shelf, a region which had not previously been investigated, there was only one new species among a total of 62.

The circumpolar nature of the fauna, which has been attributed to dispersal by the circumpolar currents, is reflected by most groups of benthic animals.

Although collections have been made at several localities, particularly about Graham Land, descriptions of total dredge hauls or benthic communities are unfortunately lacking for most areas.

In recent years Russian workers have collected material in the Indian Ocean sector of the Antarctic. Some of this work has been reviewed by Pasternak and Gusev (1960).

The overall proportions of different animal groups found by the Russians between the Davis Sea and Princess Ragnhild Land is much the same as that found in the Ross Sea. Between 100 and 500 m on poorly sorted sediments the predominant groups were sponges, corals, bryozoans, and echinoderms. Pasternak and Gusev present a table which shows that below 500 m there is a reduction in the number of sponges, bryozoans, and ascidians with a relative increase in the numbers of polychaetes, crustaceans, molluscs, and echinoderms. In other words there is a reduction in the concentration of sessile organisms below 500 m with an increase in relative abundance of motile organisms.

Comparison with the Arctic Benthos

In the Arctic there is a central ocean basin surrounded by land masses with fringing continental shelves and from these land masses some of the largest rivers in the world flow into the basin. In the Antarctic, a central ice-covered land mass is surrounded by ocean basins with only a very small proportion of the coastal waters in less than 200 m and with no large rivers discharging from the land mass.

The Arctic Ocean is more or less isolated from other major oceans but exchange occurs with the North Atlantic. Little is known of the cycles and concentrations of nutrient salts in the Arctic Ocean, though the permanent cover of pack ice 6–13 ft thick over most of the basin must limit organic productivity.

The circulation in the Southern Ocean, on the other hand, must be considered in terms of the Atlantic, Pacific, and Indian Oceans which it links together. One of the features of the vertical circulation is the upwelling that brings waters rich in nutrient salts to the surface near the Antarctic Coast (Deacon, 1937).

The benthic fauna in the Arctic Ocean basins is poor. This has become apparent following recent work from stations established on the drifting ice. Benthos collected by the Russian icebreaker *Sedov* and the drifting ice islands T3 and NP2 (reviewed by Mohr, 1959) amounts to a few polychaetes, ophiuroids, and sponge fragments.

More recently, the Arctic Drift Station "Charlie" moved across a shallow projection of the Chukchi Shelf (Cromie, 1961) and bottom photographs and trawl samples were obtained from 250–400 m and from deeper waters. The sediment at both shallow and deep stations was a fine mud, with pebbles scattered on its surface. (See also Menzies, 1963.)

Nothing like the abundance of life sampled in the Ross Sea was found. For example, ophiuroids predominate in most photographs, but only two or three are visible per square metre. The published photographs resemble those of the comparatively barren bottom at Sta. A 531 (plate 21) in the Ross Sea. Trawl samples yielded only a few invertebrates, echinoderms, an actinarian, bryozoans, amphipods, and polychaetes. A similar series of photographs showing a sparser fauna was taken by the Alpha station over the Alpha Rise, in 2,000–3,000 m in the Central Arctic Ocean (Hunkins *et al.*, 1960).

Neither series of Arctic bottom photographs show ripple marks and these have not been detected in Ross Sea bottom photographs. It has been suggested (Hunkins *et al.*, 1960) that pits in the sediment, not surrounded by mounds, shown in the Arctic bottom photographs are made by stones

dropped from melting ice. Similar pits have been noted in the Ross Sea photographs.

The benthic fauna on the continental shelf bordering the Arctic Ocean is rich compared with that found in the basin. The shelf fauna has been examined in several localities: about Greenland by Thorson (1934) and Vibe (1939), in Arctic North America and Canada by MacGinitie (1955) and Ellis (1960), and in the Barents and Kara Seas by Zenkevich, Brotzky, and Idelson (1928).

Several level-bottom communities have been described. The most commonly occurring is probably the *Macoma calcarea* community found on level bottoms of mixed sand and mud in depths down to 50–60 m. This community is comparable with other shelf level-bottom communities and indeed, parallel *Macoma* communities have been found on either side of the North Pacific and in Europe (Thorson, 1957).

Some hard-bottom faunas have been described from Arctic waters. About Greenland on hard bottoms, seaweeds may be abundant in shallow water, with characteristic associated molluscs and echinoderms, while the mussel *Hiatella arctica* is occasionally abundant on stony bottoms and on irregularities on the level bottom about Greenland and also off Point Barrow.

A deeper water epifauna dominated by ascidians and sponges has been found off East Greenland. On rubble below 30 m, off Point Barrow, bryozoans, anemones, holothurians, echinoids, the octocoral *Eunephthyra rubiformis*, and barnacles are predominant (MacGinitie, 1955). This rubble zone probably supports the greatest density of benthos about Point Barrow.

It may be concluded that there is no special resemblance between the Ross Sea benthos and that generally found on the Arctic continental shelf or in deeper Arctic waters.

Relation to Depth Zones

Finally, brief mention will be made of the bathyal, abyssal, and hadal benthos for comparison with the Ross Sea assemblages.

Pelagic sediments, siliceous and calcareous oozes, and red clay cover the ocean floor below the slope, grading into terrestrial sediments as the shelf is approached. Abundance of the deeper faunas depends probably less on depth than on the vicinity of land masses shedding organic matter and on the productivity of the surface waters (Bruun, 1957). However, both the species composition and the group composition of the benthos vary with depth. Below the shelf, motile epifaunal organisms are most common, even the coelenterates, pennatulaceans such as *Umbellula* sp., being capable of movement and are thus adapted to life on a soft substrate. Molluscs, which generally predominate on the shelf, form a comparatively small proportion of the deeper fauna. This deep fauna in which echinoderms, polychaetes, crustaceans, and some coelenterates are conspicuous appears to be remarkably uniform throughout the world (Bruun, 1957; Wolff, 1961).

Although the Ross Sea Deep Shelf Mud Bottom Assemblage is richer in animal life than the world-wide deep fauna mentioned above, the groups making up the two faunas are similar. *Umbellula* sp. occur in both faunas and both are dominated by polychaetes and echinoderms.

Conclusions

From this discussion the following features emerge:

(i) The bulk of the Ross Sea benthic organisms are sessile animals concentrated in areas where hard substrates are exposed, especially above about 500 m. The abundance of ice-rafted boulders and exposed rock in the area favours this fauna. In the absence of organic terrestrial debris, the environment is oceanic rather than coastal.

(ii) The fauna should be compared with hard substrate communities found elsewhere in the world such as tropical coral reefs, the shelf edge, deep coral communities, or certain shallow hard-substrate communities (e.g., the rubble zone off Point Barrow) rather than with the continental shelf level-bottom communities of other latitudes.

When compared with these communities, certain features of the Ross Sea benthos appear unique. Such features are the extensive development of siliceous sponges, bryozoans, and pycnogonids and the complete absence of crabs. Apart from certain shallow water occurrences of a pecten and a *Lima*, molluscs are few and inconspicuous.

(iii) On deep soft substrates in the Ross Sea the benthos has affinities with the deep water benthos in other parts of the world.

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