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RECENT NEW ZEALAND MARINE RESEARCH IN THE ROSS SEA SECTOR OF ANTARCTICA

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Abstract: The University of Canterbury Antarctic Research Unit was established in 1960 and since the summer of 1961–62 it has been responsible for the bulk of the marine ecological research in the McMurdo Sound region. The early focus of the work was on the population biology and ecology of the Weddell seal and ecological and population stidues on Adélie penguins and McCormick skuas, initially at Cape Royds and later at Cape Bird.

In the summer of 1970–71 a marine biological programme was initiated at Cape Bird. Projects carried out included a preliminary general benthic survey of the area off Cape Bird, a quantitative sampling of the bottom in depths between 25 and 200 m, and an oceanographic and sampling programme to a depth of 200 m at a permanent station. The quantitative sampling formed part of a study of marine benthic diversity along a latitudinal gradient from Stewart Island (47°S) to Cape Bird (77°S). The results of this study are briefly discussed. A range of other studies carried out at Cape Bird are listed.

In the 1976–77 summer the focus of the marine work shifted to White Island some 30 km from the edge of the McMurdo Ice Shelf. The objectives of this study were to monitor water column processes and to investigate summer plankton beneath the shelf, to determine the fish population beneath the shelf and to investigate their food supply, to sample the benthic community and to study the tide-crack production cycle. The results of these studies carried out over two seasons are briefly discussed.

In the summer of 1979–80 investigations were carried out through the sea-ice at the edge of the McMurdo Ice Shelf. Physical, chemical and biological parameters were measured weekly at six depths to 500 m. Phytoplankton and zooplankton species composition and production were monitored throughout the season. Special studies included investigations of the population structure of the euphausiid *Euphausia crystallorophias*, the biology and feeding energetics of the epipelagic fish *Pagothenia borchgrevinki* and a preliminary study of the epontic (ice-algae) community. In the 1982–83 summer a similar study of water column processes was carried out at three stations across the edge of the McMurdo Ice Shelf, from Scott Base to the Dailey Islands. Based on the above investigations and work carried out by other investigators a scheme of the circulation patterns beneath the McMurdo Ice Shelf is advanced.

1. Introduction

During IGY and the period immediately following thereon, New Zealand research in the Ross Sea included a range of oceanographic studies and in particular studies on the benthic communities of the region (BULLIVANT, 1967). Based on the collections obtained, the New Zealand Oceanographic Institute sponsored a series of monographic

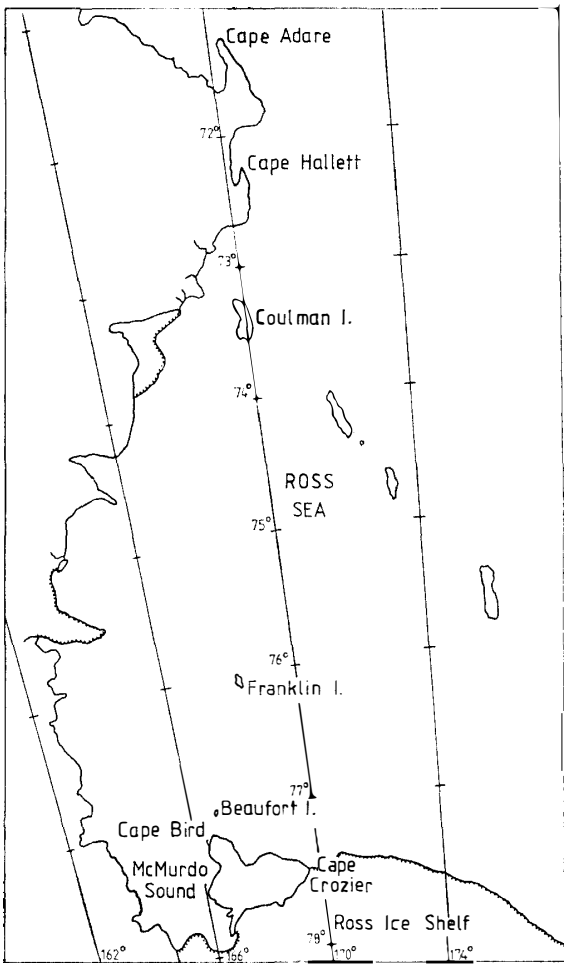

Fig. 1. Map of the Ross Sea region.

treatments of various invertebrate groups. In addition, ornithological work was commenced at Cape Hallett and Cape Royds (Figs. 1 and 2) on the ecology and population biology of Adélie penguins and McCormick skuas. Notable amongst these early studies was the pioneering work of E. C. YOUNG on the breeding behaviour, feeding habits and interactions with Adélie penguins of the McCormick skua (YOUNG, 1963a, b).

In 1960 the University of Canterbury Antarctic Research Unit was established and since the summer of 1961–62 it has been responsible for the bulk of the marine ecological research in the McMurdo Sound region. The early focus of the work was on the biology and population ecology of the Weddell seal (SMITH, 1965, 1966; STIRLING, 1967, 1969, 1971, 1974) and ecological and population studies on Adélie penguins and McCormick skuas at Cape Royds (SPELLERBERG, 1971a, b, 1974; STONEHOUSE, 1963; YEATES, 1968, 1971). In the mid-sixties the focus of the unit's ornithological research shifted to Cape Bird where the Cape Bird summer station was established and a series of intensive studies on Adélie penguin breeding behaviour (SPURR, 1972, 1974, 1975a, b, c, 1977, 1978) were commenced. Over five summers, E. C. YOUNG carried out a detailed ecological-behavioural study of the interactions between Adélie penguins and McCormick skuas (YOUNG, 1970, 1981). The results of this research will shortly be

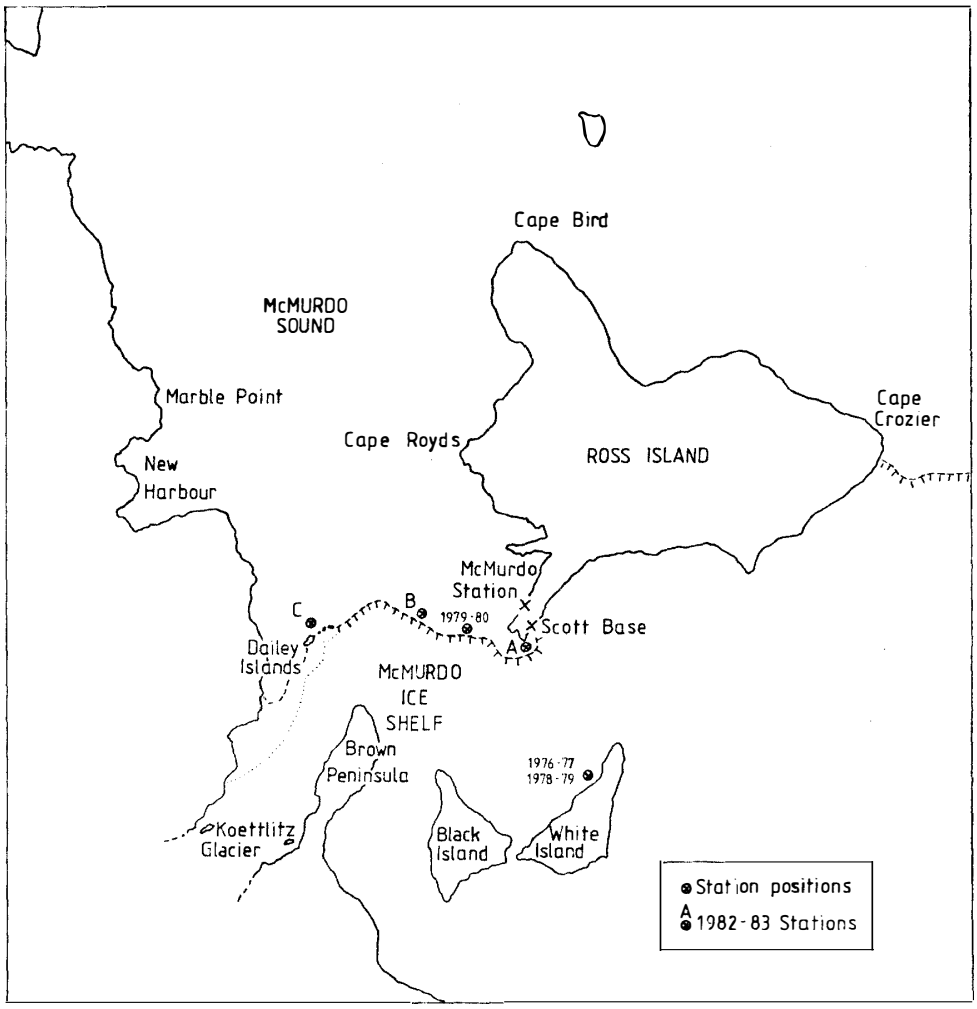

Fig. 2. Map of the McMurdo Sound region showing the locations of the research sites of the University of Canterbury Research Unit.

published as a book by Cambridge University Press. In the summer of 1970–71, the emphasis of the research programme shifted to marine studies which were commenced that summer.

2. Marine Studies at Cape Bird

During the summer of 1970–71, a marine biological programme was initiated at Cape Bird. The programme centred around the designing and construction of a small boat for inshore biological work at Cape Bird. The design criteria were: (1) a stable platform from which light oceanographic equipment could be used; (2) high manoeuvrability for operation in the pack ice of McMurdo Sound, and (3) prefabrication and lightness for ease of shipment. These design criteria resulted in the construction of a 16.5 foot trimaran, the R. V. CLIONE, with a 12 foot beam and 1.5t displacement. This provided 144 square feet of usable deck space which carried two lockers, a winch, an auxillary motor and a 3×4 foot hatch for sampling through the deck. The petrol-

driven winch was powered by a 4.5 HP Honda engine and the 1600 feet of 5/32 inch cable could be rigged for working through the deck hatch, or over the stern. Main power was supplied by a 9.5 HP Evinrude outboard motor and the auxillary engine was a 7.5 HP Evinrude.

Projects carried out during the 1970–71 summer season included:

1) A preliminary general benthic survey of the area off Cape Bird.

2) A quantitative sampling of the bottom in depths between 25 and 200 m.

3) An oceanographic and plankton sampling progarmme to a depth of 200 m at a permanent station off Cape Bird.

Benthic sampling was carried out using a box-dredge, a Smith McIntyre grab and an epibenthic sledge.

Data from the general survey is currently being worked up. The bottom sediments off Cape Bird are predominantly coarse sands derived from the scoria and larva flows of Ross Island. The main direction of the bottom currents off Cape Bird is from north to south and this is reflected in a gradation from cobbles and pebbles to fine sand in the same direction. Where the sand in unstable, the fauna is dominated by a spionid polychaete *Spiophanes techerniai* in densities of up to 10000 m^{-2}. At about 180 m a dense epifauna dominated by sponges and erect ecoprocts begins growing on a mat of sponge spicules. Associated with these growths there is a rich fauna of asteroids, ophiuroids, echiuroids, holothuroids, crinoids, polychaete worms and crustaceans, especially amphipods.

The quantitative sampling at Cape Bird formed part of J. K. LOWRY's study of marine benthic diversity along a latitudinal gradient from Stewart Island, New Zealand (47°S) to Cape Bird (77°S) (Table 1). Of interest is a comparison of the two areas in

Table 1. Number of species and individuals in soft bottom communities in a latitudinal transect from New Zealand to Antarctica (data from LOWRY, 1976a).

Locality	No. of species	No. individuals m^{-2}
Port Pegasus, Stewart Island 47°S	107	2965
Waterfall Inlet and Sandy Bay, Auckland Islands 50°S	83	47122
Perseverence Harbour, Campbell Island 52°S	55	2785
Arthur Harbour, Anvers Island 64°S	64	7502
Cape Hallett, Ross Sea 72°S	147	7755
Cape Bird, Ross Island 77°S	72	85105

the Ross Sea, Cape Hallett and Cape Bird. Although there were less than half as many species (72) in the Cape Bird samples as in that from Cape Hallett (147), the sampled population was over 10 times larger (85105 individuals m^{-2} compared to 7755 m^{-2}). The dominant species in the Cape Bird sample were the myodocopid ostracod *Philomedes heptathrix*, the burrowing anemone *Edwardsia* sp. and the tube-building polychaete *Spiophanes techerniai*. The pericarid *Notonais dimorphus* and an archianellid worm were also well distributed and abundant. At Cape Hallett, on the other hand, the samples were dominated by tube-building polychaetes, *Myxicola* sp., *Spiophanes techerniai* and *Potamilla antarctica*. Other important species were the bivalve *Thyasira borgraini*, other sedentary polychaetes, the tubificid oligochaete, *Torodrilus lowryi*, and pericarid crustaceans.

A comparison of species diversity between the macrobenthic communities along the latitudinal gradient between 47° and 77°S did not reveal any correlation between the diversity of the macrobenthos and latitude. Macrobenthic communities with the highest species diversity occurred at Cape Hallett, 72°S, and Port Pegasus, 47°S. Despite their wide geographic separation these communities have a very similar mixed suspension, deposit-feeding structure. The macrobenthic communities with intermediate diversity were found in Arthur Harbour, 64°S, and Perseverence Harbour, 52°S, and both these have a deposit-feeding trophic structure. The macrobenthic communities with the lowest diversity occur at the Auckland Islands, 80°S, and at Cape Bird, 77°S, and both have a suspension feeding trophic structure. These latter communities are found on predominantly sand bottoms.

The proportion of suspension-feeding and deposit-feeding animals in Port Pegasus is 33 and 55%, while at Cape Hallett it is 41 and 50%. Both of these communities can be classified as mixed suspension, deposit-feeding communities. Their high diversity is due to the fact that communities with a mixed basic trophic structure provide more niches and thereby support more different kinds of animals than other macrobenthic communities.

Bivalves are a very important part of the suspension-feeding (55%) and deposit-feeding (53%) populations in Port Pegasus, but at Cape Hallett, they contributed only 14% of the suspension-feeding individuals and less than 1% of the deposit-feeders. Bivalves drop from the most abundant group in the benthos in southern New Zealand to an insignificant group below the Antarctic Convergence. Pericarid crustaceans, on the other hand, show a reverse trend: from only 16% in Port Pegasus they increase to make up 21% of the Auckland Island's population, and 43% of the Campbell Island population. Even though pericarids maintain the highest proportion of macrobenthic species on the Antarctic Shelf, their proportion of the population decreases sharply from a high of 50% in Arthur Harbour to a low of 16% at Cape Bird. At Cape Bird, pericarids appear to be in direct competition with the equally successful, although less diverse, ostracods. If the situation is adjusted to include the ostracods then at Cape Bird they together with the pericarids, contribute 40% of the macrobenthos. Polychaetes are generally equally abundant along the gradient.

Other marine studies carried out at Cape Bird have included:

1) Studies on the inshore phytoplankton (EARLY and KNOX, in preparation; ENSOR and RAWLENCE, in preparation).

2) Reactive phosphorus in melt-water streams. (KNIGHT and KNIGHT, 1986).

3) Reproduction and growth of the Antarctic amphipod *Paramoera walkeri*(SAGAR, 1976, 1980).

4) Pack structure and behaviour of killer whales, minke whales (*Orcinas orca*) at Cape Bird (WILSON, in preparation).

5) Behaviour of the leopard seal (*Hydruga leptonyx*) at Cape Bird (WILSON, in preparation).

Taxonomic studies based on collections at Cape Bird and elsewhere in the Ross Sea include:

1) Description of a new podocerid amphipod (LOWRY, 1976b).

2) Publication of a catalogue of the marine gammaridean Amphipods of the Southern Ocean (LOWRY and BULLOCK, 1976).

3) A monographic treatment of the Polychaeta of the Ross Sea (KNOX and CAMERON, 1986).

3. Life Beneath the McMurdo Ice Shelf

Since 1960 the University of Canterbury Antarctic Research Unit had been studying an isolated Weddell seal population at White Island some 20km from the edge of the McMurdo Ice Shelf. This seal population was presumed to have no contact with other seal populations in the McMurdo Sound region and unlike them was believed not to migrate into the pack-ice zone in the non-breeding season, but to overwinter *in situ*, maintaining breathing holes in the pressure ridges (STIRLING, 1966, 1972). The seals at White Island number between 20 and 30. In the summer of 1976–77, a total of 20 aminals were located and tagged: 5 adult males, 1 sub-adult male, 8 adult females, 3 sub-adult females, 2 male pups and one female pup. The seals examined were all in excellent condition, in fact they were among the largest encountered in several years study of Weddell seals in the McMurdo Sound region. This implied that there was an abundant food supply available to them at some considerable distance from the edge of the shelf. To investigate this a research programme was commenced in the 1976–77 summer with the followning objectives:

1) To monitor water column processes and to investigate the summer plankton beneath the shelf.

2) To determine the fish populations beneath the shelf and to investigate their food supply.

3) To sample the benthic community.

4) To study the tide-crack production cycle.

3.1. Tide-crack production cycle

The standing crop and succession of microalgae were investigated for blooms in the surface water of a tide-crack adjacent to White Island over the period late November 1976 to late January 1977 (ENSOR *et al.*, 1986). The dominant microalgae during late November were Chlorophycophyta (*Pyramimonas* sp.). Bacillariophyceae (Diatoms) were dominant from early December until the end of the study in late January. Five species were most abundant: *Nitzschia cylindricus*, *Fragilaria* sp., *Synedra tabulata*,

Nitzschia curta and *Nitzschia obliquecostata.* The concentration of chlorophyll *a* was at the highest level (30 μgml^{-1}) when *Pyramimonas* sp. was most abundant. Incident light and the percentage transmission of light to a depth of one metre in the tide-crack were also at maximum levels at this time. Chlorophyll *a* concentrations decreased to below the limits of detection after the thaw in mid-January when there was an abrupt increase in the temperature and a decrease in the salinity of the surface waters in the tide-crack. The concentration of dissolved oxygen was at a maximum when the diatoms were most abundant. The major diatom species exhibited a changing dominance pattern related to the changes that occurred in the tide-crack enviorment as the season progressed (Fig. 3).

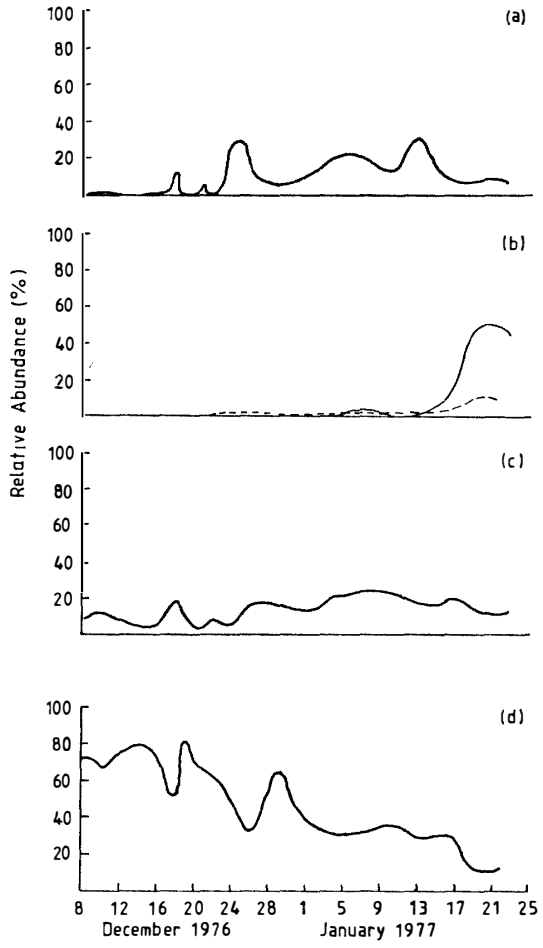

Fig. 3. The relative abundance of the dominant diatoms in the tide-crack at White Island, December 1976 - January 1977; (*a*) Fragilaria *sp.*, (*b*) Nitzschia curta (*solid line*), Nitzschia obliquecostata (*dotted line*), (*c*) Synedra tabulata, (*d*) Nitzschia cylindricus.

Three species of copepod (a calanoid, a cyclopoid and an harpacticoid) were associated with the tide-crack. Two of these have been described as new species (WAGHORN, 1979). The population structure and development stages of these three species were followed over the summer. Their cycles closely followed that of the phytoplankton. It is clear that the tide-crack is an important nursery in the summer for two of the species, *Paralabidocera grandispina* and *Pseudocyclopina belgica* and a habitat for the older stages of *Tisbe prolata.*

3.2. The water column plankton

Water column processes (temperature, salinity, current speed and direction, light penetration and dissolved oxygen) were measured at weekly intervals over the summer through a hole in the ice over a water depth of 67m (KNOX *et al.*, 1986). Seawater temperatures ranged from −1.91 to −1.96°C. Dissolved oxygen levels varied from 5.0 to 6.05 $ml \cdot l^{-1}$ in early December to 4.65 to 4.8 $ml \cdot l^{-1}$ in late January. Water current speeds of up to 0.13 $m \cdot s^{-1}$ were recorded at a depth of 50m and a predominantly northward flow was detected. Light levels under the ice were low with less than 1% of the incident light being transmitted to a depth of 3m. No chlorophyll was detected in the water column when estimated by processing one litre of water.

Zooplankton was sampled using a WP2 free-fall net. Zooplankton biomass values in the water column ranged from 12 to 447 mg net weight m^{-3} and were similar to values recorded elsewhere for Antarctic inshore waters. Thirty-two zooplankton species were recorded including an ostracod, 21 copepods (10 calanoids, 3 cyclopoids and 8 harpacticoids), 4 amphipods, 2 euphausiids (*Euphausia crystallorophias* and *Thysanoessa macrura*), a chaetognath, and 3 pteropods. Larvae of polychaetes and fish (*Prionodraco evarni* and *Pleurogramma antarcticum*) were found on some occasions. The species composition of the zooplankton was similar to that found in the inner Ross Sea. Amongst the copepoda, however, there were a number of species which have previously not been rcorded from the region, but which are know not be associated with ice in other localities in Antarctica.

3.3. Benthic fish

A special study of the fish present in the area was made as they are food of the Weddell seal (ZURR, 1977). Two notothenid fishes *Trematomus bernacchii* and *T. centronotus* were common. *T. centronotus* was caught predominantly early in the season while more *T. bernacchii* were caught later. The *T. bernacchii* were significantly larger than the *T. centronotus* and were predominantly older females. Age and growth of the two species were investigated using length/weight relationships and an examination of scales and otoliths. In addition stomach contents of the fish were examined in order to determine the food of the two species.

3.4. The 1978–79 summer season

The research at White Island was continued during the 1978–79 summer season. The water column beneath the permanent ice shelf was sampled at weekly intervals from 25 November 1978 until 20 January 1979. Phytoplankton, zooplankton, seston and nutrients were sampled and physical and chemical parameters were measured at each of five depths (5, 10, 25, 50 and 70m). The water column depth was 75m. Estimation of seston included the determination of the concentration of chlorophyll, ATP, particulate organic carbon, total nitrogen and determination of dry weight from separate volumetric samples. ATP levels revealed a marked peak in early January following the peak phytoplankton production which occurred in McMurdo Sound (Fig. 4).

During the 1976–77 White Island expedition no chlorophyll was detected when one litre of water was processed. During the 1978–79 season when large volumes of water were filtered, low concentrations of chlorophyll were measured. In order to obtain a

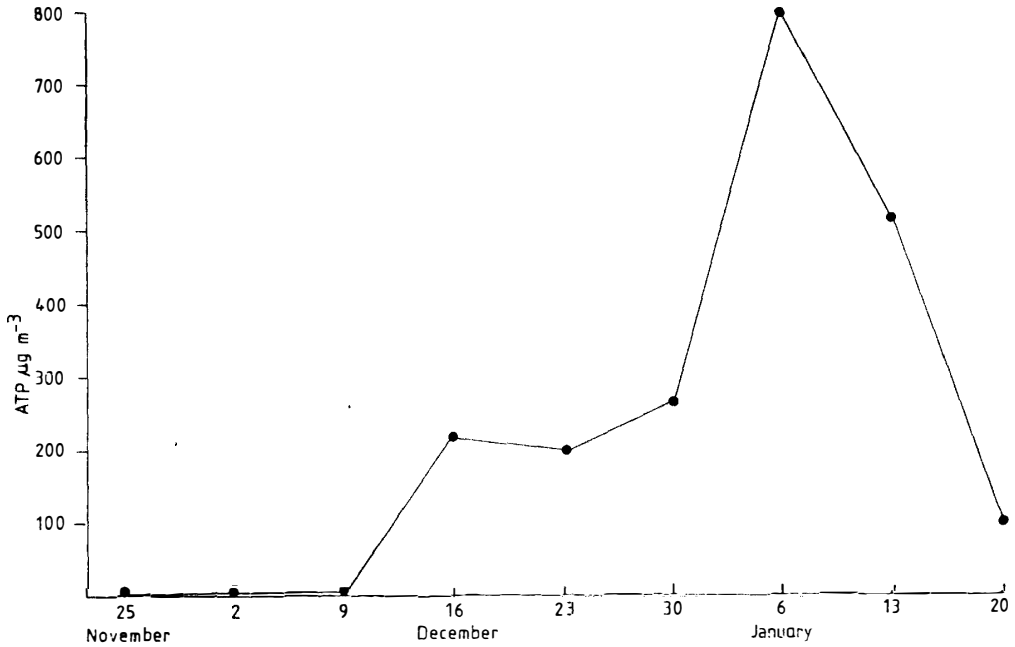

Fig. 4. Seasonal distribution of ATP in the water column at White Island.

significant reading, 16*l* of water had to be filtered during November but later in the season this volume was reduced to 4*l*. The zooplankton was similar to that recorded in the 1976–77 season but it was more varied and more abundant in the early part of the season. This difference can be attributed to the earlier breakout of the sea-ice in McMurdo Sound in the 1978–79 season. Other studies carried out included investigations of the bacterial populations in the bottom sediments and studies on the sediment nitrogen cycle.

3.5. The benthic community beneath the McMurdo Ice Shelf at White Island

During the two seasons at White Island, benthic collections were made through the ice holes using an orange peel grab. Analysis of the samples revealed a rich benthic fauna. A total of over 300 species have been recorded (Table 2). The species composition of the benthic fauna at White Island was similar to that found at comparable depths near the northern edge of the Ross Ice Shelf in McMurdo Sound. However some differences were apparent. The thick layer of sponge spicules, mollusc shells and debris that is characteristic of the bottom community at similar depths in eastern McMurdo Sound was not found at White Island. The bottom was composed of pebbles and cobbles with a relatively coarse sediment between them. The most common epifaunal species were suspension feeding sponges, alyconarians and bryozoans, suggesting that the major food source was plankton and detritus. Detrital feeding amphipods were abundant. It is clear that the input of organic matter to the benthos is sufficient to maintain an abundant fauna that provides adequate food for the benthic fishes which comprise the food of the Weddell seals.

Table 2. Number of species of benthic invertebrates recorded at White Island (from KNOX and ENSOR, in preparation).

	No. of species	New species		No. of species	New species
Foraminifera	33		Amphipoda	17	3
Porifera	10		Isopoda	16	1
Hydrozoa	7	1	Mollusca		
Anthozoa			Amphineura	1	
Actinaria	8		Gastropoda	24	
Alcyonaria	2		Bivalvia	12	
Platyhelminthes	1		Bryozoa	24	2
Nemertina	3		Brachiopoda	1	
Nematoda	6		Echinodermata		
Polychaeta	74	6	Echinoidea	2	
Acarina	3		Asteroidea	5	
Pycnogonida	12		Ophiuroidea	10	
Crustacea			Crinoidea	2	
Ostrocoda	12	1	Holothuroidea	2	
Copepoda	5		Ascidiacea	5	
Cumacea	3				
Tanaidacea	5	4	Total	305	18

4. Plankton Beneath the Sea Ice at the Edge of the McMurdo Ice Shelf

In the summer of 1979–80 a camp was established at the edge of the McMurdo Ice Shelf some 17 km from McMurdo Station (Fig. 2). The objectives of the research programme carried out during that summer were to study the dynamics and productivity of the pelagic ecosystem under the seasonal sea ice so as to enable a comparison to be made with that under the permanent ice at White Island, and to estimate the transport of phytoplankton, zooplankton and detritus under the McMurdo Ice Shelf. A number of subsidary studies were also planned. For the main programme two holes were established trough the sea ice over a water depth of 540 m.

4.1. The pelagic ecosystem

Over the summer (December 1979–January 1980), the water column was sampled weekly. At each of six depths (0, 25, 75, 150, 275 and 500 m) the following physical, chemical and biological parameters were measured:

Temperature	Nutrients–PO_4–P
Salinity	–total–P
Oxygen	Chlorophyll
Current velocities	ATP
Nutrients–NH_4–N	Phytoplankton composition and density
–NO_2–N	Seston dry weight
–NO_3–N	Bacterial numbers.
–total–N	

In addition the zooplankton in a vertical column to a depth of 500 m was sampled with coarse and fine WP2 free-fall nets. Stratified zooplankton samples were taken on

several occasions to determine the depth distribution of the species present. Primary productivity was measured on a number of occasions using the light and dark bottle oxygen technique. Weekly samples were taken at a depth of 200 m with a detrital trap. The four samples taken on each occasion were processed on each occasion for dry weights, total nitrogen, total organic carbon and ATP.

Phytoplankton samples showed the predictable *Phaeocystis* bloom in early December followed by a varied diatom community. Zooplankton faecal pellets were abundant in the fine net samples and microscopic examination revealed that on occasions they contained large numbers of relatively intact diatoms. The zooplankton samples were numerically dominated by Copepoda; the numbers being generally much higher in January than in December. The euphausiid, *Euphausia chrystallorophias*, was also common, with higher numbers in January. A second euphausiid, *Thysanoessa macrura* was sparsely present. Cnidaria were abundant in all samples. Amphipoda and Ostracoda were generally present and were most numerous in the latter samples. Pteropoda were present on all occasions, the most common species being *Limacina helicina*. Larval fish, especially *Pleurogramma antarcticum*, were recorded from all samples after, and including, 4 January. Less abundant members of the zooplankton included a mysid, polychaete larvae and Chaetognatha.

There were a number of differences between the community under the sea ice and that sampled at White Island in previous seasons. Cnidaria especially the siphonophoran, *Pyrostephos vanhoffenii*, were abundant under the sea ice but were virtually absent at White Island. A large mysid which was present in the samples was not collected at White Island. Total numbers of zooplankton in the surface 100 m of the water column were low but they rapidly increased with depth.

4.2. Population structure of Euphausia crystallorophias

Euphausia crystallorophias is one of the dominant zooplankton species in the under sea ice water column and in McMurdo Sound the population is at the extreme end of its range. It is the principal food of the minke whales which are abundant along the ice edge in McMurdo Sound. Additional plankton samples were taken to investigate the population structure of *E. crystallorophias*. On six occasions over the season, vertical hauls were made from the surface to 500 m using the 1 mm mesh WP2 free-fall plankton net. Sex and developmental stages, following the recommended BIOMASS methods, were determined for the euphausids in the samples. Lengths of all individuals were measured to the nearest millimetre and wet weights were determined. Wet weight/dry weight relationships were determined for a representative sample. The data from this study are currently being analysed.

4.3. Biology and feeding energetics of Pagothenia borchgrevinki

BRADFIELD (1980) studied the biology and feeding energetics of *Pagothenia* (*Trematomus*) *borchgrevinki*, a small epipelagic fish associated with the under surface of the sea ice. Length frequency distributions of both sexes were normal and did not exhibit polymodality. Scales and otoliths did not reveal annual growth markings. Weight-length relationships indicated that females were larger than males of a given length. BRADFIELD postulated that year-round spawning, short life-span and rapid growth, ac-

counted for the length frequencies observed. Fecundity was low with relatively few (1154 to 3125) small eggs being produced. Because of the evidence of constant growth, BRADFIELD believed that spawning probably took place throughout the year. Constant spawning and the small egg size are probably a consequence of the fact that the presence of different sized zooplankters and the epontic (ice-algal) community invertebrates (ANDRIASHEV, 1966; BRADFORD, 1978) enables the larval *P. borchgrevinki* to start feeding immediately upon hatching. As the fish grow in size, they switch to increasingly large food items.

Oxygen consumption/metabolic rates were also measured. Metabolic rates were high, comparable with values obtained for a variety of temperate fishes (PROSSER, 1973) indicating a high degree of cold adaptation. Calorific values for *P. borchgrevinki* muscle, bone and epidermis and for the major prey species were determined. Muscle tissue was found to have a high energy content reflecting the large amount of lipid present in this tissue.

Composition of the diet was determined from the examination of the stomach contents of 156 fish. A list of the food items encountered is given in Table 3. *Pleurogramma antarcticum* larvae and the amphipod *Hyperiella macronyx* occurred in half the stomachs, with the latter occurring in the largest numbers. The most important food items in terms of biomass were *P. antarcticum*, *Euphausia crystallorophias* and the amphipods *Orchomene plebs* and *H. macronyx*. Diet composition was compared with the relative abundance of zooplankton species in the water column and the animals of the epontic community. Epontic species that were common in the diet were the annelid *Harmothoe* sp. and the amphipods *Orchomene plebs* and *Eusirus antarcticus*. While *Pleurogramma antarcticum* larvae were relatively rare in the plankton they occurred in over half the stomachs examined. This suggests that they were also associated with the epontic community. Prey-size distribution and prey diversity suggested an opportunistic feeding strategy and it was concluded that *P. borchgrevinki* obtains its food from animals associated with the epontic community or in the top few metres of the

Table 3. List of food items from stomach contents of Trematomus borchgrevinki *(from BRADFIELD, 1980).*

	Size (mm)		Size (mm)
Invertebrates		Amphipods	
Polychaetes		*Hyperiella macronyx*	6
Harmothoe sp.	10	*Orchomene plebs*	12
Molluscs		*Eusirus antarcticus*	10
Clione antarctica	9	Euphausiids	
Limacina helicina	1.5	*Euphausia crystallorophias*	20
Crustaceans		Vertebrates	
Small copepods		Fish	
Calanoides arcutus, *Metridia gerlachei*, *Calanus propinquus*	4	*Pleurogramma antarcticum* (larva)	50
Large copepods		Eggs	1.5
Euchaeta antarctica, *E. eribi*	8		

water column below the sea ice. It is thus a major consumer in the sub-ice ecosystem and is itself the predominant food of the large Weddell seal populations.

4.4. Studies on the epontic (ice-algal community)

Over the summer a preliminary study of the ice-algal community which develops in association with the bottom-layer of the sea ice was carried out. Sampling was successfully carried out using a Sipre ice auger, with which complete cores were readily obtained. Sea ice thickness at the main sampling site, close to the main ice holes, ranged from 2.3 to 2.5 m.

Early in the season two complete cores were divided into 25cm sections, melted and the resulting sample used to determine a range of parameters or to obtain subsamples for subsequent analysis. These were

Salinity
Chlorophyll
ATP
Algal dry weight
Bacterial numbers
Algal sample for species determination and relative abundance.

As it was found that the algae were concentrated in the lower 20–25cm of the core, future sampling, apart from two core analyses later in the season, concentrated on this section of the core.

A total of 32 algal species were found, 30 diatoms, one flagellate and one dinoflagellate. The animals present in the community were limited to several species of protozoa, a nematode and a mite. On several occasions the bottom 24cm of the core was cut into 2cm sections and algal species determination and counts made on subsamples from

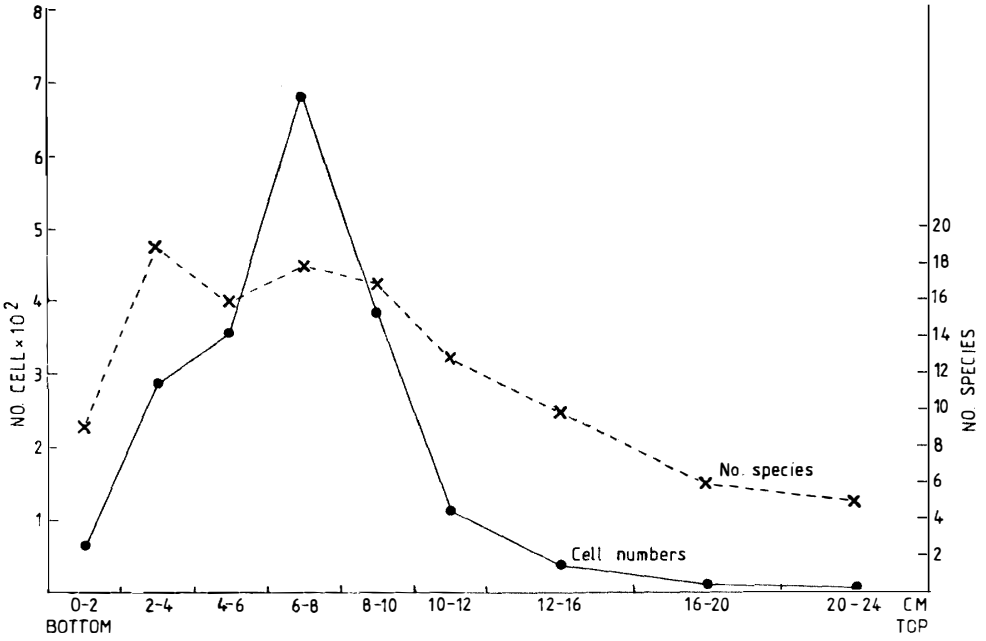

Fig. 5. Distribution of algal species and total cell numbers in bottom 25 cm of a core through the sea-ice in McMurdo Sound. (The cell nos are based on standard microscope counts of a small subsample from the 2 cm melted section.)

the melted sections. A pronounced pattern of the distribution of individual species, the number of species present and total algal numbers with distance from the bottom of the core was observed. A typical pattern is shown in Fig. 5. Peak cell numbers occurred in the 6–8 cm section and peak species numbers in the 2–10 cm section. There was a rapid decrease, both in species numbers and total numbers, above 12 cm from the bottom. Other parameters followed a similar trend. A series of cores were sampled throughout the season in order to determine seasonal changes in community composition. Comparisons were also made between samples from an area kept free of surface snow, and from areas covered with various depths of snow. Marked differences in algal numbers and species dominance were noted.

5. Circulation and Production Beneath the McMurdo Ice Shelf

Because of its possible biological significance, there has been considerable interest in the circulation and hydrology under the seasonal sea ice in McMurdo Sound and under the McMurdo Ice Shelf (TRESSLER and OMMUNDSEN, 1962; GILMOUR *et al.*, 1962; GILMOUR, 1963, 1975). DAYTON and OLIVER (1977) have drawn attention to the contrasts in the benthic faunal assemblages on the east and west sides of McMurdo Sound. In their study, DAYTON and OLIVER recorded 37 species and 2828 individuals in a core (0.018 m^2) in 20 m of water off Cape Armitage on the east side of the Sound and 50 species and 176 individuals in a similar core taken in 40 m of water at New Harbour on the west side of the Sound. These differences can be correlated with the different patterns of water movement and ice cover in the east and west sides of the Sound.

In view of these differences the 1982–83 programme was designed to compare water column production processes at three sites across the Sound (Fig. 2):

Station A: 1.5 km south from Scott Base; water depth 340 m.
Station B: approximately 1.0 km north from the edge of the McMurdo Ice Shelf and 22 km from Cape Armitage; water depth 350 m^+.
Station C: approximately 2.0 km north of the most westerly of the Dailey Islands on the west side of the Sound; water depth 210 m.

Station A was sampled 5 times over the season and Stations B and C twice. The sampling programme was similar to that carried out in the 1979–80 programme.

At Station A there was no chlorophyll present in the water column on the first and second samplings on 29 November and 6 December. Significant chlorophyll levels were recorded on 23 December, coincident with a *Phaeocystis* bloom being advected under the ice. Very high chlorophyll levels were recorded at Station B on 5 January, 1983 following the breakout of the sea-ice in the outer part of McMurdo Sound. As expected, low chlorophyll levels were recorded on both occasions at Station C.

Zooplankton samples were as usual dominated by copepods with numbers increasing over the season. The first two samplings at Station A (29 November and 6 December) revealed a very sparse fauna. Juveniles of the euphausiid, *Euphausia crystallorophias* were present throughout the sampling period with adults occurring later in the season. Numbers increased as the season progressed. Amphipods and ostracods were generally present and were most numerous in the later samples. Pteropods were present in all samples and on several occasions occurred in large numbers. Larval

fish were present in the latter part of the season. There were some significant differences between the three stations. Station B in the middle of the Sound had the richest fauna both in terms of species and numbers on all occasions. Station C on the west side of the Sound had the sparsest fauna.

Based on the results of the two seasons at White Island and the two seasons sampling through the sea-ice along the edge of the McMurdo Ice Shelf, information on the current patterns in the Sound and investigations carried out by U. S. scientists, a scheme of the circulation patterns underneath the McMurdo Ice Shelf has been advanced (Fig. 6).

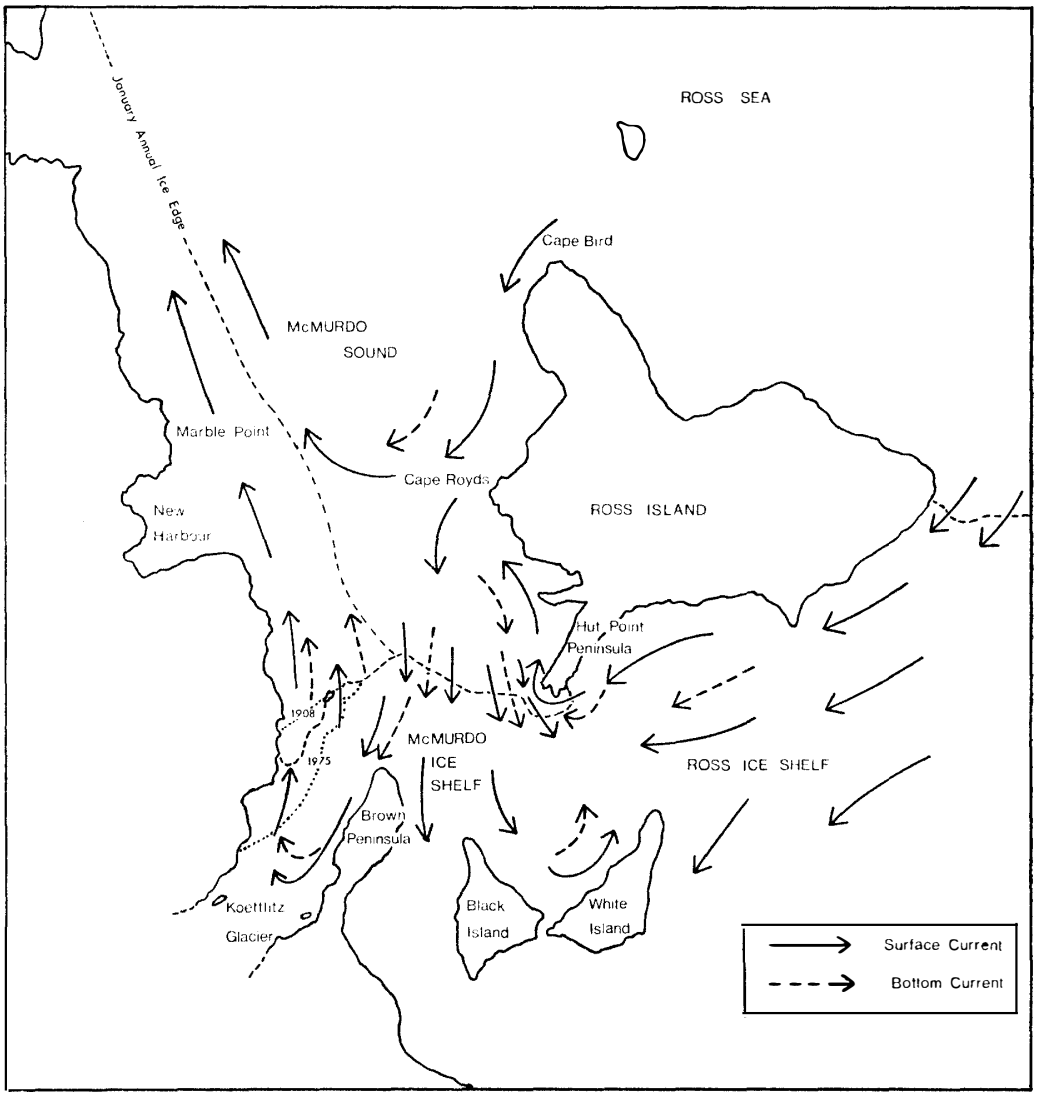

Fig. 6. Hypothesized circulation pattern beneath the McMurdo Ice Shelf.

6. Recent Ornithological Research in the Ross Sea Region

Early ornithological research in the Ross Sea region was briefly summarized in the Introduction to this paper. Here more recent research will be outlined. Studies carried out at Cape Bird have included:

1) Feeding of the Adélie penguin *Pygoscelis adeliae* (PAULIN, 1975).
2) Monitoring of McCormick skua (*Catharacta maccormicki*) populations.
3) Vocal communication between parents and chicks of the Adélie penguin (AOYANAGI and TAMIYA, 1981).
4) Yolk formation in Adélie penguin eggs.

6.1. *Annual census of Adélie penguins at Cape Bird*

For the past 200 years, apart from two seasons, an annual census of occupied Adélie penguin nests at Cape Bird has been carried out at the same time each year, December 7 to 14. This is the largest continuous census of a penguin colony that has been carried out anywhere in Antarctica. Data for the period 1970–1983 is given in Table 4. Over this period the colony has shown a remarkable stability varying only from 30252 occupied nests to 36843. Although numbers declined over the period 1977–1979, the 1980 numbers were higher than they were in 1974. Weather and sea-ice distributions are being examined to see if there are any correlations with the fluctuations in population size. In addition to the overall census data, distributions within the individual colonies within the main rookeries have been monitored and some interesting changes documented. In addition, the Unit has also carried out the annual census of the Cape Royds colony, the southernmost Adélie penguin colony in Antarctica.

Table 4. Number of occupied Adélie penguin nests at Cape Bird in late November–early December.

	1970	1974	1975	1976	1977	1978	1979	1980	1981
Northern rookery	21099	25250	24516	24619	23667	23304	22896	25133	24937
Middle rookery	1257	1625	1642	1558	1483	1493	1487	1643	1670
Southern rookery	7896	9450	9827	10236	9637	9938	9554	10067	9593
Total	30252	36325	35985	36413	34787	34735	33937	36843	36200

6.2. *The New Zealand contribution to the ISAS (International Survey of Antarctic Seabirds) Programme*

A very active New Zealand ISAS Programme has been in progress since 1979 (HARPER and TAYLOR, 1984; HARPER *et al.*, 1985a, b). By 1980, 31 colonies of Adélie penguins, 8 colonies of Emperor penguins, and a small colony of Chinstrap penguins had been located in the Ross Sea Sector. Census data for many of these colonies was 20 to 25 years old. The priorities that were established for the New Zealand ISAS Programme were: update the census data; ensure the continuation of the Cape Bird and Cape Royds monitoring studies; expand penguin feeding studies; and, with the support of nations having research ships, undertake surveys on the abundance ecology and distribution of seabirds in Antarctic areas.

Aerial surveys of the majority of the Adélie penguin colonies have been completed (TAYLOR and WILSON, 1982). A number of new colonies have been discovered and ground counts have been made of colonies not previously surveyed. A visit to Cape Adare in January 1982 produced a new census of Adélie penguins there: 220900 breeding pairs. This is probably the largset known penguin colony of any type in Antarctica and was last censused in 1966 (about 289000 breeding paris). About 80000 Emperor penguins and approximately 1.5 million Adélie penguins representing a third of the

world's population of the two species breed in the Ross Sea Sector. Petrels too, number in the millions. A comprehensive review of the status and conservation of birds in the Ross Sea Sector has been published (HARPER *et al.*, 1985a, b).

In addition to the aerial and ground census work, New Zealand ornithologists and observers have been able to make valuable observations of birds at sea. In all, over 10000 ten minute observational data cards have been completed, a number not exceeded by any other ISAS programme. This data has been computerized and is currently being analysed.

A four person ISAS/NZ expedition spent five weeks at Cape Hallett in January–February 1983 (WILSON, 1983b). During the period the Hallett Station was occupied (year-round from 1956 to 1984, and during the summer months from 1965 to 1972) the Adélie penguin colony had declined markedly; from 65000 breeding pairs in 1956 to 43000 in 1971. In 1984 only 26493 penguin chicks were counted. Heavy snow in December may have been the reason for the low numbers. Eighty-four pairs of territorial skuas were counted compared to 180 in 1959–61 and 98 in 1971–72. Stomach contents, as part of a feeding study, from 76 Adélie penguins were taken using a water off-loading technique. *Euphausia* spp. made up the bulk of the food with fish a minor part of the diet. Kinsky in the late 1950's collected a number of stomach contents of Adélie penguins at Cape Hallett but did not analyse them. These have now been examined and some interesting differences in euphausiid dominance in the contents have been recorded between the two studies.

In addition to the field work ISAS/NZ was requested by the BIOMASS Working Party on Bird Ecology to compile two major documents: one a synthesis of current knowledge on the distribution and abundance of Antarctic and sub-Antarctic penguins (WILSON, 1983a); and a key to foraging techniques used by Antarctic seabirds (HARPER *et al.*, 1984, 1985). The latter handbook is designed to produce conformity in the recording of observations on feeding behaviour by investigators with differing backgrounds and expertise.

7. Publications of the University of Canterbury Antarctic Research Unit

Table 5 lists the publications arising from the research carried out by the University of Canterbury Antarctic Research Unit. Annual research teams have numbered from 3 to 8 with an average of 4–5. Eighty-one papers have been published, six are in press and a further 27 are in various stages of preparation. The Unit has made a significant contribution to Antarctic marine biology.

Table 5. University of Canterbury Antarctic Research Unit Marine Research Publications.

	Marine mammals	Marine birds	Marine biology	Total
Published papers	21	44	16	81
Papers in press	1	1	4	6
Papers in preparation	3	3	21	27
Honours Theses	2	3	6	11
M. Sc. Theses	1	2	1	4
Ph. O. Theses	2	1	1	4

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