CRUISE REPORT SS 01/99

January 10 – February 4, 1999

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CSIRO
MARINE RESEARCH

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Departed: Hobart 0900 Sunday, 10 January 1999
Arrived: Hobart 1930 Wednesday, 3 February 1999

AREA OF OPERATION

The cruise was carried out in waters in the vicinity of Macquarie Island and the Macquarie Ridge between 53°S - 56° 17' S and 158° 30' E - 159° 25' E.

RESEARCH BACKGROUND

The cruise is designed to provide the scientific basis for management of the Macquarie Island Patagonian toothfish (*Dissostichus eleginoides*) fishery, based upon, on the one hand, an assessment of population size and hence sustainable yield, and on the other hand, additional information on ecological interactions of the fishery with marine mammal and seabird populations that breed on the State Reserve of Macquarie Island. A benthic survey will contribute to the planning and development of a Commonwealth Marine Protected Area within Australia's EEZ around Macquarie Island.

CRUISE OBJECTIVES

1. Conduct an acoustic/trawl survey around Macquarie Island and along the Macquarie Ridge to 1500 m to assess the distribution and relative abundance of Patagonian toothfish and, so far as possible, an assessment of absolute abundance. To complete this objective the following sub-objectives will be achieved:
   - Obtain *in situ* target strength measurements of Patagonian toothfish and other dominant species.
   - Test use of the acoustic multi-frequency system to discriminate between species in the survey area.
2. Assess the diet of Patagonian toothfish and dominant nekton species in order to establish a food web for the nekton and higher predators and assess predatory and competitive interactions.
3. Describe the abundance and community structure of the nekton in the upper 1500 m of the water column in relation to oceanographic conditions, *i.e.* across the sub-Antarctic Front, on Macquarie Ridge (Patagonian toothfish habitat) and in deepwater based upon depth-stratified sampling.
4. Assess the abundance of zooplankton in the upper 200 m of the water column in relation to ocean conditions in the same habitats as Objective 3.
5. Undertake systematic observations of the seabirds and sea mammals in relation to physical and biological ocean conditions across the sub-Antarctic Front along the Macquarie Ridge and off Macquarie Island.
6. Obtain data for a baseline description of the benthic invertebrate community within and around the area of a potential MPA and assess the impact of trawling on it based on broad-scale acoustic mapping and detailed habitat assessments from camera/video transects and dredge sampling from 200-1500 m.
7. Collect genetic material from Patagonian toothfish for stock discrimination studies.

RESULTS

The cruise consisted of the following components: an acoustic/trawl survey of Patagonian toothfish; oceanographic sampling of the water column with Bongo and surface nets for zooplankton and with the Midwater Opening/Closing net system (MIDOC) for nekton, and with the CTD to measure physical and chemical properties and chlorophyll concentration in the upper water column; and benthic sampling with a deepwater video and dredge. Results are presented under those headings. A complete list of stations is found in Appendix A.

Acoustic survey of Patagonian toothfish

Intensive acoustic surveys with the deep water multi-frequency towed body (MUFTI) were undertaken in the following regions on the Macquarie Ridge from 53.5° S to 56.3° S (see Appendix A for positions):

Aurora Trough
Beer Garden, Grand Canyon, Colgate Valley
East Macquarie
West Macquarie
Southern Ridge

The towed system was deployed at 100-400 m below the surface and towed at speeds of 6-9 knots. Acoustic fish marks observed during the survey were recorded and relayed to the Austral Leader for trawling. Several acoustic marks that were observed within the 3 NM limit of Macquarie Island were trawled by the *Southern Surveyor*. The vessel mounted and towed acoustic systems were calibrated at the start of the voyage and the deep water system was calibrated to a depth of 500 m at the completion of the acoustic work. Measurements of the water column temperature and salinity were conducted to estimate the sound speed and absorption profiles for the various frequencies. The cold 6° C surface water that declined to around 2° C at 800 m increased the absorption of our 38kHz system to 9.8dB whilst reducing the 120kHz absorption to 36dB. Independent experiments were carried out to estimate the absolute absorption at 38kHz for these waters.

Along with the multi-frequency towed system, the vessel's 12kHz, 38kHz and 28kHz echosounders were also digitally recorded during the survey. In general the hull mounted acoustic systems (12, 28 kHz) were of poor quality and could not be used for identification of acoustic marks. The weather conditions on the western side of Macquarie Island were generally 30-35 knot westerly winds. These conditions soon rendered the vessel hull-mounted acoustic systems useless. However a 38kHz transducer mounted on a pole that extends 3 m below the ships hull was operable for 80% of the survey and proved to be a useful backup to the towed system. The towed acoustic system produced acoustic echograms of high data quality in all weather conditions encountered during the survey.

Initial catch results indicate that whilst low to moderate catches of Patagonian toothfish were caught in most trawls there were also significant catches of species with gas-filled swim bladders: namely morids and whiptails. As Patagonian toothfish do not have a gas-filled swim bladder their reflectance is expected to be significantly less than the gas-bladdered species, as is the case with orange roughy. No acoustic mark identified during the broad acoustic survey could be definitely and uniquely attributed to Patagonian toothfish.

The largest catches of Patagonian toothfish during this survey originated from a region in Aurora Trough known as the Golden Mile. Extra acoustic surveying took place in this region with the deepwater multi-frequency towed system deployed 50-100 m off bottom to measure *in situ* target strengths. Several marks observed with our multi-frequency system as being typical of non-gas-bladdered fish were target trawled by the *Austral Leader*. Catches were higher on these marks and after further analysis will assist in our acoustic identification of Patagonian Toothfish. Unfortunately

these marks were very small, 5-10 m high and 0.2 NM long and would be difficult to resolve and identify with vessel- or shallow-towed acoustic systems. Another area that contained significant quantities of juvenile toothfish was located near the 3 NM boundary and deep water multi-frequency acoustic signatures complemented the trawl catches obtained.

Given the lack of any significant acoustic mark that could be attributed to Patagonian toothfish and the low catches during the survey with a high proportion of gas-bladdered species such as the morids and whiptails, an acoustic assessment of biomass will not be possible.

Midwater Trawl Sampling

The mesopelagic fauna was sampled at five sites with a pelagic trawl fitted with a MIDOC multiple codend. This allowed sampling in four depth strata: 1000-750 m, 750-500 m, 500-250 m and 250 m-surface. Two samples during the daytime and two at night were attempted at each station, but at most stations it was only possible to obtain one night-time sample because of the shortness of the night.

The following stations were sampled.

STATION	Number of samples
Macquarie offshore — deep water to west of Ridge	2 day, 2 night
Aurora Trough — on Macquarie Ridge	2 day, 1 night
Beer Garden — on Macquarie Ridge	2 day, 1 night
Ridge Gap — gap in Macquarie Ridge north of island	2 day, 1 night
North Site — north of Ridge Gap, close to sub-Antarctic Front	1 day

Despite the differences in submarine topography and a latitude range of 140 NM, there was little difference in the species composition between sites. Species composition by both number and weight was dominated by a range of species of myctophid fish from the genera *Protomyctophum*, *Krefftichthys*, *Electrona*, *Gymnoscopelus* and *Lampanyctus*, and other fish such as *Bathylagus* sp. *Stomias* sp. and *Borostomias* sp. Among invertebrates, coronate medusae, the ostracod *Gigantocypris mulleri*, the hyperiid amphipod *Themisto gaudichaudi*, *Euphausia triacantha* and *E. vallentini* and the decapod crustaceans *Pasiphaea* sp. and 'red carid' were typical of all stations.

Some small differences were apparent, however. The sites on Macquarie Ridge, Beer Garden and in particular Aurora Trough, produced a number of benthopelagic shelf-dwelling species in the deepest net, *e.g. Halargyreus johnsoni*, *Coryphaenoides subserrulatus* and *Melanostigma gelatinosum*. In these locations, the deepest net would have been within 100-200 m of the bottom. The more northerly stations at Ridge Gap and North Ridge also contained a few individuals characteristic of the sub-Antarctic Front and waters to the north, such as *Electrona subaspera*, *Phosichthyus argenteus*, *Polymetme* sp. and *Protomyctophum* (*Hierops*) sp. Additionally, the North Ridge station produced other species characteristic of waters north of the sub-Antarctic Front such as *Diaphus hudsoni*, *Persparsia kopua*, *Woodsia meyerwaardeni* and *Rosenblattia robusta*.

There were marked differences in species composition and abundance with depth. In the daytime hauls, net 2 (1000-750 m) had by far the largest catches, particularly of medusae, *Bathylagus* sp. and the myctophids *Lampanyctus* sp. and *Gymnoscopelus braueri*. Net 3 (750-500 m) generally had the next largest catch, with a similar species composition to net 2, and the other nets at shallower depths generally produced low catches containing few species.

There was some evidence of diurnal vertical migration, but in few cases was this strongly evident. *Protomyctophum* sp. was usually found over the whole depth range sampled during the day, but at

night was concentrated in the top 500 m. *Gymnoscopelus braueri*, *Lampanyctus* spp. and *Bathylagus* spp. were mostly found in the lower nets by day, but spread more evenly through the depths at night.

Catches of all fish species per net, expressed as crude grams per haul without correction for volume filtered, are given in the following table.

	DAY				NIGHT			
Station	1000-750	750-500	500-250	250-0	1000-750	750-500	500-250	250-0
MO	767.1	149.9	11.9	231.6	169	0	531.1	144.9
AT	2309.7	469.6	78.4	73.5	1287.1	466.8	173	196.6
BG	720.2	214.4	57.7	127.8	1080.5	559.7	132	462.6
RG	1146.4	585.8	72.6	578.4	959.3	476.8	772.4	715.8
NR	269	589.5	13.6	20.6				

For most sites, catches in the deeper nets were greater by day than by night, and the reverse was generally true for the shallower nets, which presumably reflects the diurnal vertical migration of some species. Differences between sites are also evident. By day, Aurora Trough (AT) and Ridge Gap (RG) have the greatest biomass at most depths, and at night Beer Garden (BG) has a comparable biomass with AT and RG for most depths. The Macquarie Offshore (MO) site had considerably less biomass than the three sites on or near Macquarie Ridge, except for the shallowest stratum by day and the 500-250 m stratum at night. This supports the theory of there being some concentrating effect by the Macquarie Ridge on the mesopelagic fauna, especially at depths greater than 500 m where the toothfish is thought to feed.

For each MIDOC trawl, vessel pole-mounted acoustics were recorded to estimate the biomass in each 250 m depth layer associated with the MIDOC trawl depths and times. In general the daytime echograms on or near the ridge at 38kHz showed distinct layers, typically at 0-30 m, 100-150 m, 400-550 m, and 600-900 m depth. The acoustic layer at 100-150 m during the day was of the highest intensity and its structure typical of a tightly schooling small gas-bladdered fish (*e.g.* a myctophid). Additionally the deep water towed system was deployed to ca 900 m depth and slowly brought to the surface to obtain the target strengths of the dominate species as a function of depth. The multi-frequency echograms from the deep towed system showed distinct layering of species in each depth layer that will be compared to the species caught in the individual depth layers.

Benthic survey

On the ridge sites both north and south of Macquarie Island, stony coral was collected mainly on the top of the ridges, with very little if any in the deeper samples (*i.e.* on the slope or base). While live coral was collected only on the site at the north end of the Gap, this may reflect a sampling artefact, not a lack of live coral at the other sites. The shallowest samples on these ridge sites also had the largest quantities and greatest diversity of gorgonacean-type octocorals. The octocorals decreased markedly both in diversity and abundance further down the slope at all these sites. Both stony coral (live or dead) and octocorals were virtually absent from the sites directly east and west of Macquarie Island. Generally, the ridge sites also had more sponges and a greater variety of crustaceans and echinoderms than the sites east and west of Macquarie Island.

The shallow sites east and west of Macquarie Island had very large quantities of brachiopods, mostly attached to dead bivalve shells. Two species of solitary ascidians were also present in very large numbers and attached to dead bivalve shells. The dead shells were predominantly from a species of *Chlamys* and a small venerid, both of which were also collected live. The quantities of dead shell and

its associated fauna decreased markedly with depth, particularly on the east side. None of these species were collected from the ridge sites. The east side samples also had far more sediment and sediment-related fauna, such as sea pens, than the west side samples, because the west side is much more exposed to heavy weather conditions.

Deeper samples at all sites tended to have more rocks and rubble than the shallowest samples, indicating that the slopes in all the areas have significant amounts of rock scree present. Unstable scree is not a suitable substrate for the development of communities of large fixed invertebrates, and may be one reason why they are not present in the deeper water.

Little can be said about biogeographic affinities until more of the material has been positively identified. However the fauna appears substantially different from that found on the seamounts south of Tasmania.

Survey of the sea birds and mammals

David Eades (Birds Australia) carried out hourly standardised observations of sea birds and mammals at all sites. The relatively shallow waters of the main part of the Macquarie Ridge appear to be an important foraging area for most seabird species with significant breeding populations at Macquarie Island. The same areas may also represent a significant foraging site for some seabird species breeding at the New Zealand sub-Antarctic islands to the north, particularly for Southern Royal Albatrosses from Campbell Island and Shy Albatrosses from the Auckland Islands. Numbers of birds per count were generally highest around Macquarie Island and along the ridge toward the south. Counts decreased north of the island and offshore. A total of 30 species of seabird were recorded on counts made at the nine main sites. Six species breeding locally at Macquarie Island accounted for the bulk of seabird abundance: Antarctic Prion, Rockhopper Penguin, Royal Penguin, Northern Giant-Petrel, Black-browed Albatross and King Penguin. No sea mammals were recorded during the standardised observations. See Appendix B for a full report of the sea bird observations.

CRUISE NARRATIVE

The vessel departed Hobart at 0900 on 10 January and proceeded initially to a sheltered anchorage off Port Arthur to calibrate the towed body, hull and pole-mounted acoustic systems. Several difficulties were encountered, due to brisk winds. To obtain additional stability, the trawl doors were lowered, but these crossed and confounded the calibration, and also tangled upon retrieval. There was also difficulty lowering the pole in the vessel's moonpool.

The vessel departed Port Arthur at about midnight for the passage to Macquarie Island. The trip was uncomfortable but uneventful except for an accident during a test deployment of the towed body, which resulted in Matt Sherlock losing the end of the middle finger on his left hand, when it was crushed between the towed body and cradle. The end of the finger was retrieved, he sewed it back on and he was put on antibiotics. Matt received further medical attention subsequently at Macquarie Island, and the finger seems to be healing well. Within the shelter of Buckles Bay off the northeast corner of Macquarie Island, Dick Williams and Tim Lamb were trans-shipped to the fishing vessel, *Austral Leader*, for the duration of the acoustic survey, and the cruise leader and Rudy Kloser went aboard *Austral Leader* to discuss the acoustic survey with Mr. Halli Stefansson, skipper of the *Austral Leader*. Halli kindly provided *Southern Surveyor* with his vessel's digital bathymetric data for Macquarie Ridge, which was to prove invaluable throughout the cruise.

The acoustic survey of Patagonian toothfish was carried out from 14 through 18 January. The first area surveyed was the Aurora Trough, just west of Macquarie Island, where the fishery has centred since its inception. The first transect was across an area where juvenile toothfish have been found

northwest of the island, followed by a series of six transects laid systematically across the trough to cover all the ground at depths greater than 500 m with transect spacing of 2° longitude (2.15 km). Because of the unevenness of the ground, two passes were generally made with the towed body: first, at a depth of about 200-300 m, and then ~100-150 m above bottom for target strength (TS) measurement. There were few acoustic marks, and most of these were small. *Austral Leader* carried out 15 trawls in the area, covering much of the transects. Typical catches were several hundred kg of toothfish, sometimes up to a ton or so and sometimes less than 100 kg. Intermittent problems with the towed body transducer and the onset of a gale caused *Southern Surveyor* to take shelter behind Macquarie Island late on January 14. Repair of the towed body required retermination of the cable, which requires ~12 hours to perform. In the interim, *Southern Surveyor* carried out three tows on acoustic marks observed on the innermost transect, which were inside State waters and where only *Southern Surveyor* had permission to trawl. The tows yielded relatively few toothfish along with whiptails (the small *Coryphaenoides subserrulatus* and the large *Macrourus carinatus*), carapid eels, and a variety of small 'feed' fishes (*e.g.* myctophids and *Bathylagus*).

After completion of a CTD cast in the trough area, *Southern Surveyor* undertook a series of zig-zag transects on January 17 between 500 and 1000 m depth along the edge of the Ridge, en route to the northern toothfish grounds. Acoustic transects were carried out in the northern complex of fishing grounds: again, few marks were observed, but those observed were passed along and fished by *Austral Leader*. Catches of toothfish remained poor. Conditions were marginal with winds of 30-40 knots throughout the day. The acoustic survey of the northern fishing grounds was completed on January 18. Several further marks were passed on to *Austral Leader*. Although some of the marks were substantial, there was no evidence from either vessel of the major aggregation that was fished several years ago.

After completing this portion of the survey, *Southern Surveyor* proceeded south, carrying out zig-zag acoustic transects along the slope on the eastern side of the ridge. The vessel then continued south of Macquarie Island, surveying the Caroline Trough, south of Aurora Trough, zig-zagging between the 500 m depth contour on the ridges to either side of the trough. The trough extends about 20 NM. Two significant acoustic marks were seen, which were passed on to *Austral Leader*.

The vessel then continued south, surveying a series of banks en route to the first benthic survey site at 56° S. However, the bank indicated on the chart of the New Zealand Oceanographic Institute did not exist, not the first time that this chart proved grossly inaccurate, even in areas where its 'reliability scale' indicated there were adequate soundings. A site somewhat to the south was therefore selected. A CTD cast was made to ~1000 m, which indicated that the surface water was significantly colder (4° C cf 6 °C) and fresher than in Aurora Trough. Temperatures at depths >500 m were between 2° C and 3° C.

Four benthic sled tows were carried out: one on top of the ridge at 500-600 m and three on the slope between 600 m and 1300 m. Only one of the latter tows was successful. The tow on top of the hill yielded a number of gold and black corals and about 20 kg of dead colonial coral, but a different genus and species than that found on the seamounts south of Tasmania; rather it appeared to be the coral found in New Zealand waters. There were considerable quantities of sponge as well and some prawns but no squat lobsters, brisingid seastars, urchins, and virtually no starfish, as found around Tasmania. However there was a *Paralaemonema* and a muraenolepid. The tow on the slope yielded about a tonne of rock and a few sponges and bits of coral. One of the other tows on the slope yielded two rocks only, so it appears that there is in fact little life on the slope (at least the west-facing slope).

Having completed the acoustic survey portion of the cruise, we steamed back to Macquarie Island. A deepwater calibration of the acoustic system was carried out in the early morning of January 20 in the lee of the island. At 0900, the Cruise Leader and Rudy Kloser went ashore to review the project with Simon Goldsworthy, who reported that the fur seals were foraging in the approximate region of the northern toothfish fishing ground, though more in the lee of the ridge. Most crew and scientists also

went ashore for a mid-cruise break for the morning. Halli Stefansson later came aboard *Southern Surveyor* to review the acoustic survey. There was general agreement that there was little sign of any concentration of toothfish and that the data were too inconclusive to establish the appearance of toothfish acoustically.

Southern Surveyor weighed anchor at 1300, and an acoustic experiment was carried out to measure sound absorption in seawater. The deepwater video pressure housings were then successfully pressure tested by lowering and retrieving them from 1500 m. The following morning, the camera system was first used at 100 m depth in the vicinity of Buckles Bay. The camera and lights needed adjustment, and there were electronic problems communicating with the camera. These problems were corrected later that day.

The vessel proceeded to Aurora Trough, where, during January 21 and 22 it carried out oceanographic and benthic sampling of this key site in the toothfish fishery. The water column down to ~1000 m was sampled in four 250 m depth horizons with the MIDOC trawl system. Replicate samples were obtained in daytime but only one sample from the night period, due to the short length of the night, which at this latitude and time of year is only about 6.5 hours from sunset to sunrise; sampling of the water column required 3 hours, exclusive of turnaround time on deck, and it was desirable not to sample within an hour of sunrise and sunset. Zooplankton sampling of the upper 200 m of the water column with the Bongo net and a surface net was aborted due to problems with the block, which, in combination with deteriorating weather conditions (winds of ~30 knots) caused the tow cable to repeatedly jump out of the block. Benthic sampling was carried out at three depth horizons: 200-500 m, 500-700 m and 700-900 m. The shallow dredge sample yielded a large number of bivalve shells, to which were attached numerous brachiopods and ascidians. The mid-depth sample, however, which came from the steep portion of the slope, had to be repeated four times to obtain a reasonable sample, which consisted mostly of cobbles with their attached fauna. There was little in the dredge sample from the base of the trough, consistent with observations from the fishery, from which there has been little benthic invertebrate bycatch.

Southern Surveyor proceeded to the offshore sampling site, 25 NM west of Macquarie Island on January 23. Two day and two night MIDOC sets of samples were obtained, although the second night MIDOC series came up somewhat late (0345) and apparently experienced a twist in the net, causing the samples from the first four nets to be deposited together in the fourth codend. The following day (January 24), a CTD cast was carried out to 1500 m, and six replicate Bongo net samples were obtained, following modification of the block to minimise the risk of the cable jumping the block. Acoustic sampling of the water column was carried out, following the transect used for MIDOC sampling, by lowering the towed body to about 900 m and gradually raising it to measure both nekton abundance with three acoustic frequencies (12, 38 and 120kHz) and their target strength distribution for comparison with the midwater trawl sampling. The vessel then returned to Aurora Trough to obtain Bongo zooplankton samples from that site.

On January 25, the camera system was successfully deployed on the leeward, east side of Macquarie Island, initially at 200-400 m depth, then at 400 m and finally from 400 m to about 1400 m depth. Through this series of deployments, various teething problems were worked out. Because the footage cannot be viewed 'live' and there is little control over the tilt of the system, much of the footage is imperfect. Nonetheless the quality is impressive, much of it of professional 'broadcast' standard, in addition to being of immense value scientifically. While the dredge is able to obtain samples of specimens for study in hand, the video footage, supplemented by a laser-based positioning and measurement system, can provide quantitative data on abundance, community composition, size distribution, and spatial distribution in relation to habitat structure. These deployments showed what was only suggested from the dredge sampling: an exceptionally rugged slope with rubble fields, steep overhangs where suspension feeders (*e.g.* sponges, gorgonians, psolid holothurians, anemones and hydrocorals) were most abundant, and generally a moderate abundance of lithodid crabs (relatives of

the Alaskan king crab and equally tasty), the occasional toothfish, while crustaceans, carapid eels and other fishes were patchily abundant over the bottom. There was relatively little life on the cobble fields, which may be due to instability of this environment. Three samples were obtained the following day with the dredge over this depth horizon at the east Macquarie site, which generally confirmed the picture obtained from the video system.

The vessel then proceeded to the Beer Garden fishing ground. The weather was exceptionally fine initially, so the camera system was deployed first. However a tangle in the towlines during deployment ended with the electrical cable between the depth pinger and camera going under the vessel, being caught in the propeller and severed. Unfortunately, the fine conditions required for deployment of the system were never again obtained while at a suitable site.

Four benthic dredge shots were then carried out. The first covered the top of the eastern ridge that defined the ground, from about 400 to 600 m. The sample contained a number of gorgonian coral species, as well as sponges and other suspension feeders. The second shot, aimed at the steep portion of the slope, failed to obtain a sample, but the succeeding one brought up the codend full of rocks, indicative of the rubble seen on the steep portion of the slope in the video from the east side of Macquarie Island. Mixed in were a number of sponges, occasional corals, some fish and lithodid crabs, all reminiscent of the fauna seen on the video of the slope. The final sled sample from the base of the slope along the flat trawlable floor of the valley yielded very little, consistent with the sampling carried out in Aurora Trough.

On January 27, two day and one night set of depth-stratified samples of the nekton were obtained of the water column with the MIDOC gear. Sea conditions then rose with winds to over 40 knots (Beaufort scale 8/9). The vessel suspended sampling for the night. In the morning, the wind had dropped considerably but sea conditions were still too rough to safely deploy gear, so the vessel proceeded north to a site within the gap between two sections of the ridge, where the sub-Antarctic Front is generally positioned (S. Rintoul, pers. comm.). Two midwater trawls with the MIDOC gear were carried out in the day, followed by a CTD cast and night deployment of the MIDOC. The CTD indicated an intrusion of extremely cold water (~1.5° C) below about 100 m. There was a strong westward set, which caused the gear to veer substantially from its intended course. The daytime midwater trawl samples were highly consistent, with small catches with low diversity near surface (the hyperiid amphipod, *Parathemisto gaudichaudi*, a myctophid, *Krefftichthys anderssoni*, and *Stomias* sp. in the upper 250 m and little more between 250 m and 500 m) but large quantities (10-35 kg) of jellyfish (Coronatae and *Atolla*) and large numbers of a fairly diverse fish fauna in the deeper layers. An acoustic transect was carried out in the night, followed by six Bongo and surface net samples on the morning of January 29, after which an acoustic transect was carried out in daylight conditions.

The vessel then returned to the Beer Garden site, where a night-time acoustic transect was conducted. Benthic sampling with the dredge was carried out at the northern edge of the Macquarie Ridge from about 0100 through most of the morning on January 30. Small samples were obtained from the 'flat' portion on top of the ridge at about 1000 m depth; from the upper portion of the slope at 1000-1200 m and a deeper sample from about 1200-1500 m depth. Two attempts were required to obtain the last sample, with extensive damage to the tow bridle and net on the last tow. The vessel then returned to the Beer Garden to complete the daytime sampling: acoustic sampling of the water column and the replicate Bongo tows. Only five Bongo tows could be completed, before rising sea conditions and the dusk tipped the balance between the potential risk and gain of further sampling.

The vessel proceeded to the extension of Macqarie Ridge north of the gap. The last day of sampling began poorly with steerage being lost at about 0200. This was corrected after 2-3 hours. Three benthic dredge samples were then obtained on the edge of the northern extension of the ridge system. There

were a number of corals in the samples. By the time the benthic sampling had been completed, sea conditions had increased to force 7/8 with winds over 35 knots, and the vessel hove to. Sea surface temperature remained at about 7° C, indicating the vessel had not passed through the sub-Antarctic Front (SAF). A CTD cast (carried out without bottles to minimize the risk of damage) indicated a single layer at about 4° C below the near-surface mixed layer. The vessel then steamed north to locate the SAF, which unfortunately proved somewhat elusive. By 1600, with the day coming to an end and needing to head back to Hobart, a last midwater trawl was carried out with the MIDOC on the western flank of an extension of the Macquarie Ridge, followed by a CTD cast to 1000 m. The vessel then headed for Hobart at 2000, January 31. The vessel arrived alongside CSIRO Marine Labs at 1930, February 3, 1999.

SUMMARY

The achievements of the present cruise need to be assessed with the perspective that this was the first cruise by CSIRO to these waters, that it was the first attempt by any group to survey Patagonian toothfish acoustically, and it was the first trial of the newly-designed and constructed deepwater video system. Sea conditions were often difficult and the benthic ground was generally exceptionally steep and rough. Despite these conditions, virtually all objectives were achieved, at least so far as was possible.

Despite the efforts of the commercial fishing vessel and the CSIRO acoustic survey, no substantial concentrations of Patagonian toothfish were found. Bycatch species were sufficiently abundant to confound any attempt to obtain an acoustic estimation of toothfish biomass, particularly since most bycatch species contained gas-filled swimbladders and therefore presented acoustic targets at least as large or larger than that of the toothfish.

Oceanographic sampling of the water column structure, zooplankton, and nekton abundance, distribution and day-night movements through the water column were carried out over the major toothfish fishing grounds and at control sites offshore to the west and in the vicinity of the Sub-Antarctic Front to the north. An initial assessment of the nekton data suggests that the dominant prey of toothfish and of fur seals and penguins are restricted to the deep and upper waters, respectively, and that there is relatively little food web interaction between them.

The benthic survey indicates considerable heterogeneity in benthic habitat along Macquarie Ridge. Suspension feeders seemed diverse and abundant along the tops of the ridges and on overhangs and ledges. Steep portions of the slope were likely unstable and were relatively depauperate, given the low growth and recruitment rates typical of the mid-slope fauna. The flat ground at the base of troughs and canyons, where most toothfish trawling has been concentrated, contained a typical soft-bottom fauna.

The seabird fauna varied considerably on and off the ridge, being substantially more abundant on the Ridge. Dominant species, such as the black-browed albatross, appeared to be largely restricted to the ridge environment, suggesting that the ridge significantly influences the biological oceanography of the region in ways that are not yet understood.

PERSONNEL

(Note: unless otherwise indicated, all personnel are staff of CSIRO Marine Research.)

LEG 1:

Dr Tony Koslow	(Cruise Leader)
Mr Rudy Kloser	
Mr Mark Lewis	
Ms Karen Gowlett-Holmes	
Mr Matt Sherlock	
Mr Jeff Cordell	
Ms Val Latham	
Mr Miroslaw Ryba	
Mr Tim Ryan	
Mr David Eades	(Birds Australia)
Mr Tim Lamb	(Australian Antarctic Division)
Mr Dick Williams	(Australian Antarctic Division)

SHIP'S COMPANY

Mr. P. Dunbar	Master
Mr. R. Pepper	Chief Mate
Mr. J. Boyes	2nd Mate
Mr. I. Murray	Chief Engineer
Mr. E. Peters	2nd Engineer
Mr. J. Hinchliffe	3rd Engineer
Mr. T. Condon	Chief Cook
Mr. W. Hatton	2nd Cook
Ms. B. Sherriff	Steward
Mr. M. McDougall	Bosun
Mr. G. McDougall	IR
Mr. L. Jacomos	IR
Mr. S. O'Doherty	IR
Mr. G. Murtagh	IR
Mr. A. Hearne	IR
Mr. P. Wallace	Greaser
Mr. N. Irvine	IR

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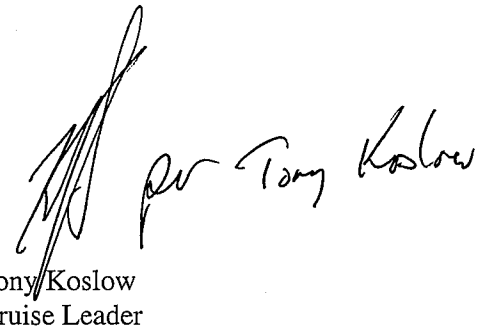

Tony Koslow
Cruise Leader

Nan Bray
Chief, CSIRO Marine Research

Date 26/4/99.

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Figure 1. SS9901. Distribution of 10-minute seabird counts in waters around Macquarie Island.

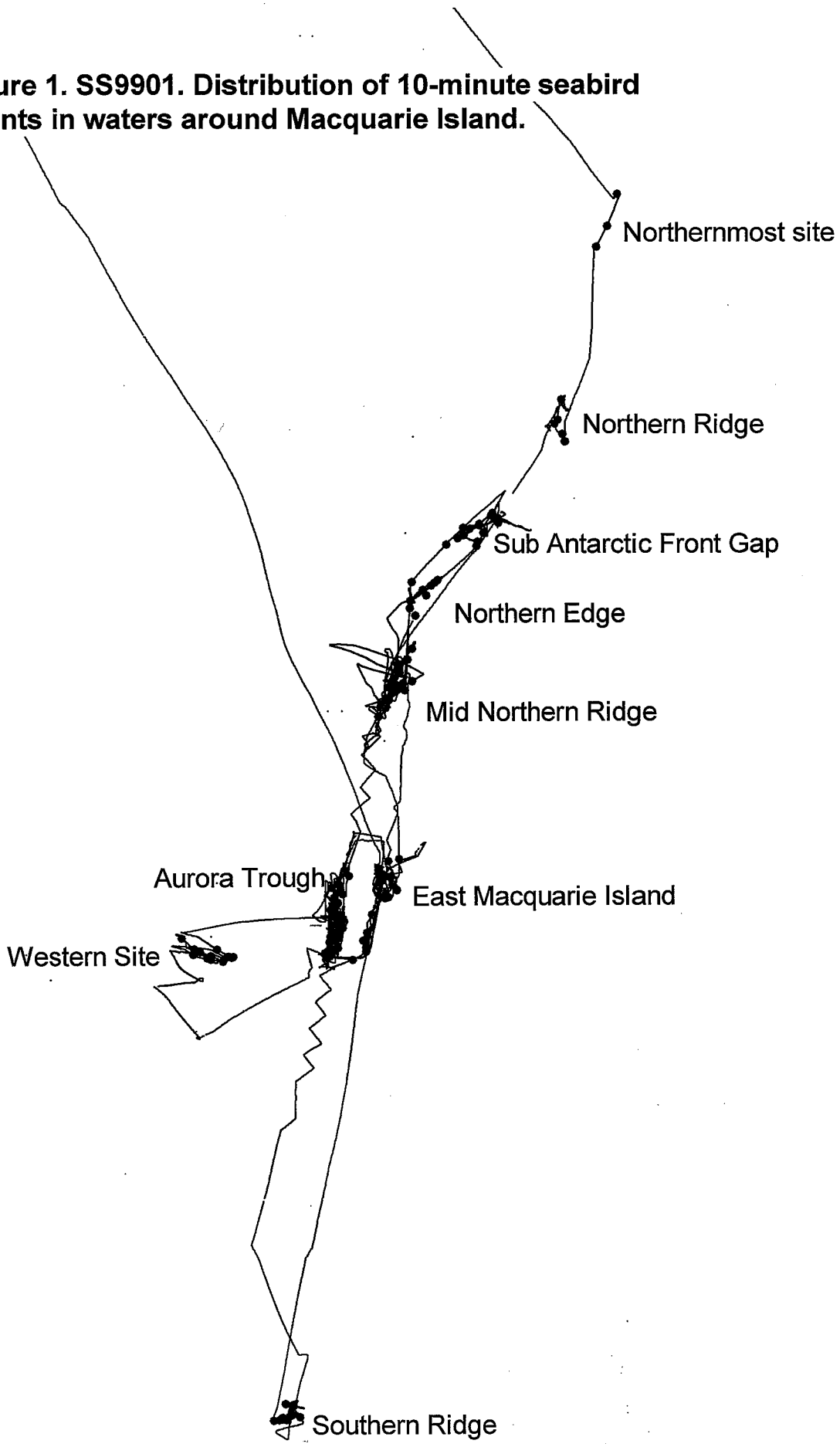


Figure 2. SS9901.Relative abundance of seabirds (number of seabirds per count, all species combined) in waters around Macquarie Island.

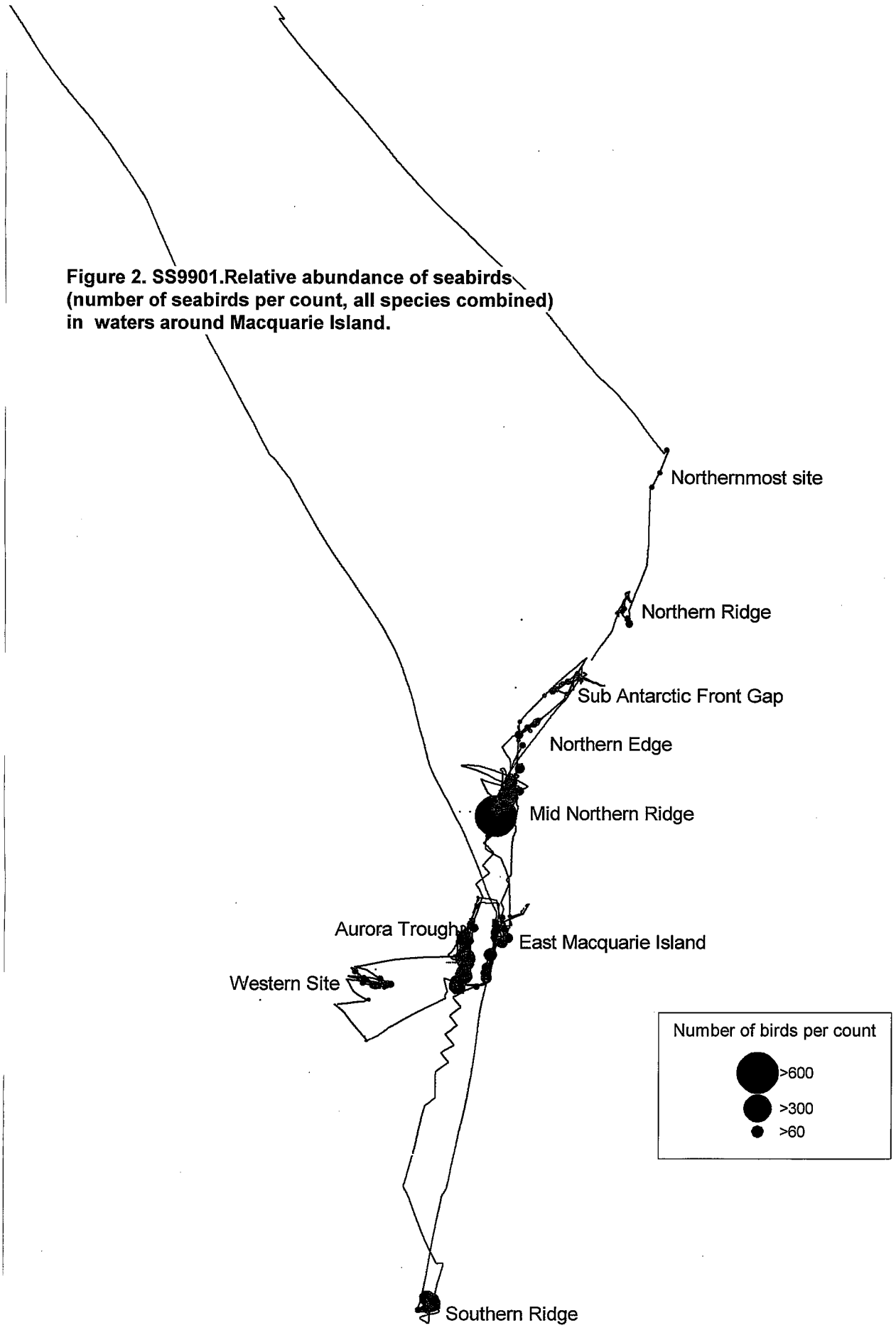
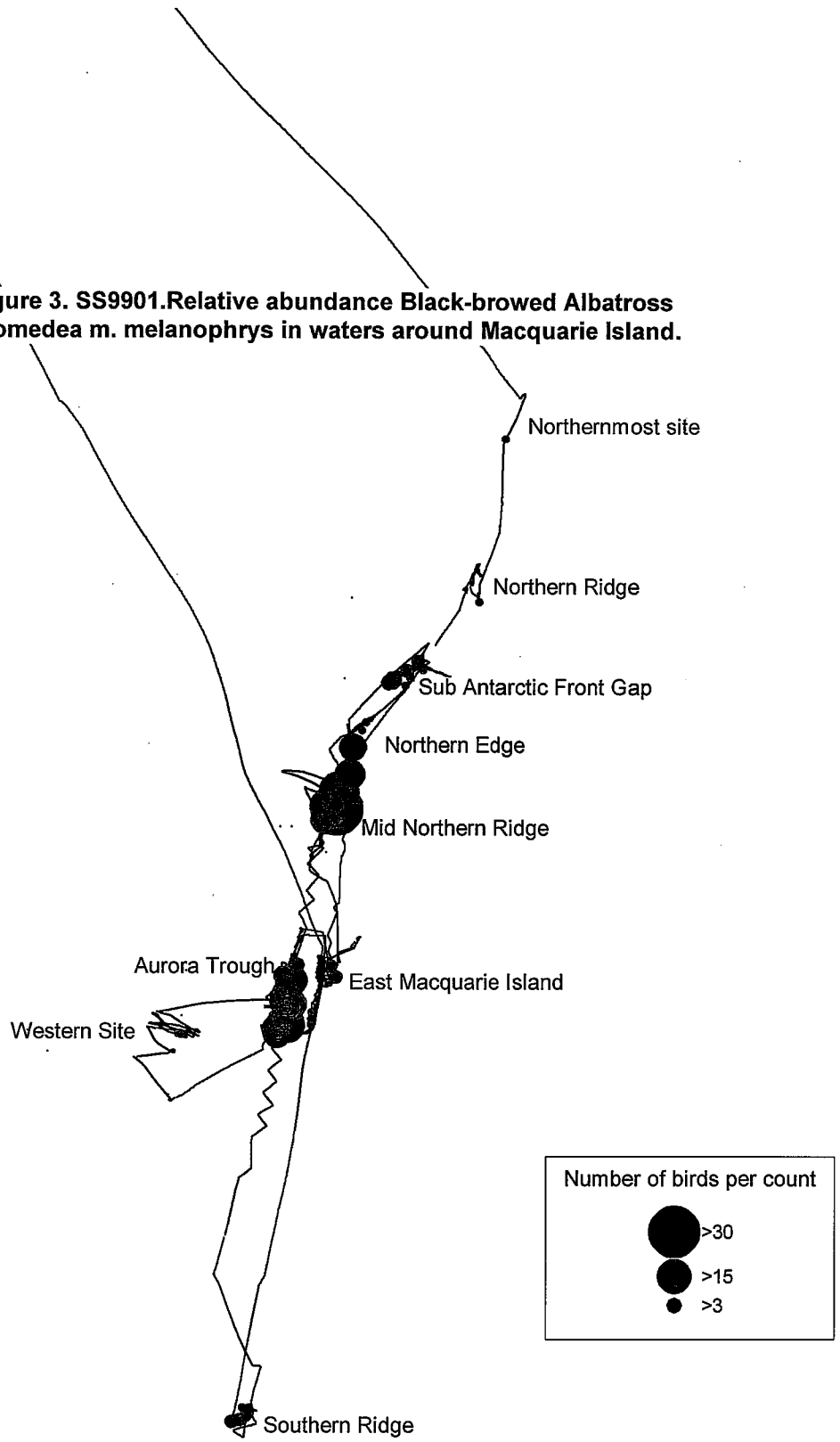


Figure 3. SS9901.Relative abundance Black-browed Albatross Diomedea m. melanophrys in waters around Macquarie Island.



Appendix A.

List of stations showing operation number (no), activity, area, and date, time and position at the start of sampling. The position of fishing grounds are commercial in confidence and are not specified.

NO	ACTIVITY	AREA	START	TIME	LATITUDE	LONGITUDE
1	Acoustic Transect	Juvenile transect	14/01/99	16:55	54° 30.800'	158° 46.499'
2	Acoustic Transect		14/01/99	17:02	54° 31.600'	158° 46.100'
3	Acoustic Transect		14/01/99	17:26	54° 34.000'	158° 44.500'
4	Acoustic Transect	Aurora Trough	14/01/99	17:26	54° 34.000'	158° 44.500'
5	Acoustic Transect	Aurora Trough	14/01/99	18:38	54° 38.200'	158° 42.901'
6	Acoustic Transect	Aurora Trough	14/01/99	19:45	54° 33.800'	158° 44.300'
7	Acoustic Transect	Aurora Trough-2	14/01/99	21:02	54° 40.100'	158° 40.000'
8	Acoustic Transect	Aurora Trough-3	14/01/99	22:32	54° 37.000'	158° 42.100'
9	Acoustic Transect	Aurora 3	15/01/99	00:10	54° 47.000'	158° 42.100'
10	Acoustic Transect	Aurora 2 again	15/01/99	03:24	54° 36.900'	158° 39.800'
11	Acoustic Transect	Aurora 4	15/01/99	06:45	54° 33.000'	158° 43.700'
13	Acoustic Transect	Aurora-4	15/01/99	15:37	54° 35.400'	158° 43.700'
14	Demersal Trawl	Aurora Trough	16/01/99	11:30	54° 43.201'	158° 43.700'
15	Demersal Trawl	Aurora Trough	16/01/99	13:30	54° 40.800'	158° 45.599'
16	Demersal Trawl	Aurora E	16/01/99	21:03	54° 43.000'	158° 44.401'
17	CTD Cast 1		17/01/99	00:30	54° 40.300'	158° 43.300'
18	Acoustic Transect	Aroura Trough	17/01/99	11:53	54° 07.600'	158° 54.100'
19	Acoustic Transect	From Aurora North	17/01/99	08:57	54° 23.600'	158° 51.600'
20	Acoustic Transect	t1 up colgate	17/01/99	13:42		
22	Acoustic Transect	t3 up colgate	17/01/99	03:20		
23	Acoustic Transect	n-s through colgate valley	17/01/99	14:58		
24	Acoustic Transect	heading towards grand canyon	17/01/99	15:56		
25	Acoustic Transect	Transect north up grand canyon	17/01/99	16:47		
26	Acoustic Transect	N-S down grand canyon line	17/01/99	17:18		
27	Acoustic Transect	Grand Canyon-1	17/01/99	19:22		

28	Acoustic Transect	Grand canyon	17/01/99	20:21			
29	Acoustic Transect	Grand canyon-3	17/01/99	20:49			
30	Acoustic Transect	Beer Garden- 1	17/01/99	21:20			
31	Acoustic Transect	Beer Garden-2	17/01/99	23:13			
32	Acoustic Transect	North East tip	18/01/99	03:52	53° 57.600'	159° 03.701'	
33	Acoustic Transect	S Macca	18/01/99	15:37	54° 50.300'	158° 42.800'	
34	Acoustic Transect	S Macca	18/01/99	16:09	54° 52.200'	158° 38.099'	
35	Acoustic Transect	S Macca	18/01/99	16:36	54° 54.700'	158° 41.600'	
36	Acoustic Transect	S Macca	18/01/99	17:15	54° 57.500'	158° 36.800'	
37	Acoustic Transect	S Macca	18/01/99	17:43	55° 00.100'	158° 39.401'	
38	Acoustic Transect	S Macca	18/01/99	18:16	55° 02.500'	158° 34.500'	
39	Acoustic Transect	S Macca	18/01/99	18:47	55° 05.400'	158° 38.200'	
40	Acoustic Transect	Macca S	18/01/99	19:19	55° 07.400'	158° 32.800'	
41	Acoustic Transect	Macca S	18/01/99	19:46	55° 10.100'	158° 35.700'	
42	Acoustic Transect	Macca S	18/01/99	20:20	55° 12.800'	158° 30.000'	
43	Acoustic Transect	Macca S	18/01/99	21:40	55° 22.200'	158° 25.200'	
44	Benthic Dredge	South Macquarie	19/01/99	09:25	56° 15.700'	158° 30.200'	
45	Benthic Dredge	SOUTH MACCA	19/01/99	11:07	56° 19.700'	158° 24.901'	
46	Benthic Dredge	S Macca	19/01/99	12:50	56° 18.700'	158° 28.700'	
47	CTD Cast 2	Southern	19/01/99	14:47	56° 19.000'	158° 24.800'	
48	Benthic Dredge	S Macca	19/01/99	16:26	56° 19.200'	158° 27.200'	
49	Video Transect	DEEP WATER TEST	20/01/99	21:50	54° 29.300'	159° 06.001'	
50	Video Transect	SHALLOW TEST	21/01/99	10:20	54° 31.900'	158° 57.700'	
51	Midoc Sampling	W Macca	21/01/99	17:24	54° 49.400'	158° 39.800'	
52	Midoc Sampling	West Macca	21/01/99	22:01	54° 50.500'	158° 40.099'	
53	Plankton Sample	Aurora Trough	22/01/99	03:33	54° 50.300'	158° 41.701'	
54	Midoc Sampling	Aurora Trough	22/01/99	04:15	54° 49.900'	158° 40.700'	
55	Midoc Sampling	Aurora Trough	22/01/99	06:41	54° 49.900'	158° 40.500'	
56	Bongo Net	Aurora Trough	22/01/99	11:19	54° 47.800'	158° 40.799'	
57	Bongo Net	Aurora Trough	22/01/99	11:09	54° 48.000'	158° 40.600'	
59	Bongo Net	Aurora Trough	22/01/99	12:09	54° 47.700'	158° 39.200'	
60	Benthic Dredge	W Macquarie	22/01/99	14:50	54° 42.700'	158° 46.100'	
61	Benthic Dredge	W Macquarie	22/01/99	16:13	54° 42.100'	158° 46.100'	
62	Benthic Dredge	W Macquarie	22/01/99	18:24	54° 41.900'	158° 45.900'	

63	Benthic Dredge	W Macquarie	22/01/99	19:55	54°	40.800'	158°	38.999'
64	Benthic Dredge	W Macquarie	22/01/99	21:38	54°	42.700'	158°	45.599'
65	Benthic Dredge	W Macquarie	22/01/99	23:46	54°	42.700'	158°	45.200'
66	Midoc Sampling	Deep Station	23/01/99	05:25	54°	43.500'	157°	52.900'
67	CTD Cast 3	deep station	23/01/99	07:56	54°	47.500'	158°	06.099'
68	Midoc Sampling	Macquarie offshore	23/01/99	12:44	54°	43.900'	157°	50.401'
69	Bongo Net	West Macca #1	23/01/99	17:01	54°	47.800'	157°	55.799'
70	Midoc Sampling	Offshore Macquarie	23/01/99	20:51	54°	48.900'	158°	08.099'
71	Midoc Sampling	Deep station west Macca	24/01/99	00:42	54°	47.300'	157°	48.799'
72	CTD Cast 4		24/01/99	04:45	54°	53.000'	157°	56.900'
73	CTD Cast 5		24/01/99	04:00	54°	52.400'	157°	58.300'
74	Bongo Net	Deep station west Macca	24/01/99	05:14	54°	53.200'	157°	55.600'
75	Bongo Net	West Macca	24/01/99	06:44	54°	53.500'	157°	50.500'
76	Bongo Net	West Macca	24/01/99	06:08	54°	53.400'	157°	52.500'
77	Bongo Net	West Macca	24/01/99	06:33	54°	53.500'	157°	51.099'
78	Bongo Net	West Macca	24/01/99	06:56	54°	53.600'	157°	50.000'
80	Bongo Net	Aurora Trough	24/01/99	15:42	54°	49.900'	158°	35.000'
81	Bongo Net	Aurora Trough	24/01/99	16:06	54°	49.500'	158°	34.901'
82	Bongo Net	Aurora Trough	24/01/99	16:30	54°	49.000'	158°	34.700'
83	Bongo Net	Aurora Trough	24/01/99	16:53	54°	48.400'	158°	34.400'
84	Bongo Net	Aurora Trough	24/01/99	17:14	54°	47.800'	158°	34.201'
85	Video Transect	East of Macquarie Island	25/01/99	00:10	54°	34.800'	158°	56.600'
86	Video Transect	East Macca	25/01/99	03:17	54°	34.700'	158°	56.299'
87	Video Transect	Buckles Bay, Macca	25/01/99	14:04	54°	31.400'	158°	58.200'
89	Benthic Dredge	East Macquarie	26/01/99	03:56	54°	31.300'	158°	58.599'
90	Benthic Dredge	East Macca	26/01/99	05:01	54°	31.600'	158°	59.300'
92	CTD Cast 8	Buckles Bay	26/01/99	06:55	54°	35.800'	158°	59.500'
93	Benthic Dredge	East Macca	26/01/99	08:57	54°	35.701'	158°	56.600'
94	Benthic Dredge	Beer Garden	26/01/99	17:19				
95	Benthic Dredge	Beer Garden	26/01/99	18:45				
96	Benthic Dredge	Beer Garden	26/01/99	20:58				
97	Benthic Dredge	Beer Garden	26/01/99	21:37				
98	Midoc Sampling	Beer Garden	27/01/99	00:25				
99	CTD Cast 9	Beer Garden	27/01/99	03:53				

100	Midoc Sampling	Beer Garden	27/01/99	05:26			
101	Midoc Sampling	Beer Garden	27/01/99	10:20			
102	Midoc Sampling	Beer Garden	27/01/99	14:05			
103	Midoc Sampling	SAF	28/01/99	13:17	53° 16.799'	159° 40.300'	
104	Midoc Sampling	SAF	28/01/99	21:56	53° 23.600'	159° 34.100'	
105	CTD Cast 10	SAF	28/01/99	20:34	53° 23.300'	159° 33.500'	
106	Midoc Sampling	Sub-Antarctic Front	28/01/99	22:02	53° 23.100'	159° 34.500'	
107	Acoustic Transect	Sub Antarctic Front	29/01/99	01:20	53° 24.400'	159° 47.700'	
108	CTD Cast 11	Sub Ant Front	29/01/99	05:00	53° 19.300'	159° 38.300'	
109	Acoustic Transect	Sub Antarctic Front	29/01/99	07:00	53° 23.400'	159° 38.000'	
110	Bongo Net Cast	Sub Antarctiic Front	29/01/99	09:00	53° 23.200'	159° 33.500'	
111	Bongo Net Cast	Sub Antarctic Front	29/01/99	10:24	53° 27.600'	159° 30.599'	
112	Bongo Net Cast	Sub Antarctic Front	29/01/99	10:51	53° 27.100'	159° 31.000'	
113	Bongo Net Cast	Sub Antarctic Front	29/01/99	11:16	53° 26.800'	159° 31.600'	
114	Bongo Net Cast	Sub Antarctic Front	29/01/99	11:39	53° 26.600'	159° 30.400'	
115	Bongo Net Cast	Sub Antarctic Front	29/01/99	12:02	53° 26.400'	159° 29.100'	
116	Bongo Net Cast	Sub Antarctic Front	29/01/99	12:26	53° 26.300'	159° 28.400'	
117	Acoustic Transect	Sub-Antarctic Front	29/01/99	14:05	53° 24.000'	159° 27.901'	
118	Acoustic Transect	Beer Garden Night run	29/01/99	21:51			
119	Benthic Dredge	North Macca Ridge	30/01/99	02:10	53° 38.100'	159° 09.599'	
120	Benthic Dredge	North Macca ridge	30/01/99	03:42	53° 38.000'	159° 09.500'	
121	Benthic Dredge	North Macca Ridge	30/01/99	05:32	53° 37.700'	159° 09.800'	
122	Benthic Dredge	North end of Gap	30/01/99	05:47	53° 37.100'	159° 11.600'	
122	Benthic Dredge	South End of Gap	30/01/99	09:16	53° 37.200'	159° 11.299'	
123	Acoustic Transect	Beer Gardn	30/01/99	13:28			
123	Acoustic Transect	Beer Gardn Day	30/01/99	13:34			
124	Bongo Net Cast	beer garden 1 through 6	30/01/99	17:23			
125	Bongo Net Cast	Beer Garden #2	30/01/99	18:36			
126	Bongo Net Cast	Beergarden #3	30/01/99	19:04			
127	Bongo Net Cast	Beergarden #4	30/01/99	19:28			
128	Bongo Net Cast	Beergarden #5	30/01/99	19:54			
129	Benthic Dredge	North end of Gap	31/01/99	05:59	52° 59.600'	159° 59.800'	
130	Benthic Dredge	North end of Gap	31/01/99	07:07	52° 59.400'	159° 59.000'	
131	Benthic Dredge	North end of Gap	31/01/99	08:23	53° 00.200'	159° 58.300'	

132 CTD Cast 12		31/01/99 10:46 53° 06.700' 160° 00.200'
133 Midoc Sampling	N Site: 52 30	31/01/99 16:02 52° 28.400' 160° 11.299'
134 CTD Cast 13	CTD North Site	31/01/99 19:20 52° 18.300' 160° 18.000'

Appendix B. Observations of seabirds in Macquarie Island waters

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1. Introduction

Although the biology of the seabird species breeding on Macquarie Island is fairly well-known from land-based studies, comparatively little is known about their distribution at sea in surrounding waters, nor of the non-breeding species that also frequent these waters (Scott 1994). The present survey is a first attempt at determining the distribution and relative abundance of all seabird species occurring in Macquarie Island waters, especially in relation to the main bathymetric and oceanographic features of the study area, namely the Macquarie Ridge and Subantarctic Front, respectively. To this end, observations of seabirds were made by the author from aboard the CSIRO Research Vessel *Southern Surveyor* while it conducted acoustic, trawling and benthic surveys in the waters immediately round Macquarie Island and northwards along the Macquarie Ridge during 14-31 January 1999.

2. Study area

The nine main sites within the study area and the distribution of seabird counts at each site are shown in Fig. 1. Most observations were made over the relatively shallow waters of the main part of the Macquarie Ridge ie. close inshore off the east and west coasts of the island and northward along the ridge to the southern edge of the Subantartic Front Gap (sites 2-5). Additional observations were made in shallow waters well south of the island at the southernmost part of the ridge (site 7), and at two other ridge sites north of the Subantarctic Front Gap (sites 8 and 9). Observations were also carried out at two deep-water (pelagic) sites: at site 6 in waters c.25 miles west of Aurora Trough, and at the Subantarctic Front Gap (site 1) immediately north of the main north-south ridge through the island.

3. Count methods

Depending on the ship's activities and operations, two standard count methods (BIOMASS Working Party on Bird Ecology 1984) were variously employed to census seabird numbers. While in transit between sites (at ship-speeds of ≥6 knots), one 10-minute 90° forward quadrant 300-m wide Transect count was conducted every thirty minutes to determine relative abundance (no. birds/count) and density (no. birds/km^2). When ship-speeds were ≤ 5 knots eg. when on station or while conducting trawling and acoustic surveys, one 10-minute 360° Station count was made of all seabirds visible round the ship to determine relative abundance. No counts were made when visibility was <300m. All observations were conducted from the bridge deck; for both count methods a pair of 10x42 magnification binoculars were used to detect birds.

4. Results

Counts: For the 9 main sites in study area a total of 67 Transect and 74 Station counts were made, giving a grand total of 131 counts. Count effort by site is summarised in Table 1.

Table 1

Summary by site of count effort, no. of birds and mean abundance of seabirds (all species combined).

SITE	NO. COUNTS	NO. BIRDS	MEAN NO. BIRDS/COUNT
1	16	173	10.8
2	9	148	16.4
3	21	1563	74.4
4	14	455	32.5
5	39	1712	43.9
6	11	189	17.2
7	13	518	39.8
8	5	82	16.4
9	3	42	14.0

4.1 Analysis of count data

Data from both count-types were combined to give a rough index of relative abundance (mean no. birds/count) for each of the nine sites in the study area; a more rigorous analysis of the count data will appear elsewhere (Eades and Koslow in prep.). The mean abundance for all species, subspecies and birds identified only to species-group level is given for each site in Tables 3-11, which also summarise the main environmental parameters (depth, sea surface temperature and salinity) that broadly characterise the habitat (ridge or pelagic) of each site. From these data the following main trends and broad conclusions can be drawn.

4.2 Patterns of distribution and relative abundance

The mean number of birds/count for all species combined is summarised for each site in Table 1, and their relative abundance shown in Fig. 2. For all sites combined, the mean no. of birds/count by species is given in Table 2. Total abundance (all species combined) was highest over the relatively shallow waters of the main part of the ridge (sites 3-5, 32.5—74.4/count), similar at the southernmost ridge (site 7, 39.8/count), but was markedly lower at the northern end of the ridge (site 2, 16.4/count). Total abundance decreased markedly at the two ridge sites north of the main ridge (sites 8 and 9, 14.0-16.4/count), reflecting a general trend of decreasing abundance with increasing distance from the island northwards along the ridge and into deeper waters. Compared to the relatively high abundance of seabirds over the main part of the ridge, total abundance of seabirds at the two pelagic sites (1 and 6, 10.8-17.2/count) was markedly lower and comparable to that at the northernmost two ridge sites (sites 8 and 9).

A total of 30 species of seabird were recorded on counts made at the nine main sites (Table 2; total excludes those birds not identified to species, and subspecies are lumped). Taking all sites together, six species breeding locally at Macquarie Island accounted for the bulk of seabird abundance (2.7-12.0 birds/count) - Antarctic Prion, Rockhopper Penguin, Royal Penguin, Northern Giant-Petrel,

Black-browed Albatross (nominate *melanophrys*) and King Penguin. Mean abundance for all other species was <2.0 birds/count. Broad patterns of distribution for the six most abundant species across all sites are briefly described below.

Antarctic Prion
Antarctic Prions occurred at all sites but were most abundant over the northern part of the main ridge (8.1-51.5/count) and at the southernmost ridge site (27.8/count). Abundance was lower in eastern and western ridge waters (6.9/count) and lowest at the two northernmost ridge sites and the two pelagic sites (1.4-3.9/count), suggesting that prions were foraging mainly over ridge waters close to the island.

Penguins
Rockhopper Penguins were recorded at all main and southernmost ridge sites but were not seen at the two northernmost sites farthest from the island. Abundance of Rockhoppers was low at most ridge and one pelagic site (0.1-0.3/count) and was highest at Aurora Trough (site 5), closest to the breeding colonies. Royal Penguins were recorded at all sites except the northernmost two ridge sites. Abundance was highest (9.6/count) in eastern waters just offshore from breeding colonies but was also relatively high in western waters over the ridge at Aurora Trough (3.4/count) and farther offshore in pelagic waters at the Western site (2.6/count); numbers were lower at the northern and southern parts of the main ridge and over deep waters at the Subantarctic Front Gap (0.1-1.2/count). King Penguins were recorded only in eastern waters in close proximity to their breeding colonies (1.4/count).

Northern Giant-Petrel
Northern Giant-Petrels were recorded at all sites but abundance was greatest (10.3/count) over the ridge at Aurora Trough and in eastern waters (4.9/count). Numbers were lower elsewhere along the main and southern ridge sites (0.1-3.8/count) and at the two pelagic sites (0.3-2.6/count).

Black-browed Albatross (nominate *melanophrys*)
The distribution and relative abundance of Black-browed Albatrosses is shown in Fig. 3. Black-brows were concentrated over ridge waters, with highest abundances recorded over the Mid Northern Ridge (8.9/count) and in Aurora Trough (4.9/count). Abundance at other ridge sites was markedly lower (0.3-1.5/count), similar to rates recorded for the two pelagic sites (0.2-1.4/count). There were fourteen sightings of breeding adult birds colour-marked by researchers on Macquarie Island. Except for two sightings at the pelagic site west of Aurora trough, all others were concentrated over ridge waters at Aurora Trough and over the northern part of the main ridge, suggesting that breeding birds are mainly foraging over relatively shallow waters close to their breeding colonies at the northern and southern tips of the island.

Other species
The following main points of interest were noted:

Grey-headed and Wandering Albatrosses tended to be most abundant in pelagic waters and least abundant over the shallow waters of the ridge, a pattern reflecting their preference for foraging over deep waters at greater distances from the island than does the Black-browed Albatross, a ridge specialist.

Significant numbers of Southern Royal and Shy Albatrosses and Sooty Shearwaters were noted over the ridge areas, suggesting that the Macquarie Ridge may be a regular foraging area for these New Zealand subantarctic breeding species.

Small numbers of Mottled Petrels were regularly sighted moving through the more open and pelagic waters of the study area, suggesting that this species regularly passes through Macquarie I. waters while in transit to and from it's southern New Zealand breeding areas and it's favoured foraging grounds in antarctic waters to the south and south-west of Macquarie Island.

Two sightings of vagrant birds were made while in the study area. An adult Chinstrap Penguin was noted swimming with Royal Penguins at the Southern Ridge in an area where sea surface temperatures and salinities were markedly lower than those over the main ridge area immediately round the island. An Antarctic Petrel was also reported from Aurora Trough by Dick Williams. Both sightings of these antarctic-breeding species are far north of their normal distribution during summer.

5. Conclusions

The relatively shallow waters of the main part of the Macquarie Ridge appear to be an important foraging area for most seabird species with significant breeding populations at Macquarie Island. The same areas may also represent a significant foraging site for some seabird species breeding at the New Zealand subantarctic islands to the north, particularly for Southern Royal Albatrosses from Campbell Island and Shy Albatrosses from the Auckland Islands.

6. References

BIOMASS Working Party on Bird Ecology. 1984. Recording observations of birds at sea (rev. edn). BIOMASS Handbook 18.

Scott, J. 1994. Marine Conservation at Macquarie Island. Tas. Parks & Wildlife 141 pp.

Table 2

List of seabird species and their relative abundance (mean no./count) for all sites (1-9) combined.

SPECIES CODE	SPECIES NAME	NO. BIRDS	MEAN NO. BIRDS/COUNT
42	Antarctic Prion	1971	12.0
60	Rockhopper Penguin	206	6.1
61	Macaroni/Royal Penguin	341	5.8
6	giant-petrel sp.	259	5.5
5	Northern Giant-Petrel	645	4.0
91	Crested Penguin sp.	109	3.9
84	Black-browed Albatross (melanophrys)	434	3.6
56	King Penguin	19	2.7
37	penguin sp.	14	2.0
29	petrel sp.	14	1.8
4	Southern Giant-Petrel	131	1.6
44	Sooty Shearwater	92	1.5
9	Black-browed Albatross	41	1.5
43	Short-tailed Shearwater	3	1.5
46	Southern Royal Albatross	132	1.3
12	Shy Albatross (cauta/steadi)	77	1.3
72	Kelp Gull	12	1.3
101	Short-tailed/Sooty Shearwater	5	1.3
25	Mottled Petrel	46	1.2
20	White-headed Petrel	63	1.1
13	Light-mantled Sooty Albatross	59	1.1
34	Great Skua	20	1.1
85	Black-browed Albatross (impavida)	17	1.1
21	Black-bellied Storm-Petrel	16	1.1
7	Wandering Albatross	73	1.0
8	Grey-headed Albatross	37	1.0
17	White-chinned Petrel	10	1.0
71	'great' albatross sp.	5	1.0
23	Wilson's Storm-Petrel	4	1.0
15	Cape Petrel (australe)	3	1.0
45	diving-petrel sp.	3	1.0
68	Common Diving-Petrel	3	1.0
83	'mollymawk' sp.	3	1.0
48	Grey-backed Storm-Petrel	3	1.0
10	Buller's Albatross	2	1.0
14	albatross sp.	2	1.0
24	storm-petrel sp.	1	1.0
75	Antarctic Tern	1	1.0
70	Blue-eyed Cormorant	1	1.0
62	Northern Royal Albatross	1	1.0
52	Soft-plumaged Petrel	1	1.0
49	Salvin's Albatross	1	1.0
47	Chinstrap Penguin	1	1.0
28	Grey Petrel	1	1.0

Table 3

Site 1: Subantarctic Front Gap	
Habitat	Pelagic
Number of Station Counts	11
Number Transect Counts	5
Depth Range	146-1586
Sea Surface Temp Range	7.2-7.8
Salinity Range	33.76-33.86

SITE CODE	SPECIES	SPECIES NAME	NO. BIRDS	MEAN NO. COUNT
1	42	Antarctic Prion	34	2.1
1	7	Wandering Albatross	27	1.7
1	84	Black-browed Albatross (melanophrys)	22	1.4
1	20	White-headed Petrel	18	1.1
1	25	Mottled Petrel	12	0.8
1	12	Shy Albatross (cauta/steadi)	9	0.6
1	44	Sooty Shearwater	8	0.5
1	8	Grey-headed Albatross	7	0.4
1	46	Southern Royal Albatross	6	0.4
1	5	Northern Giant-Petrel	4	0.3
1	13	Light-mantled Sooty Albatross	4	0.3
1	61	Macaroni/Royal Penguin	3	0.2
1	85	Black-browed Albatross (impavida)	3	0.2
1	4	Southern Giant-Petrel	2	0.1
1	6	giant-petrel sp.	2	0.1
1	29	petrel sp.	2	0.1
1	9	Black-browed Albatross	2	0.1
1	10	Buller's Albatross	1	0.1
1	48	Grey-backed Storm-Petrel	1	0.1
1	71	'great' albatross sp.	1	0.1
1	68	Common Diving-Petrel	1	0.1
1	45	diving-petrel sp.	1	0.1
1	34	Great Skua	1	0.1
1	17	White-chinned Petrel	1	0.1
1	28	Grey Petrel	1	0.1

Table 4

Site 2: Northern Edge	
Habitat	Ridge
Number of Station Counts	4
Number Transect Counts	5
Depth Range	988-2141
Sea Surface Temp Range	7.4-7.7
Salinity Range	33.80-33.84

SITE CODE	SPECIES	SPECIES NAME	NO. BIRDS	MEAN NO. COUNT
2	42	Antarctic Prion	73	8.1
2	12	Shy Albatross (cauta/steadi)	15	1.7
2	84	Black-browed Albatross (melanophrys)	13	1.4
2	7	Wandering Albatross	11	1.2
2	20	White-headed Petrel	6	0.7
2	44	Sooty Shearwater	5	0.6
2	25	Mottled Petrel	4	0.4
2	46	Southern Royal Albatross	4	0.4
2	13	Light-mantled Sooty Albatross	3	0.3
2	17	White-chinned Petrel	3	0.3
2	60	Rockhopper Penguin	2	0.2
2	5	Northern Giant-Petrel	1	0.1
2	8	Grey-headed Albatross	1	0.1
2	9	Black-browed Albatross	1	0.1
2	91	Crested Penguin sp.	1	0.1
2	61	Macaroni/Royal Penguin	1	0.1
2	48	Grey-backed Storm-Petrel	1	0.1
2	21	Black-bellied Storm-Petrel	1	0.1
2	14	albatross sp.	1	0.1
2	10	Buller's Albatross	1	0.1

Table 5

Site 3: Mid Northern Ridge	
Habitat	Ridge
Number of Station Counts	17
Number Transect Counts	4
Depth Range	392-1528
Sea Surface Temp Range	7.2-8.0
Salinity Range	33.84-34.04

SITE CODE	SPECIES	SPECIES NAME	NO. BIRDS	MEAN NO. COUNT
3	42	Antarctic Prion	1082	51.5
3	84	Black-browed Albatross (melanophrys)	175	8.3
3	5	Northern Giant-Petrel	80	3.8
3	46	Southern Royal Albatross	34	1.6
3	61	Macaroni/Royal Penguin	25	1.2
3	8	Grey-headed Albatross	23	1.1
3	44	Sooty Shearwater	22	1.0
3	12	Shy Albatross (cauta/steadi)	19	0.9
3	6	giant-petrel sp.	15	0.7
3	4	Southern Giant-Petrel	14	0.7
3	7	Wandering Albatross	14	0.7
3	13	Light-mantled Sooty Albatross	12	0.6
3	20	White-headed Petrel	10	0.5
3	9	Black-browed Albatross	6	0.3
3	21	Black-bellied Storm-Petrel	6	0.3
3	85	Black-browed Albatross (impavida)	6	0.3
3	34	Great Skua	4	0.2
3	25	Mottled Petrel	3	0.1
3	17	White-chinned Petrel	2	0.1
3	60	Rockhopper Penguin	2	0.1
3	43	Short-tailed Shearwater	2	0.1
3	37	penguin sp.	2	0.1
3	68	Common Diving-Petrel	1	0.0
3	71	'great' albatross sp.	1	0.0
3	72	Kelp Gull	1	0.0
3	75	Identified but not listed	1	0.0
3	83	'mollymawk' sp.	1	0.0

Table 6

Site 4: East Macquarie I.	
Habitat	Ridge
Number of Station Counts	3
Number Transect Counts	11
Depth Range	103-2197
Sea Surface Temp Range	6.8-7.8
Salinity Range	33.86-34.01

SITE CODE	SPECIES	SPECIES NAME	NO. BIRDS	MEAN NO. COUNT
4	61	Macaroni/Royal Penguin	135	9.6
4	42	Antarctic Prion	97	6.9
4	5	Northern Giant-Petrel	69	4.9
4	6	giant-petrel sp.	37	2.6
4	4	Southern Giant-Petrel	21	1.5
4	56	King Penguin	19	1.4
4	13	Light-mantled Sooty Albatross	13	0.9
4	44	Sooty Shearwater	13	0.9
4	84	Black-browed Albatross (melanophrys)	10	0.7
4	91	Crested Penguin sp.	9	0.6
4	37	penguin sp.	8	0.6
4	9	Black-browed Albatross	5	0.4
4	46	Southern Royal Albatross	5	0.4
4	60	Rockhopper Penguin	4	0.3
4	20	White-headed Petrel	3	0.2
4	34	Great Skua	3	0.2
4	8	Grey-headed Albatross	1	0.1
4	17	White-chinned Petrel	1	0.1
4	72	Kelp Gull	1	0.1
4	25	Mottled Petrel	1	0.1

Table 7

Site 5: Aurora Trough	
Habitat	Ridge
Number of Station Counts	15
Number Transect Counts	24
Depth Range	131-989
Sea Surface Temp Range	7.0-7.6
Salinity Range	33.83-34.09

SITE CODE	SPECIES	SPECIES NAME	NO. BIRDS	MEAN NO. COUNT
5	5	Northern Giant-Petrel	402	10.3
5	42	Antarctic Prion	269	6.9
5	60	Rockhopper Penguin	195	5.0
5	84	Black-browed Albatross (melanophrys)	191	4.9
5	6	giant-petrel sp.	184	4.7
5	61	Macaroni/Royal Penguin	132	3.4
5	91	Crested Penguin sp.	96	2.5
5	4	Southern Giant-Petrel	76	1.9
5	46	Southern Royal Albatross	40	1.0
5	9	Black-browed Albatross	24	0.6
5	44	Sooty Shearwater	23	0.6
5	13	Light-mantled Sooty Albatross	16	0.4
5	7	Wandering Albatross	10	0.3
5	72	Kelp Gull	10	0.3
5	34	Great Skua	9	0.2
5	12	Shy Albatross (cauta/steadi)	6	0.2
5	29	petrel sp.	6	0.2
5	23	Wilson's Storm-Petrel	4	0.1
5	15	Cape Petrel (australe)	3	0.1
5	20	White-headed Petrel	3	0.1
5	37	penguin sp.	3	0.1
5	8	Grey-headed Albatross	2	0.1
5	71	'great' albatross sp.	2	0.1
5	25	Mottled Petrel	1	0.0
5	85	Black-browed Albatross (impavida)	1	0.0
5	101	Short-tailed/Sooty Shearwater	1	0.0
5	49	Salvin's Albatross	1	0.0
5	62	Northern Royal Albatross	1	0.0
5	70	Blue-eyed Cormorant	1	0.0

Table 8

Site 6: Western site	
Habitat	Pelagic
Number of Station Counts	8
Number Transect Counts	3
Depth Range	462-4220
Sea Surface Temp Range	6.3-6.7
Salinity Range	33.78-33.86

SITE CODE	SPECIES	SPECIES NAME	NO. BIRDS	MEAN NO. COUNT
6	42	Antarctic Prion	43	3.9
6	5	Northern Giant-Petrel	41	3.7
6	61	Macaroni/Royal Penguin	29	2.6
6	25	Mottled Petrel	17	1.5
6	44	Sooty Shearwater	14	1.3
6	6	giant-petrel sp.	12	1.1
6	4	Southern Giant-Petrel	7	0.6
6	7	Wandering Albatross	6	0.5
6	20	White-headed Petrel	3	0.3
6	17	White-chinned Petrel	2	0.2
6	84	Black-browed Albatross (melanophrys)	2	0.2
6	91	Crested Penguin sp.	2	0.2
6	8	Grey-headed Albatross	1	0.1
6	12	Shy Albatross (cauta/steadi)	1	0.1
6	13	Light-mantled Sooty Albatross	1	0.1
6	101	Short-tailed/Sooty Shearwater	1	0.1
6	83	'mollymawk' sp.	1	0.1
6	71	'great' albatross sp.	1	0.1
6	60	Rockhopper Penguin	1	0.1
6	52	Soft-plumaged Petrel	1	0.1
6	45	diving-petrel sp.	1	0.1
6	34	Great Skua	1	0.1
6	21	Black-bellied Storm-Petrel	1	0.1

Table 9

Site 7: Southern Ridge	
Habitat	Ridge
Number of Station Counts	9
Number Transect Counts	4
Depth Range	518-1911
Sea Surface Temp Range	5.3-5.9
Salinity Range	33.70-33.96

SITE CODE	SPECIES	SPECIES NAME	NO. BIRDS	MEAN NO. COUNT
7	42	Antarctic Prion	361	27.8
7	5	Northern Giant-Petrel	35	2.7
7	46	Southern Royal Albatross	30	2.3
7	84	Black-browed Albatross (melanophrys)	19	1.5
7	61	Macaroni/Royal Penguin	16	1.2
7	4	Southern Giant-Petrel	10	0.8
7	6	giant-petrel sp.	6	0.5
7	25	Mottled Petrel	6	0.5
7	12	Shy Albatross (cauta/steadi)	5	0.4
7	13	Light-mantled Sooty Albatross	5	0.4
7	85	Black-browed Albatross (impavida)	5	0.4
7	44	Sooty Shearwater	3	0.2
7	9	Black-browed Albatross	2	0.2
7	60	Rockhopper Penguin	2	0.2
7	34	Great Skua	2	0.2
7	101	Short-tailed/Sooty Shearwater	2	0.2
7	29	petrel sp.	2	0.2
7	21	Black-bellied Storm-Petrel	1	0.1
7	91	Crested Penguin sp.	1	0.1
7	68	Common Diving-Petrel	1	0.1
7	47	Chinstrap Penguin	1	0.1
7	43	Short-tailed Shearwater	1	0.1
7	37	penguin sp.	1	0.1
7	24	storm-petrel sp.	1	0.1

Table 10

Site 8: Northern Ridge	
Habitat	Ridge
Number of Station Counts	4
Number Transect Counts	1
Depth Range	362-1724
Sea Surface Temp Range	7.4-7.5
Salinity Range	33.91-33.95

SITE CODE	SPECIES	SPECIES NAME	NO. BIRDS	MEAN NO. COUNT
8	12	Shy Albatross (cauta/steadi)	17	3.4
8	20	White-headed Petrel	15	3.0
8	5	Northern Giant-Petrel	10	2.0
8	42	Antarctic Prion	7	1.4
8	46	Southern Royal Albatross	7	1.4
8	21	Black-bellied Storm-Petrel	4	0.8
8	44	Sooty Shearwater	4	0.8
8	6	giant-petrel sp.	3	0.6
8	7	Wandering Albatross	3	0.6
8	13	Light-mantled Sooty Albatross	2	0.4
8	85	Black-browed Albatross (impavida)	2	0.4
8	29	petrel sp.	2	0.4
8	4	Southern Giant-Petrel	1	0.2
8	48	Grey-backed Storm-Petrel	1	0.2
8	101	Short-tailed/Sooty Shearwater	1	0.2
8	84	Black-browed Albatross (melanophrys)	1	0.2
8	9	Black-browed Albatross	1	0.2
8	14	albatross sp.	1	0.2

Table 11

Site 9: Northernmost site	
Habitat	Ridge
Number of Station Counts	3
Number Transect Counts	0
Depth Range	1714-1722
Sea Surface Temp Range	8.2
Salinity Range	34.02-34.03

SITE CODE	SPECIES	SPECIES NAME	NO. BIRDS	MEAN NO. COUNT
9	46	Southern Royal Albatross	6	2.0
9	12	Shy Albatross (cauta/steadi)	5	1.7
9	42	Antarctic Prion	5	1.7
9	20	White-headed Petrel	5	1.7
9	5	Northern Giant-Petrel	3	1.0
9	13	Light-mantled Sooty Albatross	3	1.0
9	21	Black-bellied Storm-Petrel	3	1.0
9	7	Wandering Albatross	2	0.7
9	8	Grey-headed Albatross	2	0.7
9	25	Mottled Petrel	2	0.7
9	29	petrel sp.	2	0.7
9	17	White-chinned Petrel	1	0.3
9	45	diving-petrel sp.	1	0.3
9	83	'mollymawk' sp.	1	0.3
9	84	Black-browed Albatross (melanophrys)	1	0.3