

4. Discussion

4.1 Present status of the NORFANZ collection

Generally good progress has been made towards upgrading the taxonomy of the NORFANZ faunal collection in the two years since the survey was completed. The initial reports from the taxonomic team provide overviews for higher level taxa, and insights into the importance of these collections; details are given in Section 3.1 and Appendices 1-6 for fishes, and several major invertebrate groups including Porifera (sponges); Cnidaria including the Scyphozoa (jellyfishes) and Octocorallia (octocorals); the Polychaeta (bristle worms); Mollusca including the Opisthobranchia (nudibranchs), Cephalopoda (squids and octopods) and micro-molluscs; Ophiuroidea (brittlestars), and Holothuroidea (sea cucumbers); Crustacea including Cirripedia (barnacles), Amphipoda (amphipods), Euphausiacea (krill), Stomatopoda (mantis shrimps), Polychelidae (blind, deep-sea lobsters), Galatheididae (squatlobsters), and Glyphocrangonidae (deepwater shrimps) and other Decapoda, principally dendrobranchiate prawns and brachyuran crabs; and Pycnogonida (sea spiders). Published taxonomic results for several specific taxa are already in the scientific literature (Appendix 11).

The degree of progress varies greatly across the many components of the fauna, and mostly reflects the complexity of the groups involved, the volume of material to be examined, and the availability of the relevant experts. There was also a large difference in the starting point for upgrades between fishes and invertebrates because confidence in the 'at-sea' taxonomic determinations was generally higher for fishes. This was for

five key reasons: (1) the fish fauna is generally better known than the invertebrate fauna; (2) a higher diversity and number of invertebrate taxa was collected; (3) sorting invertebrates took longer; (4) the microscopic examination necessary to determine OTU identifications for many invertebrate taxa was not possible at sea; and (5) there were no experts on the seagoing team for some invertebrate groups. For these reasons, upgrading the invertebrate collection has required considerably more effort and involved more experts than upgrading the fishes, and a variety of invertebrate groups, including some at high taxonomic levels, remain known only from shipboard identifications.

Upgraded taxa have upgraded codes in a national database – Codes for Australia’s Aquatic Biota (CAAB) – while non-upgraded OTUs retain the temporary codes assigned at sea. These 8-digit codes, which identify Phylum (2 digits), Family (3 digits) and species (3 digits), form part of the taxonomic checklists provided here in Appendices 1-6. They also form the first component of the filename for each of the images in the photographic inventories (Appendices 7 and 8).

At present, we recognize the survey collection is comprised of:

- 1,618 macro-invertebrate OTUs of which 860 (53%) have identifications upgraded to species level by a taxonomic expert; 225 OTUs are with the respective experts, but have not yet been examined, and 533 OTUs remain in checklists as non-upgraded shipboard identifications that are not expected to be upgraded in the foreseeable future (see Table 3.3.1.3). We estimate the majority of OTUs without upgrades are represented by single species, but recognize several that are likely to include multiple taxa, for example the hydroids. Among

the upgraded taxa, a total of 103 have already been confirmed as new species, and in addition 35 species were identified as new records for Australian waters (Appendices 3 and 14).

- 588 fish species-level OTUs from 122 families (see Table 3.3.2.1). Of these, 375 (64%) are recognized as benthic, while 207 (36%) are reported in the literature as epi, meso- or bathypelagic. Of the 347 OTUs held at CSIRO, 29 were identified as new species, one as a new Australian record, and two as rare species (Appendix 6).
- a large but unknown number of micro-invertebrates (animals only a few millimetres in size that require sorting under a microscope). One group, the micro-molluscs, is characterized by extraordinary diversity; sorting of only part of the collection revealed 1,200 species-level OTUs, of which possibly 600 are new species.

Where follow-up taxonomic work has occurred, exciting aspects of biodiversity and ecology are being revealed, and this is well illustrated by the work of Davie, Dall and Bruce (page 42). They illustrated the habitat relationships between small crustaceans and glass sponges. The first is a fascinating obligate relationship between a pair of male and female shrimps of the potentially new species *Spongicaris* sp. 1 [CAAB 28724802] which are imprisoned in a glass sponge *Hexactinellida* sp. 51 [CAAB 10300885] after settling as larvae inside the cavity of the glass sponge and then becoming too large to escape through the small holes in the sponge matrix. The other examples are the first habitat records for the crab *Miersiograpsus australiensis* and a shrimp *Hamiger novaezealandiae*. Both were found living inside the folds of a new species of large glass sponge *Lophocalyx* sp. (K. Tabachnik pers. comm. to A.J. Bruce)(= *Hexactinellida* sp.

47). This is the first record of *Hamiger novaezealandiae* (Borradaile) since it was described from the type specimen in 1910, and the first ever record of its host (Bruce 2005). Shrimps in this family (Palaemonidae: Pontoniinae) are common commensals on a wide variety of shallow water invertebrate hosts, but this is the first to be definitely found associated with deepwater hexactinellid sponges. It was also particularly exciting to discover the home of the crab, *Miersiograpsus australiensis*, because crabs of this family are normally free-living. These large sponges are like apartment blocks for large numbers of this seldom before found crab. More generally for the sponges, Schlacher-Hoenlinger (page 9) records that there are highly localized species distributions, high levels of 'spot endemism', elevated numbers of 'living fossils' (Lithistids), and representation of highly specialized carnivorous forms.

Thus, taxonomic work completed, and that which remains 'in-progress', demonstrates a wealth of new and exciting information. The large numbers of species taxa collected indicates that species richness is generally high in the survey area. The value of the collection to understanding Australia's deep sea biodiversity is demonstrated by the already confirmed numbers of new species and new records of known species recorded from Australian waters: at least 11% of the 860 upgraded macro-invertebrate taxa (103 new, 13 new records) and nearly 9% of 347 fishes in the CSIRO sub-collection (29 new species, 1 new record).

4.2 Biodiversity patterns

Patterns in biodiversity distribution may be described in terms of the numbers or richness of taxa present (ideally at species level), the numbers of species that are

unique or rare, i.e. endemic at a particular spatial scale, and in terms of the affinities of particular (informative) faunal elements with adjacent regions. Here we have completed an analysis to examine the correlation of faunal distributions with measured biological and physical parameters (predominantly depth, latitude and longitude) using multiple species-level taxa (OTUs). Estimates of local diversity and apparent endemism are made, but these are preliminary because sampling density was generally low at each location. Detailing the affinity of the fauna remains largely work-in-progress, although some preliminary findings are discussed for echinoderms (ophiuroids) and selected fishes with respect to faunal differences between the two submarine ridges, the Lord Howe Rise and Norfolk Ridge.

4.2.1 Invertebrate fauna

Analysis of a reduced data set (comprised of records for 1,562 OTUs after minor gear types and unrepresentative samples were eliminated) showed that a large proportion of animals occurred infrequently: two-thirds of all OTUs were recorded from only one sample, and another one-sixth from only two samples (Fig. 3.3.1.3). Only one-sixth were found in three or more samples – although some species were caught many times with the broadest distribution being present in 38 samples.

These patterns indicate the fauna is comprised mostly of species with locally restricted ranges – ‘spot’ or ‘apparent’ endemics – suggesting that the region is characterised by a generally high level of endemism. However, similar patterns can arise where undersampling underestimates species’ distributional ranges due to sample gears working ineffectively or too few samples being taken. This may contribute to the patterns seen here because many sites were extremely difficult to sample, being characterised by

hard, rugged and complex terrains with bedrock outcrops and steep slopes (see Appendix 9), and it is possible that even large samples from such terrains did not properly represent the fauna present. However, the interpretation of limited distributional ranges for most species is supported by:

- this pattern being repeated in each gear type considered separately;
- systematically targeting a set of depth strata at each site (vs. a more randomised sampling design) to reduce variability; and
- eliminating unrepresentative (small) catches from the analysis.

To confirm that these patterns represent a high level of endemism requires firstly, that taxa are identified as *species*, and secondly, they are compared to documented distributions. It is important to note that, while the taxonomic resolution of many groups in faunal collections from other surveys in the Coral and Tasman Seas region is of *species-level taxa*, identification are of coded 'operational taxonomic units' or OTUs – as is the case in the NORFANZ collection. This enables estimation of 'species richness' – the numbers of species-level taxa present – but does not permit comparison of species lists between surveys (e.g. Williams et al., 2006) because there is no consistency in the nomenclature of the coded OTUs. For example, sponge #1 in survey #1 is not likely to be coded as sponge #1 in survey #2, unless the same taxonomic expert(s) are aboard the survey, and rigorous comparisons are made in real time. For many, if not most groups, microscopic examinations are necessary and these need to be performed in the laboratory. Consequently, in the absence of a large laboratory-based comparative study, distributions of invertebrate species remain largely unknown. Thus, it is necessary to reconcile the coded identifications between surveys to enable our observation of

apparent high local endemism to be confirmed as high levels of true endemism at local and regional scales.

It is surprising that from the relatively numerous surveys of deep Tasman and Coral Seas (relative to other deep ocean areas), comprehensive species identifications are known for only one macro-invertebrate group: the ophiuroids (identified by T. O'Hara of Museum Victoria). Preliminary analysis of 113 species from the regional data set (Williams et al. 2006, Appendix 5) also showed that a high percentage of species occurred in only one or few samples in the NORFANZ study area and that apparent endemism is high. However, the analysis also indicated that while many species may have restricted distributions, there are too few data to confirm the level of true endemism at the level of sub-areas (ridges or individual seamounts).

We found that sampling gears were highly selective for the invertebrate fauna, but analyses of multispecies distributions for each gear separately consistently showed spatial patterns influenced by sampling depth and latitude, and to a lesser extent by longitude. This indicated that the fauna as a whole varied more with depth, and from north to south, than between the two submarine ridges – the Lord Howe Rise and Norfolk Ridge.

In the NORFANZ study area, the depth gradient showed the highest correlation (33%) to the reduced data set of 1556 OTUs. In particular, the species composition at depths shallower than 500 m was different from that at greater depth. Depth is recognised as a primary environmental correlate with changes in fauna in continental shelf and slope depths for invertebrates (Bax et al. 2000) and may be mediated through a variety of

mechanisms such as temperature, currents, food availability or pressure. For example, the influence of pressure on calcium carbonate availability may partly structure the underlying pattern in the NORFANZ sponge collection, with demosponges dominant in depths to 500 to 700 m, and hexactinellids (glass sponges) dominant at deeper depths. Depths around 600 to 1000 m mark the saturation point of aragonite (Ca^{2+}) that, together with carbonate (CO_3^{2-}), represents the dissociated form of calcium carbonate (CaCO_3) (Li et al 1969; B Tilbrook, pers. comm.). The aragonite saturation depth is known to form a natural boundary between species with a greater reliance on aragonite and calcium carbonate in their skeletons (e.g. demosponges) and those adapted to living at greater depths with skeletons composed of other building materials, such as silica (e.g. glass sponges).

The latitude gradient showed a correlation of 25% to the reduced data set of 1556 OTUs. One explanation for this is the influence of major water masses which have a complex, but predominantly north-south structure across the NORFANZ study area. A major feature is the Tasman Front which separates the NORFANZ study area into the warmer Coral Sea to the north and the cooler Tasman Sea to the south and marks the path of the separated components of the East Australian Current (EAC) (Condie *et al.* 2003). At depths (> 600 m), Antarctic Intermediate Water (AAIW) is represented by different 'arms' in the Tasman and Coral Seas that oppose each other along the path of the Tasman Front. This effectively separates the NORFANZ region into north (northern Norfolk Ridge and Lord Howe Rise sites) and south (west and south Norfolk Ridge sites), with some sites (Lord Howe Plateau and the Wanganella bank immediately in the path of the Tasman Front. Each of these waters masses, and a series of semi-permanent eddies associated with the Tasman Front (see overview in Williams et al.

2006), has the capacity to influence contemporary species distributions through their effects on the supply of planktonic larvae. Results from analysis of catches made by the primary invertebrate sampling tool (the Sherman sled) shows a N-S division that correlates to the oceanographic pattern. In fact this was the strongest pattern in the between ridge comparison, especially when depth effects were removed.

The effect of longitude on the invertebrate fauna as a whole (the reduced data set of 1556 OTUs) – which effectively measures variation due to differences between the Lord Howe and Norfolk Rise – was relatively minor (16% correlation) alongside depth and latitude.

Comparing species diversity between ridges, regions, or sites using quantitative biodiversity indices such as species accumulation curves cannot be done reliably for a number of reasons. Data suited to these metrics was difficult to acquire due to the colonial or modular nature of many invertebrate groups meaning there was incomplete abundance and biomass data for analyses such as rarefaction curves. Sampling density at each site was relatively low, and not all gears were used in each area meaning that analyses such as 'collector's curves' that rely on multiple samples from any one ridge/area/site were not possible. And finally, because two-thirds of species were collected in only one sample it is unlikely that a rarefaction or collectors curve would reach an asymptote, i.e. comparisons could be made for the relative dominance (slope of the curve near the origin), but not species richness (the asymptote).

4.2.2 Fishes

A detailed analysis of fishes is being undertaken by Clive Roberts (TePapa) and Malcolm Clark (NIWA). Their preliminary findings, which relied on ship-board identifications and combined the fish catch data from all gears, were presented in a report to MFish (Roberts and Clark 2006). Among the key findings were:

- About 20% of the fish species sampled are either new records for the region, or new to science.
- There are a large number of reliable identifications of fishes that are informative and support common patterns of distribution. These comprise both valid species and species of uncertain scientific name that have been consistently identified during the voyage under an OTU.
- Four main types of distribution patterns can be recognised within the survey area: (1) Widespread; (2) Southern; (3) Norfolk Ridge; and (4) Restricted.
- Relatively few species are widespread in distribution; most are deepwater fishes of southern origin that occur in both New Zealand and Australian slope waters, but appear to be absent from the New Caledonian EEZ; only two species are northern in origin, being known from New Caledonian waters.
- Southern distributions are abundantly represented among the fish fauna and comprise deepwater fishes (from within the two strata 500-1000 and 1000-1500 m depths; a few extending deeper, but none shallower) that also occur widely outside the NORFANZ survey area.
- Many fishes are documented here at their northern limits of distribution for the first time. This northern limit is demarcated by a band at about latitude 30-32° S,

- which correlates approximately with the position of the tropical convergence, a recognised biogeographical barrier that forms strongly during summer months.
- Orange roughy is at its northern limit of distribution in the southern NORFANZ area.
 - Norfolk Ridge distributions comprise northern and southern ridge (= West Norfolk Ridge and Reinga Ridge) species. Some are known outside the survey area, but several are not (e.g. skate *Dipturus* NFZ1, catshark *Apristurus* sp. E, boarfishes *Antigonia* spp. A and B, and rattail *Caelorinchus* NFZ3), indicating a possible area of endemism along the Norfolk Ridge. Further evaluation of taxonomic status and distribution is needed for these species.
 - Restricted distributions (only known from one or two sites) are shown by over 30 fish species. About half of these species are not known outside the survey area (e.g. rattails *Caelorinchus* sp. 1; redfishes or golden snappers *Centroberyx* spp. A, B, and C; perchlets *Plectranthias* spp. B and C) and these may be defining areas of endemism. As above, further evaluation is needed.
 - Based on taxonomic and distribution data for fishes, potential areas of endemism in the northern Tasman Sea include: (1) the seamount north of Middlesex Bank; (2) Lord Howe Island shelf and slope; (3) Norfolk Island shelf; (4) Norfolk Ridge, Wanganella Bank, and Reinga Ridge.
 - Distribution patterns within the survey area, and affinities of species with fish faunas outside the area, indicate faunal relationships that differ substantially between locations in the northern Tasman Sea.
 - The strongest faunal relationships based on affinities of fish species are: (1) Three Kings shelf, Reinga Ridge, West Norfolk Ridge and Lord Howe Plateau, with the northern New Zealand region; (2) Norfolk Ridge with northern New

- Zealand region; (3) northern Norfolk Ridge with New Caledonia and Coral Sea; (4) Lord Howe Island shelf with Australian shelf; and (5) seamount north of Middlesex Bank with Queensland shelf and Lord Howe Seamount chain.
- Several cumulative fish species curves show no indication of an asymptote. For example, when raw data are plotted for the whole survey by depth strata 1-3, or when randomised and plotted with EstimateS (Colwell 2000). Therefore the species diversity shown by the fish samples are not an accurate measure of actual diversity. Because the fish fauna on these seamount and slope habitats is richer than these samples indicate, more intensive sampling is required at these 14 sites to better quantify the true level of biodiversity present.
 - In terms of similarity between areas (measured as % species shared), the most similar areas were West Norfolk Ridge and Lord Howe Plateau (30.0% shared), and West Norfolk Ridge and Southern Norfolk Ridge (23.5% shared).
 - Least similar areas were: Lord Howe Island and all other areas (4.5-10.0%), and Northern Norfolk Ridge and all other areas (10.0-13.0%).
 - In general, all areas were surprisingly dissimilar (70.0-95.5% not shared). Of note are some adjacent areas that had very few species in common, e.g. Southern Norfolk Ridge and Northern Norfolk Ridge (only 13.0% shared), and Lord Howe Island and Lord Howe Plateau (only 8.0% shared).
 - Taken in combination, levels of percentage similarity/dissimilarity between sites, differences in species distributions, numbers of potential areas of endemism identified, and affinities with faunas outside the survey area, are strong evidence for the northern Tasman Sea being a very biologically heterogeneous and complex area.

- In particular, the oceanic bathymetric features of the Norfolk Ridge and Lord Howe Rise areas support marine faunas that are sufficiently divergent that differences in faunal composition and diversity are evident between even adjacent or contiguous sites (e.g. Lord Howe Island cf. Lord Howe Plateau, and southern Norfolk Ridge cf. northern Norfolk Ridge, respectively).
- Such faunal differences have high conservation value and require management strategies that address these differences.
- Despite the success of the NORFANZ voyage, sampling intensity was inadequate in most areas to accurately document the very high levels of diversity and enable detailed analyses of faunal composition in these deepwater habitats.

For our report, a more compartmentalized analysis of fish data was based on partially upgraded identifications, excluded pelagic species and, as in the invertebrate data analyses, excluded stations where very few species were sampled. In addition, data from only two gears were analysed, and these were done separately.

As for invertebrates, there was a high proportion of species that were recorded from only one station (49% in the ORH trawl, 39% in the Ratcatcher trawl). The distribution patterns were very strongly influenced by sampling depth (67% correlation – OHR trawl) – consistent with observations elsewhere in Australian waters where depth is the strongest gradient for changes in deep fish communities, e.g. Williams et al. (2001); Last et al. (2005).

Lower correlations were observed between patterns of fish distribution and latitude and longitude than with depth – being generally similar to patterns observed in invertebrates.

With latitude (21% correlation), a depth averaged comparison between ridges was significant for each of the north-south comparisons (ANOSIM $R > 0.5$, (sig. 5%). With longitude (12% correlation) there was only a barely significant east-west difference in the northern part of the survey area – that between the North Norfolk Ridge and Lord Howe Rise (ANOSIM $R = 0.75$, sig. 11%).

Data for fishes was more useful for comparing species diversity/richness between sampling sites because their abundance (numbers and biomass) could be recorded consistently. None of the rarefaction curves for groups of sites, plotted using numbers of individuals, reached an asymptote. The Lord Howe sites (LHR and LHP) have steeper curves than the Norfolk Ridge sites (NNR, SNR and WNR) indicating a higher level of dominance by few common species at the Lord Howe sites, however this may be an artefact of fewer samples taken at Lord Howe sites. The OHR and Ratcatcher trawl showed similar trends to each other despite their strong sampling selectivities, indicating this was a consistent pattern across different elements of the fish fauna.

4.3 Communication/ public interest

A NORFANZ website was set up to communicate ‘real-time’ (daily) results from the voyage via a daily diary from key seagoing staff and a “Creature Feature” section, which showcased particularly interesting fishes and invertebrates as they were collected. Its aim was (and remains) to communicate the uniqueness and scientific importance of little-explored seamount communities to the general public, and to promote their conservation and sustainable management. Its success can be judged by visitation statistics, which peaked in July 2003 with 759,025 visits. The “Creature Feature” page

was the most popular element of the site. Organisations and individuals from the Netherlands, Washington DC, South Africa, France, Virginia USA, Ohio USA, Idaho USA, California USA, Hungary, Israel and Australia are known to have included students and teachers, marine scientists, mainstream and specialist science journalists, and educational publishers.

In addition a series of posters have been used to show and provide information on a range of the most unusual species, and distributed (free of charge) at a range of promotional activities ranging from school festivals to major national marine science conferences. The posters have been made widely available in Australia through distribution at conferences and other meetings.

A targeted media campaign made use of milestones and interesting finds throughout the voyage and highlighted these through media releases to mainstream media on both sides of the Tasman. All media releases contained multiple references to the website and each media release corresponded with a surge in enquiries regarding the voyage. The NORFANZ story received extensive coverage in various forms and was carried by national radio, press and television media in Australia. In addition to the mainstream media campaign, Australia's National Oceans Office received many enquiries through the website from international media interested in carrying the story. A list of major mainstream media outlets that have used or are using NORFANZ material is provided in Appendix 12.

4.4 Applying the results from the NORFANZ project

Initial results from the project have been applied to assessing conservation values within a unique marine area of the Australian Commonwealth Marine Jurisdiction – the Norfolk Seamounts region (DEH 2004). This was done in the context of developing Australia’s National Representative System of Marine Protected Areas (NRSMPA). As such, the project’s data set contributed to an outcome that found the Norfolk Seamounts region possesses biodiversity values worthy of protection, and would contribute to the representativeness and comprehensiveness of the NRSMPA (Williams et al. 2006). In broader terms, the area could form a prospectively valuable component of a Tasman Sea deep sea biodiversity conservation initiative that would include areas in another nation’s EEZ and/or the high seas (Williams et al. 2006). These initial results can help identify suitable subregions for either purpose.

4.5 The NORFANZ project and lessons for future biodiversity surveys

NORFANZ was a large and complex project in terms of logistics, administration, and communication. It is characterised by many strengths that provide directions for future surveys and projects with broadly similar goals. However, it also indicates ways in which future survey aims could be enhanced or improved – a summary of these aspects is outlined here:

Strengths included:

- a very high level of collaboration and cooperation between administrative staff and scientists in the New Zealand and Australian funding and science agencies and museums in the planning stages
- a modern, multidisciplinary research vessel (RV Tangaroa) with accommodation for a large science team
- a large international team of scientists involved, including key staff with extensive seagoing experience
- a multidisciplinary survey design using cutting edge technology, most prominently multibeam sonar ('swath') mapping to optimize the sampling effort (through pre-stratification of sampling sites and minimising failed catches
- a suite of physical samplers (3 net types, 3 sled types) matched to the terrains and depths to be sampled
- post-survey work was coordinated so that the field data were upgraded, managed, collated, documented and distributed to all project participants; key elements of this are that supporting data (station data, swath maps, seabed imagery) are in this final report together with metadata records, and all taxonomic upgrades are in a centralized database
- an effective communications strategy resulted in a sustained level of international scientific and public interest

Scope for enhancement would be provided by:

- broader consultation for specialist input on the sampling design

- realistic post-survey project resources provided to ensure the taxonomy, project coordination and reporting returns maximum value for the investment made in the survey
- post survey work detailed in contractual arrangements
- needs for standardised data reporting clearly articulated and agreed before survey
- a plan and framework for publishing science results, e.g. dedicated journal volume, formally agreed to at an early stage of project development

A formal set of suggestions for future biodiversity surveys, based in part on our experience with NORFANZ, was provided by CMAR for discussion at the Census of Marine Life – AMSA workshop on this subject held in July 2005. This is appended here in Appendix 13.

In conclusion, the NORFANZ project aimed to provide a major increase in scientific knowledge of marine biodiversity in the region of the Norfolk Ridge and Lord Howe Rise. It has delivered on this in the form of an extensive collection of benthic fishes and macro-invertebrate animals, a high quality data set, and initial results that will help develop Australia's National Representative System of Marine Protected Areas and contribute to broader biodiversity conservation initiatives in Tasman Sea region.

5. Acknowledgements

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