SEAMOUNT INVERTEBRATES: COMPOSITION AND VULNERABILITY TO FISHING

Karen Stocks
University of California San Diego, SDSC, MC 0505, 9500 Gilman Drive, La Jolla, CA 92093-0505 USA
kstocks@sdsc.edu

ABSTRACT

To describe the invertebrate communities found on seamounts and their vulnerability to fishing, a global review of seamount data was conducted. Using data from SeamountsOnline (http://seamounts.sdsc.edu), data from 1771 kinds of organisms on 171 seamounts were evaluated, representing the largest global synthesis of seamount data to date. The data clearly indicate that seamount communities differ from those found in other deep-sea habitats. Filter-feeding corals, anemones, sponges, and feather stars are common on hard-bottomed seamounts, compared to the deposit-feeding species found most often in the muddy deep sea. The total abundance of life is generally high, leading to descriptions of seamounts as 'underwater oases'. On almost every seamount that has been studied, new species have been found, leading to the conclusion that many species may be endemic to just one or a few seamounts. Extremely long-lived and slow-growing species have also been discovered on seamounts, representing some of the oldest animals known on earth. These same qualities also make seamount communities extremely vulnerable to fishing pressure. The tree-like and flower-like forms of the filter-feeders on seamounts are highly vulnerable to damage by bottom trawls, and the one existing study comparing fished and unfished seamounts indicates that trawling in that area reduced the overall biomass by a factor of seven and the species diversity by a factor of two. Endemic species, thought to be common on seamounts, are at greater risk for extinction. Also, impacts of trawling on very long-lived seamounts species may persist for centuries. Because of the fragility of these systems, and their potential importance to scientific research into ocean biodiversity, to future pharmaceutical discoveries, and to ocean communities as a whole, damage from trawling warrants serious attention.

INTRODUCTION

Seamounts are undersea peaks on the ocean's floor – submerged mountains that do not break the water's surface. As shown by Kitchingman and Lai (this vol.), they are common features on the floor of all oceans. Increasingly, seamounts have become targets for commercial fishing, raising concerns over the impacts that this activity may be having on seamount ecosystems. Here, we review what is known about the non-fish components of seamount communities, and discuss their vulnerability to fishing impacts.

HOW MUCH IS KNOWN ABOUT SEAMOUNT INVERTEBRATES?

For this review, we bring together data from 171 seamounts to undertake the largest global synthesis of seamount invertebrate ecology to date. While many seamount studies have been conducted, most focus on a restricted seamount or small seamount group. Not since a paper by Wilson and Kaufmann (1987) has a global review of the data been conducted. In the 1987 review, data was reported on 596 species from 59 seamounts. In the intervening time, many new seamounts have been sampled and new discoveries, such as the observation of centuries-old deep-coral beds, have been made.

Here, data on 1971 invertebrate taxa from 171 seamounts are reviewed, giving a much expanded perspective of these unique habitats (Figure 1). The data are drawn from SeamountsOnline (see details in Stocks, this vol.), a publicly-accessible resource of seamounts information. The data compilation is a recent project and the combined results are published here for the first time.

It is true that, like all deep-sea habitats, seamounts remain understudied: perhaps only 3-4% have been sampled for invertebrates. And what sampling has been done is not necessarily representative: seamounts that are nearer to the water's surface and/or closer to land tend to be sampled more than others. Some, seamounts, such those under the Arctic ice cap, are virtually unknown. This review will not be limited to seamounts following the strict definition of being at least 1000 m in height – this is an arbitrary geological definition, and features less than 1000m can have similar biological properties as taller ones (Probert et al., 1997; Koslow et al., 2001). Therefore, data from hills less than 1000m tall are also included here.

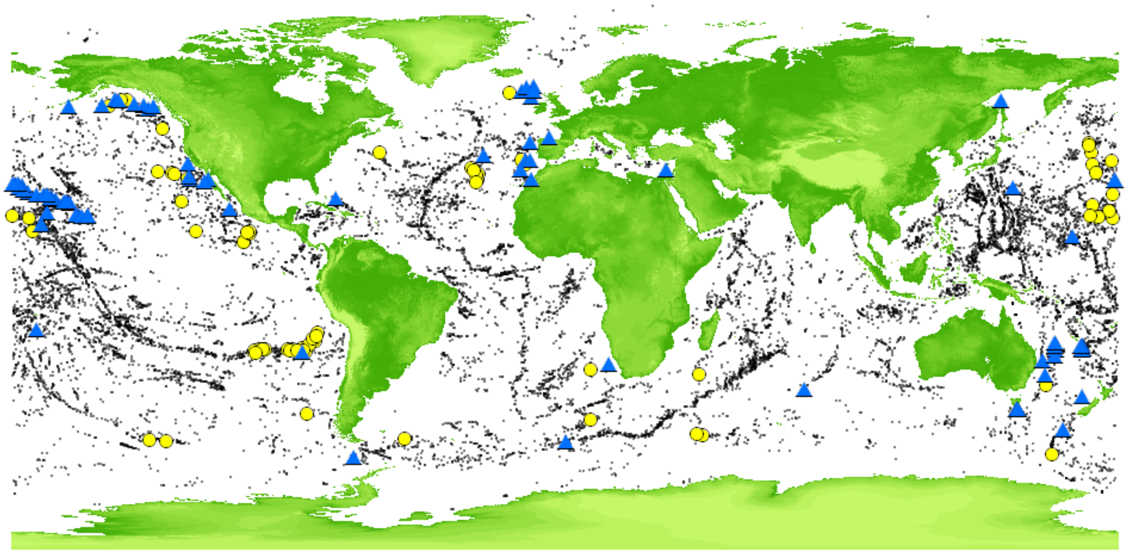

Figure 1. Locations of 171 seamounts for which SeamountsOnline has invertebrate data. Circles indicate seamounts outside any country's exclusive economic zone (EEZ). Triangles indicate seamounts within EEZs. Small dots indicate the predicted locations of the > 14,000 unsampled seamounts identified by Kitchingman and Lai (this vol.).

The data also have limitations because they were compiled from many different surveys with many different aims, instead of from a single, well-planned global sampling. Most importantly, these data should be considered 'presence only.' They indicate when a species has been recorded on a particular seamount, but the lack of a record does not necessarily indicate that the species does not occur on a seamount – the seamount may not have been sampled appropriately to find that species, even if present. Secondly, the majority of sampling done on seamount invertebrates has been through bottom trawls/dredges or visual/video observation by SCUBA diver, submersible, Remotely Operated Vehicle (ROVs), or towed video apparatus. These methods generally find the larger invertebrates, commonly called 'megafauna,' and those that live on or above the surface. Very small invertebrates, especially those that live buried in the sediment, and those that live in the water above seamounts are underrepresented and may be more common and widespread than this database indicates. This contribution is also restricted to multicellular invertebrates: fishes, other vertebrates, plants, and single-celled organisms are not considered. Finally, SeamountsOnline does not have data for every seamount that has been sampled – it is a work in progress, and much information remains to be entered.

Despite these cautions, the data in SeamountsOnline represents by far the most comprehensive summary of seamount invertebrate data that exists. Though this compilation of data, certain patterns have emerged from the sampling performed to date, and these are reported below. Care is taken to explain how sampling biases may have influenced results and which results are robust.

INVERTEBRATES ON SEAMOUNTS

Taxonomic Composition

To begin to understand the communities that live on seamounts, one can start by looking at the main groups of animals that are most common on seamounts. Table 1 summarizes the number of seamount from which each major taxonomic group has been recorded. The Crustacea is the group that has been recorded from the most seamounts (116). In part, their prevalence may be due to a sampling bias: crab and shrimp are of commercial importance and thus of particular interest in many surveys. Following the Crustacea are Anthozoa (corals and anemones), recorded from 84 seamounts. Also common (recorded on 30-45 seamounts) are gastropods, bivalves, echinoids (sea urchins), ophiuroids (brittle stars), asteroids (sea stars), polychaetes, and hexactinellids (glass and related sponges). Appendices 1a-d gives full lists of all the species recorded from each seamount. It is important to remember that these represent a minimal number of seamounts where these taxa occur, as some of the 171 seamounts have not been sampled appropriately to record a particular group even if it is present.

Table 1. Taxonomic groups recorded on seamounts. For each group, the number of seamounts from which it has been recorded is indicated. The database covers 171 seamounts: however not all seamounts have been sampled sufficiently to find every group. Therefore, the number of seamounts should be considered a minimal estimate. Note that the some records have been identified only to the phylum level, and so the number of seamounts for a given phylum (the 'All' category) can be larger than the sum of the groups within that phylum.

Phylum	Group	Seamounts #
Annelida	All	37
	Oligochaeta	2
	Polychaeta	37
Arthropoda	All	116
	Chelicerata	11
	Crustacea	116
	Malacostraca	2
Brachiopoda	All	20
	Articulata	17
	Inarticulata	4
Chaetognatha	All	3
Chordata	Tunicata (sea squirts)	7
Cnidaria	All	92
	Anthozoa (corals and anemones)	84
	Hydrozoa (hydroids)	23
	Scyphozoa (jellyfish)	8
Ctenophora	All	2
Echinodermata	All	74
	Asteroidea (sea stars)	38
	Crinoidea (feather stars)	22
	Echinoidea (sea urchins)	39
	Holothuroidea (sea cucumbers)	21
	Ophiuroidea (brittle stars)	38
Echiura	All	1
Ectoprocta	Bryozoa	14
Entoprocta	All	1
Loricifera	All	1
Mollusca	All	76
	Aplacophora	3
	Bivalvia	42
	Cephalopoda (squid and octopus)	26
	Gastropoda (snails)	43
	Polyplacophora (chitons)	12
	Scaphopoda (tusk shells)	12
Nemata (nematodes)	All	3
Porifera (sponges)	All	46
	Demospongiae	11
	Hexactinellida (glass sponges)	30
Sipuncula	All	6

This list is very different from what one would expect from a 'normal' deep sea habitat, such as the continental slopes and abyssal plains, highlighting even at a high taxonomic level the uniqueness of seamount communities. In general, species that feed on particles in the sediments ('deposit feeders') are most common in the deep sea (Gage and Tyler, 1991). Because these areas are far below the zone where light reaches and plants can grow, they feed on the gentle rain of particles, known as 'marine snow,' falling to the seafloor from shallower waters. Seamounts, in contrast, have many species that 'filter feed': they grab particles that are swept past them by currents. These include many of the corals, anemones, featherstars and sponges found on seamounts, as well as some of the sea stars and brittle stars that are adapted to draping themselves on corals and sponges to filter-feed higher in the water. These species also make seamounts visually striking: seamounts have been likened to underwater gardens because of the branching, tree-like and flower-like corals and sponges that cover many of them.

The prevalence of these emergent filter-feeders is due to two related properties of seamounts. First, because of how water currents move around them, many seamounts are swept clean of sediment and have hard rocky or cobbled bottoms. This allows forms that need a firm anchor, such as sea fans and large corals, to settle and grow. In contrast, a large part of the deep sea is covered by fine sands, mud or clays, and is inhabited primarily by species that burrow in or crawl along the bottom (Gage and Tyler, 1991). Secondly, ocean currents sweep zooplankton-rich waters by many seamounts. Zooplanktons are small animals that live in the water column and are most dense at depths of ~1000m below the surface. Species that live on seamounts can feed off of this constantly-replenishing food resource, leading to a prevalence of filter-feeders. This phenomenon also produces extremely dense aggregations of life: supplemented by the 'conveyor belt' of zooplankton, many seamounts support a much larger total mass of life than other deep sea habitats. It is precisely this feature that leads to the high densities of commercial fishes on seamounts.

Endemism

One of the most exciting discoveries in biological oceanography in the last decade, and a cause of great scientific interest in seamounts, has been the documentation of high levels of endemicity on some seamounts. Endemics are defined in this context as species that have been found on only one seamount or a restricted seamount chain and, to date, nowhere else in the oceans. Scientists say that seamounts have 'apparently' high rates of endemism because it is not possible to know the true rates of endemism until the full spatial range of every species is known. Logically, to know that a species is only found on one seamount, one would have to have looked for that species at all other locations in the oceans, which is clearly impossible. But while the true rates of endemism are not known, it is known that studies of many seamounts have found high proportions of species new to science and known from nowhere else. In 1987, a compilation of the accessible data from global seamounts found that 12-15% of all species recorded on seamounts were endemics. Since then, several major studies have found much higher rates. On the Norfolk Ridge and Lord Howe seamounts south of New Caledonia, 31-36% of species were endemic (Richer de Forges et al., 2000). On Tasmanian hills, rates of ~35% were found (Koslow et al., 2001). And in the Pacific off of Chile, the Nasca and Sala-y-Gomez seamount chains have endemism rates of 44% for fishes and 52% for bottom-living invertebrates – one out of every two invertebrate species found was new to science (Parin et al., 1997). These rates are higher, in fact, than those found at hydrothermal vents, one of the most isolated and unusual habitats in the ocean (Richer de Forges et al., 2000). These high rates are not universal, though. On the Great Meteor seamount in the North Atlantic, 9% of the fishes found were endemic (Fock et al., 2002), and on Hawaiian seamounts the rate is 'only' ~5% for fishes (Stocks, in press). However, taken together, recent work indicates that the 1987 estimate is likely too low. New species at some level have been found on almost every seamount sampled to date, and so most unsampled seamounts are likely to hold such discoveries. In some cases, these will be enormous pools of undiscovered diversity (over 250 new species were found on 5 seamounts of the Norfolk ridge alone – Richer de Forges et al., 2000), in other cases, more modest.

Growth Rates

Very recently, several researchers have independently discovered that some seamount species are among the longest-lived animals on earth. Beds of the deep coral *Lophelia* have been found on 7 seamounts in the North Atlantic. While *Lophelia* specimens from seamounts have not been aged, *Lophelia* colonies in other deep-sea habitats have been aged at 1000-6250 years old (Wilson, 1979). Individuals of *Primnoa*, a gorgonian found on a Northeast Atlantic seamount, have been aged in other areas at 300-500 years old (Risk et al., 2002). And on small seamounts off of New Caledonia, featherstars (crinoids) and bamboo corals that are several centuries old have been discovered (Richer de Forges, pers. comm.). Compared to these, land tortoises, often touted in the popular press and textbooks as the oldest living animals at ~170 years, remain youngsters.

To date, the growth rates or ages of only a few invertebrate species from seamounts are known, so it is not possible to say how prevalent extremely long life is. But, given the discoveries from a limited number of aging studies to date, it seems highly likely that there are other long-lived species yet to be discovered on seamounts.

Other Discoveries

While insufficient data exist to establish trends, several other biological oddities have been recorded on seamounts. The deepest known plant life, a macroalgae living below 200 m, was found on a seamount (Littler et al., 1985). 'Living fossils' – life forms thought extinct since the time of the dinosaurs, have been discovered on the seamounts off New Caledonia, raising the potential that seamounts act as refuges for species with shrinking ranges (Schlacher et al., 2003). Also, work on several seamounts has extended the known ranges of varying species, finding them far outside their previously described arenas. The fauna of the Nasca and Sala-y-Gomez seamounts chains close to Chile in the Southeast Pacific, for example, is far more closely related to the Indo-West Pacific fauna than to the Chilean coast species (Parin et al., 1997).

VULNERABILITY TO FISHING

Many of the ecological characteristics of seamount communities make them of high concern for careful management.

1. Taxa common on seamounts are especially vulnerable to trawling damage.

As discussed above, seamounts have a high proportion of 'emergent' epifauna – species such as corals, anemones, crinoids and sponges that grow up and out of the substrate. Studies in deep-sea habitats have consistently shown that these forms are likely to be heavily damaged by trawling. In one study led by Keith Probert, the invertebrate bycatch most often collected by commercial fishing gear on hills off New Zealand were corals – including horny corals (Gorgonacea), stony corals (Scleractinians) and black or thorny corals (Antipatharians) – followed by brittle stars (Ophiuroidea) and seastars (Asteroidea) (Probert et al., 1997). This is the only study that looked specifically at seamounts, but when trawls are conducted in other habitats with coral, coral pieces are common by-catch (Behnken, 1993a; 1993b; McAllister and Alfonso, 2001), indicating that the nets are causing heavy damage. A single pass of a trawl was found to damage 67% of vase sponges and 55% of sea whips in an experimental study off Alaska (Freese et al., 1999). A similar study by Van Dolah et al. (1987) found that trawling decreased the density of barrel sponges and caused visible damage to octocorals and hard corals. Trawl marks can be clearly seen in coral areas as parallel grooves of coral rubble (Roberts et al., 2000; Fosså et al., 2002), and the proportion of coral rubble is higher in trawled areas than untrawled areas (Hall-Spencer et al., 2002). On average, therefore, seamount communities are intrinsically more vulnerable to trawl damage than communities in the sand, mud and clay bottoms that cover the vast majority of the seafloor.

Damage to corals, sponges, anemones, etc., is of special concern because these species provide habitat for rich assemblages of other organisms. Studies have shown that gorgonians (sea fans) provide food, habitat, or shelter for a variety of crinoids, brittlestars, seastars, basketstars, anemones, molluscs, fishes, and crabs (Risk et al., 1998; Krieger and Wing, 2002). A study that examined stalks of glass sponges in one area found 139 associated species (Beaulieu, 2001) and 866 species have been recorded in association with *Lophelia pertusa* beds (Rogers, 1999). These structure-building species are the same species that are most damaged by trawling; damage to them will likely cause a cascade of disturbance effects throughout the associated communities.

2. Highly endemic species, which appear to be common on seamounts, will be at increased risk of extinction following disturbance.

From a population perspective, species with a small total number of individual, or a very localized spatial range, are expected to be at higher risk of extinction after a disturbance. Logically, taking 1000 individuals from a population of one million creates little risk of extinction, whereas taking 1000 individual from a population of 1200 may be devastating. As discussed earlier, the true ranges of most marine species are not known because the oceans are undersampled. But, within this uncertainty, rates of endemism appear to be high on seamounts. One study of seamounts off New Caledonia found that adjacent seamounts on a chain had only 21% of species in common, and that seamounts in chains separated by 1000 km shared just 4% of their species (Richer de Forges et al., 2000). This raises the concern that there are species whose entire range may be a single seamount, making them extremely vulnerable to extinction.

3. Slow growing seamount species will have very long recovery times.

Seamount species have been found that live for hundreds of years – there are invertebrates on seamounts that were alive during the America Revolution, probably during the Roman Empire, and perhaps when the great pyramids in Egypt were raised. A species that takes centuries to grow will take centuries to recover from damage, making trawling in these areas comparable to losing an old growth forest.

A direct study of trawling impacts on seamounts

Very little research has been done that directly assesses the impacts of fishing activities on seamount ecosystems – this information vacuum is the reality within which seamount management and policy must operate, and is the reason why we discuss above the characteristics of seamount species that make them more or less likely to be impacted. The author knows of only one study that examined the effects of fishing on seamounts by comparing fished and unfished seamounts. In 1997, Anthony Koslow led a team of researchers on an expedition to a cluster of hills off southern Tasmania (Koslow and Gowlett-Holmes, 1998; Koslow et al., 2001). This area is unique in the world in that it includes a marine protected area where trawling is banned and an adjacent unprotected fishing ground, so it offered the opportunity to compare fished and unfished seamounts. They found that, based on the fauna, the hills separated into three groups: fished (shallow) seamounts, unfished seamounts <1400m deep dominated by hard, 'reef building' corals, and unfished seamounts >1400 m deep where hard corals did not grow, likely because of natural limits to their depth range. Leaving aside the deepest hills without corals, Koslow et al. (2001) found that unfished hills, in comparison with fished hills, had:

- 7.2 times higher total biomass; and
- 106% more species.

The major limitation of this study is that the unfished seamounts had deeper summits than the fished seamounts. Can the observed differences still be attributed to fishing, or might they have been caused by different communities naturally occurring at different depths? Koslow et al. (2001) outline several reasons why they think it likely that the observed differences were due to fishing. First, there is no reason to assume that the hard corals could not live on the shallow seamounts. These hills are within the known depth range of the main hard coral species found, *Solenosmilia variabilis*, and supported other species that are often found in similar environments as hard corals (gorgonians, bryozoans, and solitary, non-reef-building corals). Second, fishers on the seamounts reported catching large amounts of coral in their nets in the early years of their fishery on the hills. Third, the bottoms of the fished seamounts were made up of coral rubble and coral sands, which may indicate the remains of past coral disturbance. Finally, one sample was recovered from near the base of a heavily-fished hill that had coral and other species similar to the unfished hills. It is difficult to trawl near the deep base of a seamount, so this may represent an unfished, 'natural' community, and indicate that these species used to live on this fished hill. In conclusion, the Koslow study presents evidence that is strongly suggestive of how severe trawling impacts on seamount communities are.

CONSERVATION PERSPECTIVES

It is well known that commercial fishing pressure on seamounts is high. The section above outlines the likelihood that trawling causes severe and long-lasting damage to seamount communities and potentially species extinctions. Why is this of concern? Why are seamount habitats worth conservation, and what would really be lost if these communities were lost or severely degraded?

Scientific progress

One of the reasons that scientists have devoted so much effort to studying seamounts is because of what they can teach us about the patterns of life in the oceans in general. Why do seamounts support so many endemic species – what is it about these areas that produce, or retain, more new species? The fundamental processes that promote and maintain diversity in the oceans are not well understood, and seamounts offer case studies for addressing questions with larger implications. Only on seamounts not heavily impacted by fishing can we attempt to relate the natural rates of endemism and speciation to natural characteristics of the seamount.

Pharmaceuticals

The overwhelming majority of medicines are found in nature, and many are now coming from the oceans. For example, sponges have produced more patented, medically-related compounds than any other terrestrial or marine phylum, and have been particularly important for the discovery of anti-tumor agents (Kerr and Kerr, 1999). Seamounts, which have high numbers of unique species in general and sponges in particular, are likely to house unusual compounds that may prove important to human medicine.

Importance to Oceanic Communities and Biodiversity

It has been suggested that seamounts act as centres of speciation in the oceans, as refugia for relict populations with shrinking ranges, or as stepping-stones for trans-oceanic dispersal. How important their role is in larger-scale patterns of biodiversity in the ocean is not currently understood, but there is the potential that impacts on seamounts may also impact connected ecosystems. Furthermore, we know that migratory species such as tuna, marine mammals and seabirds congregate over seamounts (Hui, 1985; Blaber, 1986; Haney et al., 1995), implying that they can have a particular importance for species with much larger ranges.

Tomorrow's discovery

Perhaps the factor that makes seamounts most valuable for conservation is what may be discovered tomorrow. Just 3-4% of the world's seamounts have been sampled, and we have already discovered living fossils, the deepest known plant, some of the oldest animal species on earth, and hundreds of new species. What discoveries await on the other 96%?

APPENDICES

Data on invertebrates collected from seamounts globally were compiled from literature publications and electronic datasets provided by researchers and institutions working on seamounts:

1. Data in invertebrates collected from seamounts globally:
    - 1a. List of species from seamounts - ordered by species;
    - 1b. List of species from seamounts - ordered by seamount;
    - 1c. Bibliography of data sources cited in appendices 1a and 1b;
    - 1d. Distribution maps for seamount invertebrates given in appendices 1a and 1b.

REFERENCES

Beaulieu, S. E. 2001. Life on glass houses: sponge stalk communities in the deep sea. Marine Biology 138(4): 803-817.

Behnken, L. 1993a. Southeast Alaska trawl closure: A case study in risk-averse management. Sea Wind 7(1): 8-14.

Behnken, L. 1993b. Photos of southeast Alaska fishing bank habitat sensitive to trawl damage. Sea Wind 7(2): 25-28.

Blaber, S. J. M. 1986. The distribution and abundance of seabirds south-east of Tasmania and over the Soela Seamount during April 1985. Emu 86: 239–244.

Fock, H., Uiblein, F., Köster, F. and Westernhagen, H. v. 2002. Biodiversity and species-environment relationships of the demersal fish assemblage at the Great Meteor Seamount (subtropical NE Atlantic), sampled by different trawls. Marine Biology 141:185-199.

Fosså, J. H., Mortensen, P. B., and Furevik, D. M. 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. Hydrobiologia 471 : 1-12.

Freese L., Auster, P. J., Heifetz, J. and Wing, B. 1999. Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska. Marine Ecology Progress Series 182: 119-126.

Gage, J. D. and Tyler, P. A. 1991. Deep-sea biology: a natural history of organisms at the seafloor. Cambridge University Press, Cambridge, 504 pp.

Hall-Spencer, J. M., Allain, V. and Fosså, J. H. 2002. Trawling damage to Northeast Atlantic ancient coral reefs. Proceedings of the Royal Society of London - Series B: Biological Sciences 269: 507-511.

Haney, J. C., Haury, L. R., Mullineaux, L. S. and Fey, C. L. 1995. Sea-bird aggregation at a deep North Pacific seamount. Marine Biology 123(1): 1-9.

Hui, C. A. 1985. Undersea topography and the comparative distributions of two pelagic cetaceans. Fishery Bulletin 83(3): 472-475.

Kerr, R. G. and Kerr, S. S. 1999. Marine natural products as therapeutic agents. Expert Opinion on Therapeutic Agents 9: 1207-1222.

Kitchingman, A. and Lai, S. 2004. Inferences of potential seamount locations from mid-resolution bathymetric data. Pp. 7-12 *In:* Morato, T. and Pauly, D. (eds.). Seamounts: Biodiversity and Fisheries. Fisheries Centre Research Report 12(5).

Koslow, J. A. and Gowlett-Holmes, K. 1998. The seamount fauna off southern Tasmania: benthic communities, their conservation and impacts of trawling: final report to Environment Australia and the Fisheries Research and Development Corporation. Report No. FRDC Project 95/058. CSIRO, Hobart, Tasmania, Australia.

Koslow, J. A., Gowlett-Holmes, K., Lowry, J. K., O'Hara, T., Poore, G. C. B. and Williams, A. 2001. Seamount benthic macrofauna off southern Tasmania: community structure and impacts of trawling. Marine Ecology Progress Series 213: 111-125.

Krieger, K. J., and Wing, B. L. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the Gulf of Alaska. Hydrobiologia 471: 83-90.

Littler, M. M, Littler, D. S., Blair, S. M. and Norris, J. N. 1985. Deepest known plant life discovered on an uncharted seamount. Science 227: 57-59.

McAllister, D. E. and Alfonso, N. 2001. The distribution and conservation of deep water corals on Canada's west coast. Pp 126-144 *In:* Willison, J. H., Hall, J, Gass, S. E., Kenchington, E. L. R., Butler, M. and Doherty, P. (eds). Proceedings of the First International Symposium on Deep-Sea Corals. Ecology Action Centre, Halifax, Canada.

Parin, N. V., Mironov, A. N. and Nesis, K. N. 1997. The Nazca and Sala y Gomez Submarine Ridges: An Outpost of the Indo-West Pacific Fauna in the Eastern Pacific. Pp. 145-242 *In;* Gebruk, A. V., Southward, E. C. and Tyler, P. A. (eds). Biogeography of the Oceans. Advances in Marine Biology 32.

Probert, P. K., McKnight, D. G. and Grove, S. L. 1997. Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. Aquatic Conservation: Marine and Freshwater Ecosystems 7(1): 27-40.

Richer de Forges, B. R., Koslow, J. A. and Poore, G. C. B. 2000. Diversity and endemism of the benthic seamount fauna in the southwest Pacific. Nature 405: 944-947.

Risk, M. J., McAllister, D. E. and Behnken, L. 1998. Conservation of cold- and warm-water seafans: Threatened ancient gorgonian groves. Sea Wind 12(1): 2-21.

Risk, M. J., Heikoop, J. M., Snow, M. G. and Beukens, R. 2002. Lifespans and growth patterns of two deep-sea corals: *Primnoa resedaeformis* and *Desmophyllum cristagalli*. Hydrobiologia 471: 125–131.

Roberts, J. M., Harvey, S. M., Lamont, P. A., Gage, J. D. and Humphery, J. D. 2000. Seabed photography, environmental assessment and evidence for deep-water trawling on the continental margin west of the Hebrides. Hydrobiologia 441: 173-183.

Rogers, A. D. 1999. The biology of *Lophelia pertusa* (Linnaeus, 1758) and other deep-water reef-forming corals and impacts from human activities. International Review of Hydrobiology, 84: 315-406.

Schlacher, T. A., Schlacher-Hoenlinger, M. A., de Forges, B. R. and Hooper, J. A. 2003. Elements of richness and endemism in sponge assemblages on seamounts. Proceedings of the 10th Deep-Sea Biology Symposium. Coos Bay, Oregon, U.S.A., 25-29 August 2003.

Stocks, K. 2004. SeamountsOnline: an online resource for data on the biodiversity of seamounts. Pp. 13-16 *In:* Morato, T. and Pauly, D. (eds.). Seamounts: Biodiversity and Fisheries. Fisheries Centre Research Report 12(5).

Stocks, K. (in press). Using SeamountsOnline, a biogeographic information system for seamounts, to examine patterns in seamount endemism. Proceedings of the 2002 International Council for the Exploration of the Seas Annual Science Conference. 1-5 October, Copenhagen, Denmark.

Van Dolah, R. F., Wendt, P. H. and Nicholson, N. 1987. Effects of a research trawl on a hardbottom assemblage of sponges and corals. Fisheries Research 5: 39-54.

Wilson, J. B. 1979. 'Patch' development of the deep-water coral *Lophelia pertusa* (L.) on Rockall Bank. Journal of the Marine Biological Association of the United Kingdom 59: 165-177.

Wilson, R. R. and Kaufmann, R. S. 1987. Seamount biota and biogeography. Pp. 355-377 *In:* Keating, B. H., Fryer, P., Batiza, R. and Boehlert, G. W. (eds). Seamounts, Islands, and Atolls. Geophysical Monographs 43, Washington, D.C., U.S.A.