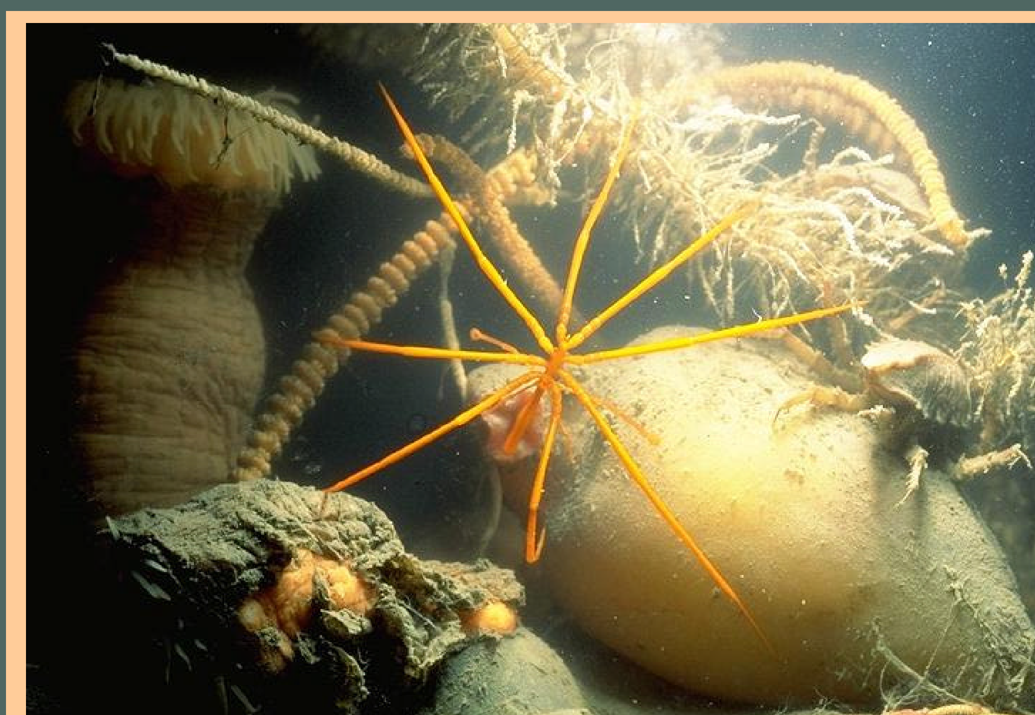
The Biology, Ecology and Vulnerability of Seamount Communities

Prepared by:
Alex D. Rogers, PhD.
British Antarctic Survey



IUCN
The World Conservation Union

The Biology, Ecology and Vulnerability of Seamount Communities

Alex D. Rogers, PhD
British Antarctic Survey, Cambridge

The Biology, Ecology and Vulnerability of Seamount Communities

Alex D. Rogers, PhD. Principal Investigator Biodiversity
British Antarctic Survey, Cambridge

Summary Points

While much remains unknown about seamount communities, scientific evidence suggests that high seas bottom trawling may have significant and irreversible impacts on the diversity and ecology of seamounts and other similar hard bottom communities. The points below explain the reasons and give more information on seamount ecology.

What are seamounts?

- Seamounts are undersea mountains that rise steeply from the seabed to heights still below sea-level.

- According to latest estimates, there may be as many as 50,000 seamounts in the Pacific Ocean and about 100,000 globally.

- Seamounts thus have a major influence on the physical structure of the water column.

- One of the most well-known oceanographic effects of seamounts with potential significance to seamount biology is the formation of eddies of water (so-called Taylor Columns) that are associated with upwellings of nutrient rich waters, leading to increased productivity in waters near the surface.

Why are seamount communities important?

- Because food supplies are restricted in the open-ocean, seamounts and the water column above them serve as important habitats, feeding grounds and sites of reproduction for many open ocean and deep-sea species of fish, sharks, sea turtles, marine mammals and seabirds.

- The distinctive benthic environment of seamounts provides habitat for a wide variety of species.

- Whilst geological/primary hard substrates and sediments form habitats for animals on seamounts, the most spectacular seamount communities are often associated with biological habitats or bioherms.
- Corals in particular may form cold, deep-water reefs on seamounts.
- Deep-water coral reefs introduce additional complexity to the seamount environment and are associated with a wealth of habitats similar to those found on shallow-water tropical coral reefs.
- The fauna of seamounts is highly unique and may have a very limited distribution restricted to a single geographic region, a seamount chain or even a single seamount location.
- Many seamount-associated species of fish are slow growing, slow to mature and exhibit extreme longevity (over 100 years in the case of orange roughy).
- Some seamount species form large, dense aggregations for reproduction that are easily targeted by trawlers, making them highly vulnerable to over-exploitation.

What are the current threats?

- Human impacts on seamounts have arisen almost solely from fishing to date.
- Fishing activities impact both target and by-catch species of corals, fish and crustaceans and impact the benthic communities of seamounts.
- Studies have also shown that trawl fisheries in particular are highly destructive to benthic communities living on seamounts.
- On bottom trawled seamounts the coral framework is entirely destroyed leaving bare rock and a markedly impoverished fauna behind.
- Such framework building corals take thousands of years to grow into a mature reef and rates of recolonisation and regrowth of areas impacted by fishing are likely to be accordingly slow if happen at all.
- Given the high levels of endemism of seamount fauna, it is likely that unregulated fishing activities have already destroyed many benthic seamount communities and reduced the distribution and abundance of associated species.
- The limited range of many seamount species means that the extinction of endemic seamount animals is also likely.
- Removal of seamount species may have had as yet undetected impacts on the wider ocean ecosystem.

Distribution, geology and oceanography of seamounts

Seamounts are undersea mountains that rise steeply from the seabed to waters below sea-level. Strictly, they are defined as having an elevation of more than 1000m and are of limited extent at the summit. However, even features of a few metres elevation known as bumps, mounds, or larger features such as hills or knolls may have a significant influence on the distribution and diversity of animals living on the deep-sea bed. Seamounts are a variety of shapes but are often conical with a circular, elliptical or elongate base. They may occur singly or in clusters, though some form chains that may stretch over considerable parts of the ocean (e.g. the Emperor Seamount Chain in the North Pacific extends over 6,000 km).

Physically, seamounts form a distinctive setting in the deep-sea. They are extremely steep, sometimes with slopes of up to 60^{o}. There are often exposed hard rocks on seamounts, which are rare elsewhere in the deep sea. Irregular surface features such as calderas, terraces, pit craters, canyons, caves, pinnacles, knobs, crevices, rocks and cobbles mean that seamounts also provide very diverse and complex habitats, with numerous niches for a wide variety of species. Oceanographic and geographic factors are also likely to be important in determining seamount biology. Factors include the distance to the nearest landmass, depth of the seamount from the sea surface, the temperature and nutrient status of overlying waters and the presence of ocean currents.

Just over 50 years ago scientists realised that there are numerous seamounts in the oceans of the world. However, it is only the advent of modern methods for surveying the bathymetry of the seabed using acoustics and particularly the use of satellite gravity maps that have detected just how common these features are. The latest estimates, based on modelling of satellite gravity data, indicate that may be there are as many as 50,000 seamounts in the Pacific Ocean and 100,000 globally[1] that have an elevation of 1km or more from the surrounding seabed.

Influence of seamounts on pelagic ecosystems

Seamounts have a major influence on the physical structure of the water column. At a large scale they may deflect major ocean currents. An example of this is the deflection of the Kuroshio and sub-arctic currents by the Emperor Seamount Chain. Smaller-scale effects include the formation of trapped waves, the reflection, amplification and distortion of internal waves and amplification of tidal currents. One of the most well-known effects of potential biological significance is the formation of Taylor Columns. These are eddies of

[1] The density contrast between seawater and sea floor basalt gives rise to gravity anomalies. These minute variations in Earth's gravitational pull cause seawater to be attracted to seamounts. This means that the sea surface has a shape that reflects underlying topographic features such as seamounts that can be detected by satellites. See Wessel P (1997) Science 277: 802 – 805; Wessel P (2001) J. Geophys. Res. 106 (B9): 19431 – 19441.

water that are formed over seamounts and may become trapped or maybe shed downstream. Taylor Columns are associated with upwelling of nutrient rich water from the deep ocean and may lead to increased productivity in the upper waters above or downstream of seamounts. These structures may be temporary, seasonal or semi-permanent and their role in seamount biology is poorly understood.

Seamounts can be highly productive areas attracting many pelagic fish species. Plankton biomass may be increased over seamounts possibly as a result of local enhancement of productivity. Most striking are the reports of extremely dense shoals of lantern fish, mysid shrimps and squid that feed above seamounts at night but which live close to the sides of seamounts during the day. These species appear to feed on vertically migrating oceanic plankton that maybe become trapped above the seamounts. In turn, they form a food source for larger, commercially valuable species of pelagic fish such as sharks, rays, tuna and swordfish. The association of such commercially valuable fish species with seamounts is well known and therefore these habitats and the waters overlying them are subject to trawling and long lining throughout the world's oceans.

Biology of seamount communities

Because seamounts are subject to very vigorous currents and are associated with hard substrates such as bedrock, cobbles and gravel they are host to very distinctive biological communities that are different to those on the soft-sediment dominated abyssal plain, which covers over 50% of the sea floor (about 270 million km^2).

For very shallow seamounts, where light still penetrates, plant life may still occur. Kelp and encrusting calcareous algae dominate hard substrates, though corals classified as tropical may also occur. The deepest records of living marine plants are from seamounts.

Deeper seamounts are dominated by organisms that feed on particles of food suspended in the water. These suspension feeders include stony corals, gorgonian corals, black corals, sea anemones, sea pens, hydroids, sponges, sea squirts (Ascidiacea) and crinoids. These sedentary/sessile species usually require hard substrate for attachment and rely on a strong flow of water to supply them with food, remove waste products, keep the organisms free of sediment and to disperse eggs and larvae. Locally induced currents play a major role in determining the distribution of suspension-feeding organisms on seamounts. Densities of these organisms are often higher near the peaks or around the rim of the summit. On a smaller scale local densities are higher on pinnacles, knobs and the edges of terraces. Many other types of organisms also occur on hard substrates including commercially valuable crustaceans such as crabs and lobsters, mobile echinoderms including starfish, sea urchins and sea cucumbers as well as polychaete worms and molluscs.

Whilst hard substrates are more common on seamounts than elsewhere in the deep sea, sediments are common towards the base of seamounts or on terraces or summits of flat-topped seamounts (so-called guyots). Seamount sediments play host to a wide diversity of organisms that may burrow into sediments, live amongst sediment particles or on its surface. Animals living in the sands and muds of seamounts include various types of segmented and unsegmented worms, crustaceans, snails, clams and sea squirts. Smaller animals that live amongst the sand grains include nematode worms, tiny crustaceans and some more unusual groups of marine invertebrates. In this case there is an inverse relationship between diversity and current strength, because vigorous currents lead to more course sediments, a poorer habitat and thus smaller diversity of burrowing organisms. Larger animals living on the sediment surface include sea pens, sponges, stalked-barnacles, gorgonians, cerianthid sea anemones, crinoids and other echinoderms. Xenophyophores, giant single celled organisms that build elaborate dwellings made of sediment particles, are particularly common on seamount sediments. Many of these organisms are suspension feeders and tend to favour areas exposed to strong currents.

Whereas primary hard substrates and sediments do provide habitat for animals on seamounts, the most spectacular seamount communities are those associated with secondary biological habitats or bioherms. Corals in particular may form cold, deep-water reefs on seamounts. These introduce additional complexity to the seamount environment and are associated with a wealth of microhabitats that strongly resemble shallow-water tropical coral reefs. These microhabitats include the free spaces between the coral branches, the living surface layer of the coral, the dead coral skeleton beneath, cavities inside the coral skeleton formed by boring organisms and sediments trapped in the reef-framework. Thus, cold-water corals may be regarded as ecosystem engineers. The diversity of animals associated with cold-water coral reefs is extremely high and comparable to tropical shallow-water coral reefs (see below). This associated fauna includes many groups of suspension feeding organisms typical of hard substrates, but also groups of animals that are specialist borers of corals (polychaete worms and sponges) or which live in coral sediments. Mobile predators, such as fish, decapod crustaceans, echinoderms and molluscs are also common on deep-water reefs. These structures may also play an important role in sheltering the juvenile stages of species of deep-sea fish, some of which are of commercial value.

Gorgonians and whip corals may form less complex "meadows" where they occur in high densities. These coral meadows may also be associated with enhanced densities of other organisms including fish and may be important as foraging areas for larger predators (e.g. Hawaiian monk seals). Even on small scales the presence of biological structures such as xenophyophore dwellings may increase the number and distribution of other species by providing living space both on and in the dwellings or beneath them in the sediment.

Seamount associated fish

Seamounts are important as habitat, feeding grounds and sites of reproduction for many deep or pelagic species of fish. In particular a guild of robust, muscular fish species have been associated with seamounts. Unlike many other deep-sea fish that have a very watery and flabby body, these species have firm, more palatable flesh and therefore are of commercial value. These species may lie on the seabed employing an ambush feeding strategy by swimming up off the bottom and eating passing animals. Others intercept daily migrating layers of plankton[2]. The plankton are pushed over seamounts by currents when they are near the ocean surface at night. At dawn they attempt to migrate downwards but are trapped by the elevated topography of seamounts and form a source of prey for seamount associated species.

Some seamount species, such as orange roughy, form spawning aggregations over seamounts that are easily targeted by trawlers (see below). Non-seamount species may also aggregate over seamounts for reproduction as recently reported for the Japanese eel *Anguilla japonica*.

Furthermore, it is now thought that because food supplies are restricted in the open-ocean, areas such as seamounts and oceanic islands are critical for many commercially valuable pelagic species. A recent survey of long-line catches of large tuna, billfishes, sharks, other commercially valuable fish, sea turtles, seabirds and marine mammals for regions across several oceans showed that extraordinary levels of diversity were observed close to topographic features including islands, shelf breaks and seamounts[3]. The reason for this is not certain but is almost certainly related to enhanced productivity and the concentration of prey in these regions.

Biodiversity of seamount communities

Recent exploration of seamounts has shown that the diversity of species inhabiting these localities can be extremely high. An investigation of the Tasman Seamounts off of south-eastern Australia revealed over 850 species[4]. Many of these species were associated with cold-water coral reefs predominantly formed by the scleractinian *Solenosmilia variabilis*. Recent investigations of several seamounts in the New Caledonia region have already identified over 2000 species, over half of which are new[5]. The occurrence of species that are new to science and which are endemic (not found anywhere else) to specific seamounts or seamount provinces is becoming increasingly apparent. In the case of the Tasman Seamounts 29 - 34% of species are thought to be endemic. Previous work has indicated that

---

[2] Small planktonic animals migrate on a daily basis. During daylight hours they live in deep, dark waters to help avoid being eaten by visual predators. At dusk they migrate upwards to feed on microscopic plants and on each other near the surface returning to depth at dawn.
[3] Worm et al. (2003) Proc. Natl. Acad. Sci. USA 100 (17): 9884 – 9888.
[4] Richer de Forges et al. (2000) Nature 405: 944 – 947.
[5] Communicated by Thomas Schlacher, Marine Science, Faculty of Science, University of the Sunshine Coast, Maroochydoore DC, Queensland 4556, Australia. tschlach@usc.edu.au

the average level of endemism amongst seamount faunas is 15%, much higher than the general background endemism in the deep sea.

Even within a small geographic area the overlap of species between seamounts may be extremely low with a high occurrence of spot endemics (species occurring on one seamount alone). Within individual seamounts the number of endemic species has been observed to increase towards the seamount summit. Towards the base of seamounts species more typical of the surrounding deep-seabed become increasingly dominant. The fauna of seamounts is therefore highly unique and may have a very limited distribution restricted to a single geographic region, seamount chain or even single seamount.

Why seamount communities are characterised by high levels of endemism is unknown. They may represent unique physical environments that exert selection on populations that inhabit them. The physical isolation of seamounts and the potential for larval retention through mechanisms such as Taylor Columns[6] may also lead to a high rate of speciation amongst seamount populations. Evidence from studies on snails of the genus *Trituba* on North Atlantic seamounts certainly suggests that geographic isolation combined with a non-dispersive life-history has promoted speciation in this group[7]. Depth, or gradients of physical conditions correlated with depth, appear to also promote or be associated with speciation. This may explain why endemism appears to increase moving from deep to shallow water. Seamounts may also act as refugia for some marine species. Evidence also suggests that seamounts may act as stepping-stones in the transoceanic dispersal of marine species, playing an important role in the evolution of the global marine fauna.

Vulnerability to human impacts

Human impacts on seamounts have arisen almost solely from fishing to date. These fishing activities impact both target and by-catch species of corals, fish or crustaceans and impact the benthic communities of seamounts. Many seamount-associated species of fish are slow growing, slow to mature and exhibit extreme longevity (over 100 years in the case of orange roughy). In addition to this some species form large, dense aggregations for reproduction that are easily targeted by trawlers. Given that these fish experience low rates of natural mortality as adults, such intense fishing pressure has rapidly led to the destruction of seamount fish stocks from which there has been no recovery. The recent finding that seamounts act as biodiversity hotspots in the pelagic and benthic realm also means that there is more likely to be a high by-catch of non-target species in these areas. The fact that many seamounts are in international waters means that regulation of such fisheries is extremely difficult under the current legal framework governing the high seas.

---

[6] Parker T & Tunnicliffe V (1994) Biol Bull. 187 (3): 336 – 345; Dower JF & Perry RI (2001) Fisheries Oceanogr. 10 (3): 268 – 274.

[7] Gofas S (2002) Am. Malacol. Bull. 17 (1-2): 45 – 63.

Studies have also shown that trawl fisheries in particular are highly destructive to benthic communities living on seamounts. Observations of fished vs. un-fished seamounts in the Tasman Seamounts province showed a striking difference in the biodiversity of contrasting localities. Unfished seamounts were characterised by cold-water coral reefs with a rich and highly endemic associated fauna. On fished seamounts the coral framework was entirely destroyed leaving bare rock and a markedly impoverished fauna. Studies of by-catches of orange roughy fisheries clearly show that framework-building corals such as *Solenosmilia variabilis* are removed by trawling[8]. Such framework building corals take thousands of years to grow into a mature reef and rates of recolonisation and regrowth of areas impacted by fishing are likely to be very slow if at all. Even if trawling does not completely remove coral, repeated damage to colonies reduces their size to a point where sexual reproduction of dispersive larvae is no longer possible.

Given the high levels of endemism of seamount faunas, especially on those associated with cold-water coral reefs, it is likely that unregulated fishing activities have already destroyed many benthic seamount communities and have reduced the distribution and abundance of associated species. The limited range of many seamount species means that the extinction of endemic seamount animals is also likely. Furthermore, we have no data as yet on the links between the animals living on and associated with seamounts to those in the rest of the ocean. Removal of seamount species may have had as yet undetected impacts on the wider ocean ecosystem.

In the future other human impacts may have a significant impact on seamount faunas. Global climate change may cause changes in sea temperatures, alterations in the flow of ocean currents and changes in patterns of productivity. Cold-water corals, such as *Lophelia pertusa*, have been shown to be extremely sensitive to the physical characteristics of overlying seawater. Mining of sediments of hydrothermal origin on seamounts is likely in the near future. High concentrations of metals maybe associated with such sediments and there is great interest in exploiting such sources of minerals especially as they maybe relatively close to the sea surface compared to other hydrothermal deposits. Cobalt crusts are another mineral resource associated with seamounts that may be sufficiently valuable in the future to be targeted by commercial mining activities. As mining activities remove substrate directly from the seabed and will produce a marked increase in the sediment load of the seawater surrounding the impacted zone they will be highly destructive to marine life, especially benthic suspension feeding organisms.

---

[8] Anderson OF, Clark MR (2003) Marine Freshwater Res. 54 (5): 643 - 652

Additional reading

Koslow JA, Boehlert GW, Gordon JDM, Haedrich RL, Lorance P, Parin N (2000)

Continental slope and deep-sea fisheries: implications for a fragile ecosystem. *ICES Journal of Marine Science* 57: 548 – 557.

Roberts CM (2002)

Deep impact; the rising toll of fishing in the deep sea. *Trends in Ecology and Evolution* 17 (5): 242 – 245.

Rogers AD (1994)

The biology of seamounts. *Advances in Marine Biology* 30: 305 – 350.

Rogers AD (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.

Wilson RR, Kaufmann RS (1987)

Seamount biota and biogeography. In: Seamounts, Islands and Atolls Eds. Keating BH, Fryer P, Batiza R, Boehlert GW. Geophysical Monograph 43. American Geophysical Union, Washington, pp319-334.