The Depths of Ignorance: An Ecosystem Evaluation Framework for Seamount Ecology, Fisheries and Conservation

Abstract

Seamounts are some of the least known habitats on the planet. Indigenous people and early navigators knew of some of them, but we are only just finding out that there may be 100,000 large seamounts and up to a million smaller features. Seamounts are steep-sided underwater volcanoes with a geological life history. The physical characteristics can generate upwelling of nutrients, the formation of density cones, or the retention of water masses. These hydrological phenomena may lead to local enhancement of primary production. However, a more important mechanism appears to be the trapping of small migrating organisms, both zooplankton and mesopelagic organisms, over the summit and flanks, depending on the depth of the peak. As a result, larger mobile sea creatures visit seamounts to feed on the concentrations of small organisms. Species of seabirds, sharks, tuna, billfish, sea turtles and marine mammals can aggregate at seamounts to 'raid the larder', and sometimes to spawn. Seamount biota, especially fishes but also corals, present an attractive target for human exploitation. Small-scale artisanal fisheries from oceanic island chains have for generations taken advantage of life on nearby seamounts, and have proven sustainable over long periods. Large-scale fisheries, in contrast, have a poor record of sustainability, often causing serial and serious depletion of fish on seamounts. Unregulated distant water fleets overexploited many high seas seamount areas in the 70s and 80s, and catch data from this period is only now being fully assembled and analysed. Trawl gear destroys delicate and long-lived benthic organisms such as cold water corals and sponges. Seamounts need some protection from trawling and other fishing, and rational management if they are to provide sustainable fisheries as well as serve as reservoirs of abundance and biodiversity; 'islands in the deep'. We present a two-part Ecosystem Evaluation Framework (EEF) for seamounts by pulling together information from the preceding chapters. Part I scores the extent of our knowledge about individual seamounts: a more detailed version might express the extent of local enhancement of biomass and biodiversity. Part II assesses the severity of a range of threats, mainly from human fisheries, to the abundance and diversity of living organisms found at individual seamounts.

Introduction

"The smallest rock in the tropical seas, by giving a foundation for the growth of innumerable kinds of seaweed and compound animals, supports likewise a large number of fish. The sharks and the seamen in the boats maintained a constant struggle which should secure the greater share of the prey caught by the fishing-lines. I have heard that a rock near the Bermudas, lying many miles out at sea, and at a considerable depth, was first discovered by the circumstance of fish having been observed in the neighbourhood." Charles Darwin (1839), Voyage of the Beagle, Chapter 1, St. Jago - Cape de Verd Islands.

The apparently featureless ocean, is packed with many tens of thousands of large seamounts, formed from extinct volcanoes. Seamounts ecosystems are islands of abundance, biomass and biodiversity in the oligotrophic deep ocean, but their discovery is quite a recent story. In the quote above, Darwin is clearly describing a shallow seamount and its associated fish fauna, as was his wont Darwin correctly guessed that flat-topped seamounts ('guyots') provide a base for coral reef formation. Darwin's 'discovery' would have been old news to indigenous people, who, as in the case of Polynesian navigators, had a phenomenal knowledge of ocean features and currents. They may also have been attracted by birds feeding on forage fish[1] forced to the surface by predators, a process termed 'trophic mediation' which we will consider again in the case of corals and sponges.

Seamounts entered the European scientific canon on July 2, 1869, when the Josephine Bank in the eastern north Atlantic was found and named by the Swedish Navy Corvette *Josephine* (Chapter 3). Research on seamount ecology began in earnest in the 1950s, with the application of underwater sonar and the development of survey devices such as Doppler and scanning sonar (Simmonds and MacLennan 2005), that can measure currents and the movement of fish and small mesopelagic organisms. Since then, the ubiquity and pivotal role of these 'islands in the deep' has begun to emerge and provides the basis for the 21 chapters of this book.

Physics and Geology

Seamounts are undersea mountains characterised by their height above the surrounding abyssal plain, depth of the peak below the surface, and to some extent, steepness of slope. Nearly all seamounts are underwater volcanoes: they represent about 20 % of global volcanic extrusions so that their distribution relates directly to spatial and temporal variations in intra-plate volcanic activity. Since they tend to occur in island arcs, where their location intercepts global water currents their geomorphology enhances the trapping of water masses in several ways. Seamounts have unique 'magnetic signatures' which may contribute to their location and use as rest stops and 'cafés' for sharks, whales and other migrants.

Seamounts obstruct currents and thus enhance tidal dissipation. Several mechanisms can enhance upwelling of nutrients. Formation of Taylor caps and wake effects may trap water masses and create upwelling currents. Taylor columns (Chapter 4) are formed by the effect of the earth's rotation on directional current flow split by a seamount. Intriguingly, the great red spot of Jupiter may have been the first Taylor column to be described (Chapter 3). Stratification of water may turn the spinning

[1] This raises the question of what is, and is not, a 'seamount species'. Sardines (*Sardinops sagax*) are often found over seamounts, but were excluded from catch in Chapter 18, as their global catch of 4.5 million t would swamp all else. The presence of sardines over seamounts would attract birds and hence early navigators.

column into a Taylor cap (or cone). Taylor caps form, or not, over a particular seamount depending on width, local current and tidal flow, height and the Coriolis force, which varies by latitude. The Rossby and Burger numbers can forecast where a Taylor cap may form (Chapter 4), some seamounts always producing Taylor cones, others only intermittently or not at all.

Taylor cones encourage a doming of water density layers, which in turn creates two physical effects, each with biological implications. First, below the thermocline, isolated topographic features may produce large vertical displacements in the density gradient so that small deep seamounts can cause significant local current structures so that deep seamounts over about 0.5 km in height are especially important in producing density-layered domes of water. Secondly, density domes over shallow seamounts may reach the euphotic zone and have powerful effects on local plankton abundance including increased vertical mixing. In addition, tides can generate similar density cones and wave spin-offs over seamounts (Chapter 4), and eddies like this can be formed by several different mechanisms. Chapters 4 and 5 outline considerable field evidence for all of these processes, although no one seamount may exhibit all of them, and some seamounts may show none.

Seamount Biota

There is therefore a range of hydrological features that may lead to higher local production and biomass, although not all of them may be observed at any one seamount, and they may operate intermittently or for most of the time. Although oceanographic processes such as Taylor columns have the potential to hold water over seamounts for periods of several days, it is unlikely that planktonic communities over seamounts are significantly and permanently different from those in the surrounding ocean. There is evidence that seamounts can cause upwelling of nutrients, with consequent enhancement of the rate of primary production. Seamounts that come close to the surface may well cause eddies downstream of the current with resulting differences in the planktonic community from surrounding open ocean areas. A few very shallow seamounts with macrophytes host significant communities. Higher primary production may be expected over some seamounts, but has not been widely observed and may not be as widespread a phenomenon as was once thought. Indeed, modelling (Chapter 12) supports this empirical evidence which suggests that enhanced local primary production would rarely be sufficient or widespread enough to account for the high biomass of both resident and visiting organisms often found at seamounts.

Enhanced current flows on the tops and flanks of seamounts may encourage higher abundances of sessile filter feeding organisms such as corals and sponges, provided they are within range of sources of settling larvae for colonies to be founded. The fixed nature of benthic animals makes it more likely that seamount communities are different from the surrounding ocean. If the seamount is very tall, the benthic community of the upper slopes will be very different from the abyssal benthic community, mainly because physical conditions are so different. Distance from a continental shelf may also determine how endemic the benthic fauna is. It appears that the invertebrate benthic communities of seamounts are more often than not similar to those to those found on nearby shelves (Chapter13). However, some communities are very different from those elsewhere in the nearby region, as shown in Chapters 7 and 9 where a few seamounts in the SW Pacific appear to have high levels of benthic invertebrate and coral endemism. Many of the organisms on seamounts are long-lived and slow growing, making the community relatively unproductive and vulnerable to exploitation and damage.

Benthic structuring organisms such as corals and sponges can live hundreds of years and can be extremely slow-growing. The interdependence of seamount fish and other motile species with benthic-structuring organisms is unknown, but the ‘feed rest’ hypothesis (see Chapters 5, 6, 8 and 10a; Genin

2004) suggests they may be important to both the safety and energy budgets of these and other fish. The role of benthic structure in the spawning and rearing of commercial and other species is equally dark, but likely significant. Chapter 8 raises serious concerns about the ability of corals destroyed by trawling to recover, or to recolonise under current and anticipated climate regime.

For many benthic animals on seamounts a major problem is to evolve a life cycle that ensures that sufficient new recruits join the local populations. With water passing continuously over the top of the seamount, and being held up for only 2 to 3 weeks by Taylor processes and by eddies, planktonic larval stages have to be short enough to ensure that there will be a shallow surface to settle on. Evidence presented in Chapter 13 shows that for species of both invertebrates and fish that live over shallow seamounts, larvae are in the plankton for less time than is true for species that live in equivalent shelf and slope waters.

There is strong evidence that vertically-migrating zooplankton can be advected over seamounts at night then and so prevented from returning to the depths. These trapped plankton concentrations around and over seamounts will attract fish that feed on plankton and may well enhance food supplies to sessile filter feeders anchored to the seamount. In this way a seamount will have the same influence on the plankton community as would an island or an oceanic front between two water masses. Given that temporary concentrations of plankton occur sufficiently often, a seamount can become a location that attracts planktivorous fish and their predators. The consistency with which plankton concentrations are found will determine how permanent these aggregations of fish are. There is evidence that tuna, sharks, turtles and some marine mammals and seabirds spend time feeding around seamounts, although it is unlikely that they remain over one seamount for more than a few days (Chapters 10a, b; 12 a,b,c).

Where all of these factors act together, it is possible that some seamounts may generate sufficient settling detritus to encourage a resident detritivore community (such as rock lobsters), and hence attract resident small fish and cephalopods (Chapter 14).

Small-scale Seamount Fisheries

Many seamounts are close to inhabited islands, such as the Azores or Hawaii. People on these islands have a long history of fishing over nearby seamounts, as detailed in Chapter 16. Many of the small-scale fisheries exploit deep water fish using relatively simple gear and labour intensive equipment. This means that fishing pressure is relatively low and such fisheries have proved to be sustainable over long time periods. Although the global catch of fish from small-scale seamount fisheries is estimated to be about 250,000 t, this is probably a very poor estimate. In many locations local landings by artisanal fishers are from a variety of locations in particular from shallow tropical coral reefs. There is no good way in which to separate the landings from these from those that come from local seamounts. Nevertheless, the cultural, social and economic importance of artisanal seamount fisheries is locally very significant. Very often, fishing is one of the only occupations that is available for the inhabitants of an island so that many people will be dependent on the catches from small-scale seamount fisheries, as indicated by the *per capita* annual consumption estimate of 37 kg from seamount fisheries compared to a global average of 13 kg (Chapter 16).

Large-scale Seamount Fisheries

Large-scale trawl fisheries on offshore seamounts have a much more recent history than do the island – based artisanal fisheries. They developed from the 1960s -1970s when large trawlers from primarily the USSR and Japan searched the world’s oceans for fisheries resources. Some high-volume fisheries were developed for deepwater species like pelagic armourhead (*Pseudopentaceros wheeleri*), alfonsino (*Beryx splendens*), orange roughy (*Hoplostethus atlanticus*), oreos (Oreosomatidae), and grenadiers (*Coryphaenoides rupestris*). The cumulative catch from these fisheries is estimated at over 2 million tonnes (Chapter 17). These fisheries have not proven sustainable, in many cases lasting a decade or less (Chapters 17, 18). In part this because deepwater species often have biological characteristics that make them less productive and more vulnerable to overfishing than shallower shelf or slope species (Chapter 9), but also the development of fishing technology in the late 20th century that allowed seamount features (and their fish) to be consistently located and successfully fished.

Impacts on ecosystems - biota/habitats

The effects of fishing on seamounts are basically the same as on other habitats. In Chapter 19 the types of fishing gear and their effects are described, and there is nothing specific to seamounts for most of them. However, seamounts are often the only features at suitable depths for commercial species of demersal fish in large areas of the abyssal ocean plains – ttrue ‘islands in the deep’. Because fish can be localised over and around seamounts, so are their fisheries. Studies off New Zealand and Australia document very high levels and densities of bottom trawling on small seamounts for orange roughy, and hence the impacts can be highly concentrated. Technology has contributed to this, with development of GPS in the 1980s-1990s making it possible for seamounts to be easily and consistently located, and with design of trawl gear that can fish rough, hard seafloor, and the introduction of factory and freezer trawlers that can stay at sea for long periods and process large quantities of fish. Trawling, and its associated impacts on seamount fish and habitat, can operate 24 hours a day, 7 days a week. Without management, fish stocks and fragile seamount ecosystems are highly vulnerable.

Management issues at seamounts

While a large undersea mountain 5-10 km across may seem rather obvious feature, on a global scale the numbers and locations of many seamounts remain unknown. For example in 2005, an American submarine ran into an uncharted Pacific seamount (Fig. 21.1), and in 2004 the Norwegian RV *G.O. Sars* involved in the CoML project MAR-ECO identified a set of topographic features at the Mid-Atlantic Ridge between the Azores and Iceland that were either not charted or mistakenly represented in available bathymetry. Determining the number and location of seamounts presents several problems. Precise hydrographic sonar surveys have charted many ocean areas, especially the EEZs of developed nations and areas of strategic military importance, yet it would take thousands of years to survey all of the world oceans. Short cuts are the use of satellite altimeters or the use of detection algorithms on approximations of ocean bathymetry. Analyses presented in this book support an estimate of over 100,000 large seamounts, with many smaller ones waiting to be discovered; about 60 % are located in the Pacific basin. Complete mapping of the world’s seamounts thus has important ramifications for marine geophysics, physical oceanography, marine ecology and fisheries conservation.

Figure 21.1 Many seamounts remain uncharted. On January 8th 2005, the US nuclear submarine *San Francisco* en route to Brisbane Australia for a port visit, ran into an underwater mountain at 35 knots about 350 miles south of Guam leaving one sailor dead: a number of sailors were awarded medals for bravery in dealing with over 70 wounded. The seamount is now named the “San Francisco seamount”.

Management Instruments

Seamount ecosystems exhibit a number of distinct features that make them of considerable interest to marine scientists, resource managers and those with an interest in marine conservation because they are particularly susceptible to fishing both as habitats, but also due the high vulnerability of seamount aggregating fish (Morato *et al.* 2006; Morato and Clark 2007). Thus, for seamounts within EEZs, compliance with management and issues of precaution in setting quotas (FAO 1995, 1996) are more critical when compared with those applied to continental slope fisheries. For this reason it is probably safer to set up exclusion zones for fisheries that are damaging to seamount biota, as they are easier to enforce than the quotas and effort limitation regulations commonly employed in the management of continental slope fisheries.

Marine Protected Areas could be the most practical way of managing seamounts, but could they be effectively policed? The same question can be applied to trawl bans or any other restriction on the way fishing is carried out. As has been shown in several chapters in the book, seamount communities often have fixed structures, such as cold water corals, that are very vulnerable to trawling. Without an effective way of limiting fishing, these communities will be destroyed very quickly and would then take tens to hundreds of years to re-establish, if further trawling could be prevented. For some seamount areas around oceanic islands with a large EEZ, it might be feasible to create a large MPA area around the islands within which only local, artisanal fisheries are allowed.

In some areas under national jurisdiction, unique regulations are coming in force. Of special interest is the case of the Azores seamounts. In this region, an autonomous region of Portugal and part of the European Union, small-scale artisanal fisheries have been practiced for many years. Deep sea trawling and other deep sea nets have been forbidden here for many years. In 2005, the revised EU Common Fisheries Policy (CFP) created a huge area, encompassing the greater portion of the EEZ, where deep-sea trawl and other deleterious deep-sea fisheries are excluded. This was extended to the two other Macaronesian archipelagos of the EU, Madeira (Portugal) and the Canaries (Spain). Also, in recognition of the distinctive features of the seamount fauna, the CFP is applied differently from other regions (see Chapter 20 for details). In fact, the "non-trawl area" created (see Fig. 20.4) can be considered as a marine protected area (MPA). But, even for the Azores it has not been possible to reach agreement to extend the MPA protection area far enough to include all the seamounts that are known in the Azores EEZ. The negative aspect of the CFP applied to the Azores is that it opened the area between the 100 and 200 miles to non local fleets and to EC central management, leading to a huge increase (the fleet has increased from around 10 ships to around 150) of pelagic long liners whose main target is the swordfish (*Xiphias gladius*), but that are having high impacts in other species like pelagic sharks (Chapter 10b) and sea turtles (Chapter 12b). No proper impact study is under way.

The fact that more than half of the world's seamounts are outside EEZs presents a serious challenge (see Chapters 2 and 20). Pitifully few are covered by international agreements and/or conventions t established in view to regulate and manage fisheries in this high seas areas (see Fig. 20.2 and Chapter 20). They are therefore highly prone to pirate fisheries and policing is a major problem.

Many international bodies and conventions now recognise the particular threat to these habitats. In Europe, OSPAR (Convention for the Protection of the Marine Environment of the North-East Atlantic) includes seamounts, and a set of other associated habitats (e.g., *Lophelia pertusa* reefs and deep-sea sponge aggregations) and species (e.g., orange roughy) in an initial list of threatened and/or declining species and habitats (OSPAR 2004). This creates obligations for the contracting parties towards the conservation of these habitats and species.

No single management model is applicable to all seamounts. Measures are likely to range from activity-based restrictions to MPAs, and regulation of activities beyond the immediate vicinity of seamounts. Given the failure of many traditional management processes in fisheries world-wide (Pitcher 2001, 2005; Pauly *et al.* 2002; Pauly and Maclean 2003; but see Hilborn 2006), MPAs and moratoria for some fishing technologies (e.g., deep-sea trawls) are of growing interest both in EEZs as also as in the high seas.

The high seas pose some complicated jurisdictional problems since, under the Law of the Sea, it is not technically possible for a state to create MPAs on the high seas. However the international community is discussing this issue and some NGOs have already made indicative applied proposals (Roberts *et al*. 2006). At present (2006), the main effort is concentrated on trying to obtain a Moratorium to the UN on "deep-sea bottom trawl fishing on the high seas until legally-binding regimes for the effective conservation and management of fisheries and the protection of biodiversity on the high seas can be developed, implemented and enforced by the global community" (see: www.savethehighseas.org).

There are few effective ways to solve the high seas policing problem. Other remote areas of the world show similar problems. Policing the Patagonian toothfish (*Dissostichus eleginoides*) fishery in the Antarctic has been poor despite using observers on board fishing boats. In the case of the toothfish, a remedy is to monitor landings of the species and to require skippers to inform the management agency as to where the fish were caught. This approach is possible for a single speciesl, but it would be difficult to implement a ban on landings of seamount fish as the fish communities on these structures are not necessarily unique (Chapter 9). How would one know that a given species had or had not come from a seamount? The alternative is to have observers on board vessels fishing beyond EEZs, but they are subject to considerable pressure being the only representative of the management authority on board. It would hardly be feasible to have inspection vessels monitoring activity over remote seamounts, so it would be very difficult to prevent single vessels cruising the oceans fishing over seamounts at will, as was done in the 1970s by vessels from the former USSR and Cuba (see Chapter 17). One glimmer of hope lies in the development of remote operated vehicles, in particular 'ocean gliders' that can remain at sea for 6-12 months, travel 1,000s of km and carry a variety of sensors. Current cost for a glider is ~$70,000. One possible use is to listen for ship activity and report by satellite. A pilot project to deploy 'Slocum' gliders, named for the first man to sail alone around the world (http://www.physics.mun.ca/~glider/ and manufactured by Webb Research (http://www.webbresearch.com/index.htm) at Canada's Bowie Seamount met with some technical difficulty, but the technology holds a lot of promise (Dale Gueret, Integrated Coastal Management Coordinator, pers. comm. 2006). The University of Washington in the US has a similar 'sea glider' (www.apl.washington.edu/projects/seaglider/new_note_seaglider.html).

We have no doubt that MPAs in some form will be a major tool in seamount conservation and restoration. In addition to the Azores, Madeira and Canary Islands in the Atlantic, there is already some protection for a few seamounts in the Pacific off New Zealand and Australia, while discussions continue in Canada and the US. As discussed above, policing will be hard, but enforcement and vigilance might be facilitated by space technologies including satellite tracking of fishing vessels.

As shown in the next section, many seamounts we know something about are often heavily exploited and underexplored. More knowledge about how seamount ecosystems work will aid future management, but of course we cannot wait around for that knowledge to be gained. In fact, we do not need more information to appreciate that most seamount ecosystems need protection now in order to recover, and really the only way to do that is to ban all trawling. The critical task is to find a way of implementing such a ban in an effective way.

Conclusion: An Ecosystem Evaluation Framework (EEF) for Seamounts

This chapter is a summary of the principal findings presented in the 20 earlier chapters of the book. But we also present a novel synthesis in the form of an Ecosystem Evaluation Framework (EEF) that attempts to evaluate the status of seamounts world-wide. Table 1 sets out the schema.

Table 21.1. Ecosystem Evaluation Framework (EEF) for knowledge of seamount attributes according the scheme presented in Chapter 14. Each seamount in the analysis is scored using the table below. Knowledge of each attribute is scored on a scale of 1 (completely unknown) to 4 (very well known).

OCEANOGRAPHIC FACTORS	**Knowledge Score**	**NOTES**
Depth of peak		*0-4 depending on*
Depth of surrounding ocean		*how well known the measure is*
Height of peak		
Slope of seamount		
Proximity to shelf		
Proximity to neighbour seamounts		
Ocean currents link to shelf		
Ocean currents to neighbour seamounts		
Taylor cap forms		
Overall Oceanographic knowledge status		

ECOLOGICAL FACTORS		
Macrophytes present		
Corals present		
Larval settlement regime		
Nutrient upwelling occurs		
Phytoplankton enhancement		
Zooplankton enhancement		
Deep Scattering layer organisms entrapped		
Settled filter feeders		
Zooplankton migrates in feeding range		
Predators/grazers present		
Detritus build-up present		
Detritivores present		
Small resident invertebrate predators		
Small resident fish predators		
Resident cephalopods		
Aggregating deep sea fish		
Visiting fish predators		
Visiting elasmobranch predators		
Visiting marine turtles		
Visiting mammal predators		
Visiting seabird predators		
Overall Ecological knowledge status		

The first part derives from the EEF analysis set out in Chapter 14 and describes the important attributes, including geological, hydrological and biotic features, that are found on seamounts and may contribute to their enhancement of local biomass and biodiversity. Not all of these features occur on all seamounts and so this part of the evaluation framework scores their presence and likely magnitude. The actual values of each attribute will determine the extent of any local enhancement effect on the food web, and indeed that is the focus of Chapter 14, but, in this version of the EEF we score how much we know about these seamount features so that scanning the EEF immediately reveals the location and depth of our ecological ignorance.

Figure 21.2 applies the EEF for some Azores and Canadian seamounts as an example. Colour coding indicates the extent of our knowledge. Green means values of an attribute (peak depth for example) are accurately measured and known, through pale green and orange, meaning that values are indirectly estimated or inferred, to red, which means completely unknown.

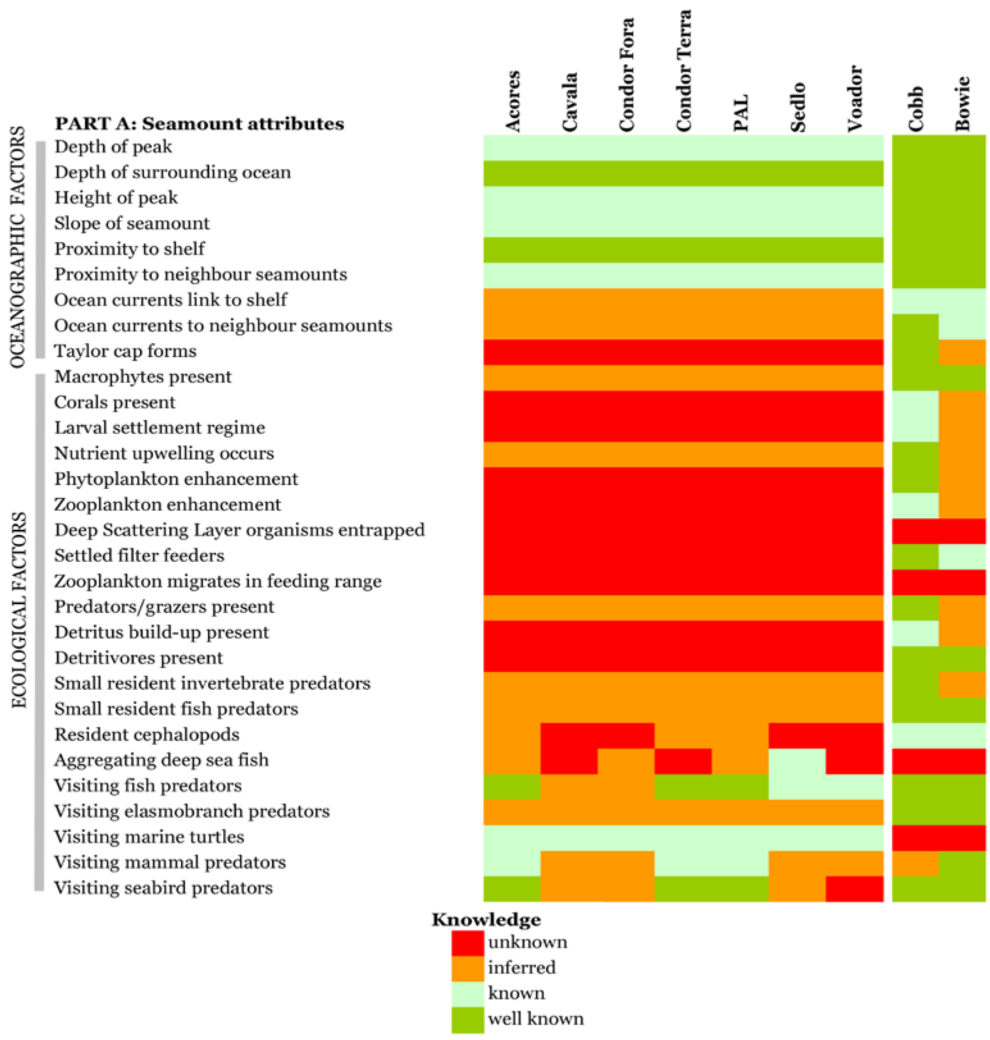

Figure 21.2 Knowledge EEF example for seven Azores and two Canadian seamounts.

Table 21.2 Ecosystem Evaluation Framework (EEF) for threats to seamounts. Each seamount in the analysis is scored using the table below. Threats posed by each fishery or factor are scored on a scale of 0 (no threat) to 10 (severe threats). Uncertainty in each score may be taken account of in the overall analysis.

FISHERIES	**Status Score**	**Limits** Low	high	**NOTES**
Trawl fishery				*Presence and status on scale 0 (none) to 10*
Longline fishery				
Handline fishery				
Purse seine fishery				
Others				
Total Fisheries Status				

CONSERVATION CONCERNS	**Status Score**	**Limits** Low	high	**NOTES**
Corals and benthos damage				
Turtle by-catch issues				
Shark by-catch issues				
Dolphin by-catch issues				
Whale by-catch issues				
Seabird by-catch issues				
Others				
Total Conservation Concern Status				

It is clear that the two Canadian seamounts are on the whole better known than the Azores seamounts; probably because there have been research cruises directed at their oceanography and, to some extent, their biota (Canessa *et al.* WWF 2003; McDaniel *et al.* 2003; Axys *et al.* 1999; Stitt 1993). Cobb seamount lies in international waters just outside the Canadian EEZ (see map in Figure 16.11, and Chapter 20), and has had more research attention than Bowie, which lies inside the EEZ, as shown by the higher incidence of green shading. For example, a persistent Taylor cap has been measured on Cobb, but only inferred over Bowie: in the Azores nothing appears to be known about Taylor caps. On the other hand, visiting turtles are known from Azores seamounts probably because of a turtle tracking project in the region (see Chapter 12b), but are either absent or not recorded from the two Canadian seamounts.

The second part of the EEF scores the severity of threats posed by human activities, principally fishing and other extractive exploitation of seamount resources. An example of an EEF for threats to Azores and Canadian seamounts is shown in Figure 21.3. It is evident that the overall fisheries status of the six of the seven Azores seamounts is better than those in Canada, mainly due to the absence of trawling: the PAL seamount in the Azores has a longline fishery. Both Canadian seamounts have sporadic longline fisheries for rockfish (*Sebastes* spp.) Pacific halibut (*Hippoglossus stenolepis*) and trap fisheries for sablefish (*Anoplopoma fimbria*); and were trawled in the years of Soviet exploration (see Chapters 17 and 20; Sasaki 1986). Bowie has since been trawled since for halibut to some extent (Axys *et al.* 1999). Other EBM concerns are less for the remote Canadian seamounts than for those in the Azores, where coral and benthos damage is reported and there are serious turtle by-catch issues in the surface longline fishery for swordfish (Morato *et al.* 2001).

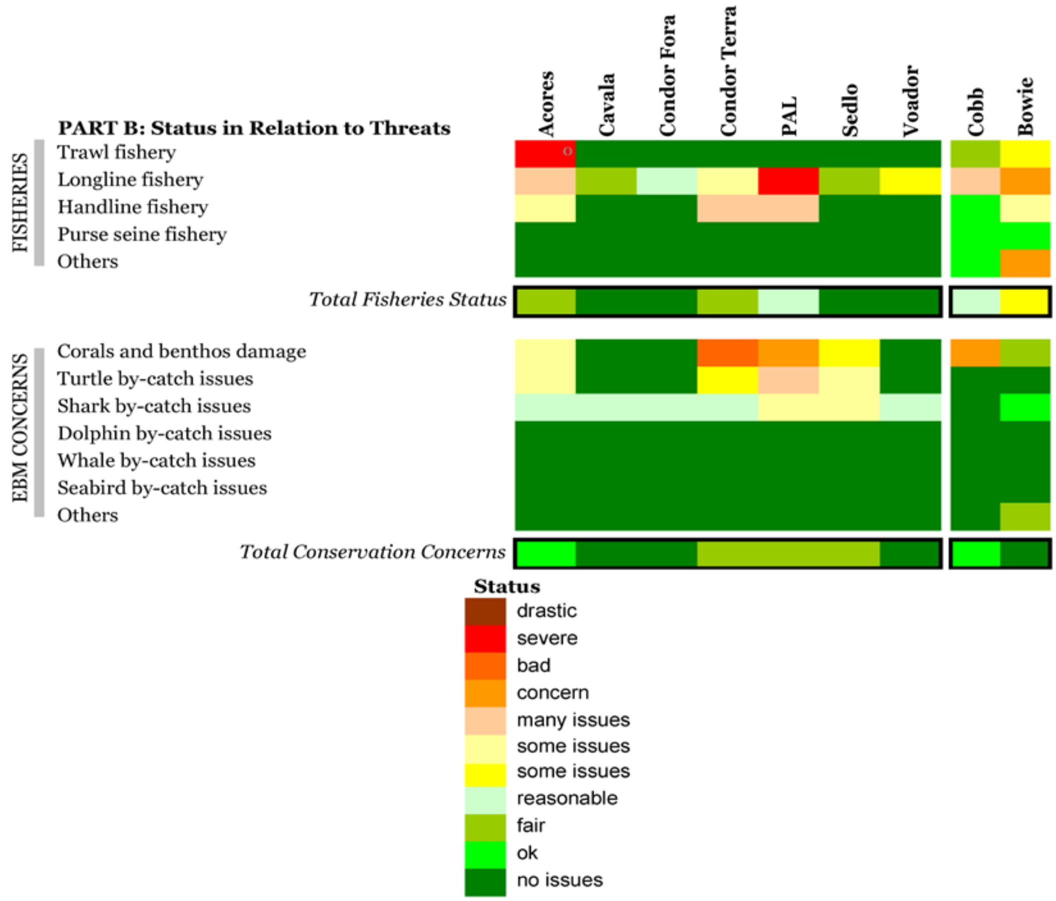

Figure 21.3 Threats—EEF example for seven Azores and two Canadian seamounts.

Conclusions

Seamounts are important islands of biodiversity in the surrounding ocean. Seamount fish and benthic structuring organisms such as corals and sponges can have very long lives. The extent to which 'seamount fishes' rely on benthic structure for shelter, feeding, spawning and rearing is unknown, but is likely significant. On the darkside, we present a history of serial depletion, destruction of benthos and handwringing about research costs and toothless international instruments.

On the bright side. We are now aware of these fragile but fascinating habitats. We have a better sense of fishing levels that seamount populations might withstand. We can draw on indigenous and artisanal fisheries for elements of sustainability. There is a growing international will to ban high seas trawling, (with the exception of Canada and Iceland). MPAs have been set up and more are in the works. There are proven vessel monitoring systems, remote sensing satellite systems, and promising low-cost innovations such as ocean gliders. It may be that the depth of our knowledge is starting to exceed that of our ignorance.

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