

The conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction: the economic problem

Charles Perrings

International Institute for Sustainability

Arizona State University

Box 873211,

Tempe,

AZ 85287-3211,

USA

Tel: + 1 480 965-1421

e-mail: Charles.Perrings@asu.edu

1. The context

The context to this paper is the difficulty – recognised by the Conference of the Parties (COP) of the Convention on Biological Diversity – of protecting deep seabed genetic resources and of conserving and sustainably using biodiversity in marine areas beyond the limits of national jurisdiction. The COP has identified a number of actions including the establishment of networks of marine protected areas (MPAs) that require international coordination. The concerns that motivate such actions are explored in some detail later, but include the effects of pollution of marine environments, sustainability of the commercial exploitation of fish and other marine animals, the transmission of pests and pathogens in ballast water, bottom trawling that harms biodiversity in the substrate, sea mounts and deep water corals, and the habitat disruption caused by the mining of seamounts for ferromanganese crusts. Hydrothermal vents are susceptible to damage from mining for polymetallic sulphides, as are bacteria in gas hydrates (Pew Commission, 2003a; FAO, 2004; UN, 2004a). I consider the socio-economic factors affecting international coordination of actions to address these threats. These include the institutional and market conditions under which marine resources beyond the limits of national jurisdiction are exploited, the importance of the environmental effects of economic activities that are external to the market, the nature of the public good to be protected by coordinated actions, and the options open to the international community to address the problem.

The resources at issue are those in both the high seas and the ‘area’ defined by the UN Convention on the Law of the Seas (UNCLOS) as the seabed and ocean floor beyond the limits of national jurisdiction. National jurisdiction includes both territorial waters and exclusive economic zones (EEZs). Most signatories of UNCLOS as well as the majority of non-signatories claim territorial sea of

12 nautical miles or less, together with a contiguous zone of 24 nautical miles. However, most coastal states also claim an exclusive economic zone of up to 200 nautical miles. A small number of states – mostly non-signatories of UNCLOS – claim territorial waters beyond 12 miles (UN, 2004a).

Under UNCLOS the Area and its resources are defined to be the common heritage of mankind, the exploration and exploitation of which is, in principle, to be carried out for the benefit of mankind as a whole. However, UNCLOS does not contain any provisions relating to the conservation or use of biodiversity, except where threatened by mining activities. Hence exploitation of the biological resources of the high seas and the sea bed is currently largely unconstrained by UNCLOS, though it is partially regulated by a plethora of bilateral and multilateral agreements. The problems posed by common pool resources to which access is only partially regulated are relatively well understood by economists. Considerable attention has been paid to the issue of the global commons recently and this work is reviewed in section 2 of this study. Section 3 then considers the economic value of the resources of the high seas and the seabed beyond national jurisdiction, and identifies areas in which current instruments of governance have left the resource exposed. The evidence from fisheries is used to indicate the nature of the problems posed by partially regulated access to marine biodiversity, in different regional commons. A fourth section considers the socio-economic determinants of the effectiveness of the main policy options currently being considered, and a final section offers a number of conclusions and identifies areas where further work is most required.

2. The problem of biodiversity conservation in the global commons

There are two main problems to be confronted in the conservation of marine biodiversity. The first is the public good nature of many conservation activities. This leads to the under-provision of national conservation efforts, and requires international coordination and funding of conservation in areas beyond national jurisdiction. The second is the harm done to marine biodiversity as an incidental but uncompensated effect of private economic activity. This results from the failure of markets to reflect the full costs of land based activities, as well as fishing, aquaculture, marine transport, seabed mining and exploration, and ocean dumping. It results in unwarranted levels of damage to marine organisms and habitats. The distribution and characteristics of marine biodiversity determines both the extent of the public good offered by conservation activities, and the impact of biodiversity externalities. The fact that the vast majority of marine organisms are to be found in benthic environments indicates that activities that damage the sea bed – mining, exploration, bottom trawling, ocean dumping - may be expected to impact more species than activities that affect pelagic environments. At the same time, the damage to species in benthic environments is likely to be more localised than damage to species in pelagic environments, where stocks of migratory fish, turtles, cetaceans and some seabirds straddle both waters in national jurisdiction and the high seas.

Public goods

The global commons are public goods (or bads in the case of the pathogen environment) that affect people globally. Public goods are those that satisfy one or both of two conditions in some measure. First, they are non-exclusive – once provided, people cannot be excluded from them. Second, they are non-rival – their consumption by one person does not diminish the amount available to others. International public goods are frequently defined in terms of their consumption by nation states (Barrett, 2005). Hence a global public good is frequently defined as one that is available to all countries, and whose consumption by any one country does not diminish the amount available to other countries. The climate system is the best-known example. By this definition biodiversity conservation is indeed a global public good since any diminution of the gene pool affects all of mankind. But conservation of particular set of habitats or group of species may also be a regional public good, which means that the benefits accrue to a particular group of countries only. It may also be a national or local public good, implying that its benefits fall entirely within a single nation state (Perrings and Gadgil, 2003).

The non-exclusiveness of international public goods at any level leads to the so-called free-rider problem, by which each country has an incentive to take advantage of the efforts of others. Since no one country can capture the benefits of its conservation efforts, conservation will be underprovided. There will be too little conservation effort relative to the socially optimal outcome, and all countries will suffer a loss of well-being relative to the socially optimal outcome. The number of countries affected in any case depends on the physical reach of the resource, or the area over which quantitative or qualitative changes in the resource affects peoples' well being. Sandler (2005), using the language of transboundary pollution control, refers to this as the 'region of spillovers'. The physical reach of a resource defines both the nature of the public good – whether it is a global, regional, national or local public good – and the natural scale at which it should be governed.

If the conservation of some group of species within one jurisdiction confers benefits on people living within another jurisdiction, then by the principle of subsidiarity, conservation should be coordinated between those two jurisdictions. If it is not, the external benefits of conservation will be ignored and too little conservation will be undertaken. It follows that the natural scale of governance of a global public good is global, implying that the natural instrument of governance is an intergovernmental body or multilateral agreement. The natural instrument of governance of a regional public good, by contrast, is a body representing the countries of the affected region, and the natural instrument of governance of a national public good is the nation state (Sandler, 2005).

The non-exclusive and non-rival nature of public goods is only partly a reflection of the good itself. There are some goods that are quintessentially public. The ozone layer and the actions taken to protect it are an example of that (Barrett, 2004). However, many goods are non-exclusive not because of the nature of the good, but because of the structure of property rights. Hardin's 'tragedy of the commons' is a case in point. This includes many of the common pool environmental resources that have been overexploited in the past. The high seas and the seabed are a classic example.

While the high seas remain an open access resource, coastal nation states have significantly extended property rights beyond their traditional terrestrial limits. The extension of territorial waters to 12 nautical miles and the declaration of 200 nautical mile exclusive economic zones (EEZs) has effectively extended national property rights over all of the most important fishing grounds, for example. Outside of the EEZs multilateral environmental agreements have attenuated access rights to many other marine resources, but as the commercial potential of resources in the UNCLOS 'area' become clearer there will continue to be pressure for further extension of national rights, particularly where the outer limits of the continental shelf extend beyond 200 nautical miles. In the meantime, however, the right of free access ensures both the non-exclusiveness of conservation efforts in those systems, and the overexploitation of the resource.

The latter problem is considered in the following section. An important qualification to the free rider problem is that the degree to which free riding matters varies with what is called the 'aggregation technology'. This indicates how the contributions of different countries aggregate to affect both the quality of the public good and the incentives to free ride (Sandler, 2005; Barrett, 2004). The classic international public good is the simple sum of the contributions by each country, implying that all contributions are perfectly substitutable (e.g. carbon emission control). But there is a wide range of aggregation technologies, some of which are highly relevant to the problem of marine biodiversity conservation. They include weighted sum (e.g. ozone control), best and better shot (e.g. information on disease control), weakest and weaker link (e.g. communicable disease control), and threshold technologies (e.g. regional flood control). Of these, free riding matters least in best and better shot, and threshold aggregation technologies. It matters the most in the case of weakest link technologies (Sandler, 1997; Sandler, 2005).

The development of marine protected areas has sparked a considerable amount of research into the best areas to protect in order to meet a number of goals, including the support of fisheries. It has been found, for example, that protecting spawning grounds offers more benefits, in terms of larval dispersal, than protecting randomly selected areas. Depending on where spawning grounds are located, this may make the aggregation technology lie anywhere between best shot or weakest link. Since the effectiveness of conservation efforts depends in part on natural conditions and in part on the resources available to establish a protection regime, it may be that the most important areas to protect lie are the primary responsibility of the nations least able to protect them. This issue is discussed further below.

Externality

The second problem to be addressed in the conservation of marine biodiversity is the external effects of a range of polluting land-based activities as well as shipping, fisheries, mariculture, seabed mining and exploration, and ocean dumping.

Land-based activities remain the principal source (something like 80 per cent) of marine pollution. The most important of these are sewage, nutrients, synthetic organic compounds, sediments, litter and plastics, metals, radionuclides, oil/hydrocarbons and polycyclic aromatic hydrocarbons (PAHs) (UN, 2004a). While this affects coastal and estuarine systems more than areas beyond national jurisdiction, it is not limited to those systems. Sewage discharges from coastal populations are a particular problem in coastal waters. All of the projected growth in human population over the next few decades is expected to occur in cities, mostly in coastal areas, this source is expected to remain the most serious problem. But it is not the only one.

Global nitrogen deposition is now dominated by anthropogenic sources, almost all land based. The application of fertilizers in agriculture, fossil fuel burning, land clearance and biomass burning have all added to the nutrient load especially in coastal and estuarine systems (Vitousek et al, 1997). This has led to the development of large anoxic zones in some coastal areas with negative effects on the fish and other marine organisms in those areas. Other effects include toxic algal blooms and damage to seagrass beds. Moreover, the damage extends to the high seas. Nitrogen and other pollutants, such as persistent organic pollutants (POPs), are transported globally in the atmosphere. A new concern relates to emissions of CO₂. Something like a third of all anthropogenic CO₂ added to the atmosphere is deposited at sea, and is now thought to be increasing the acidity of the oceans. More generally, anthropogenic climate change is expected to include changes in the spatial distribution and composition of marine biodiversity as a result of changes in sea surface temperatures (Pew Oceans Commission, 2003a).

Pollutants are also transported within the marine system by currents. For example, the Arctic ocean - parts of which lie beyond national jurisdiction - is biologically highly productive around ice edges and polynyas. This is due to the effect of circulating and mixing water layers driven by both ocean currents and air streams, and is therefore sensitive to the effects of land-based atmospheric and water pollution. This includes radionuclides, heavy metals, POPs and hydrocarbons, as well as the climatic effects of greenhouse gas emissions.

A new source of pollution (which simultaneously meets a growing proportion of the demand for fish protein) is aquaculture - the farming of aquatic organisms. While there has been considerable development of aquaculture in inland areas, the main source of growth is now in marine or brackish coastal waters. The contribution of aquaculture to global fish production has risen from 3.9 per cent in 1970 to 27.3 per cent in 2000, and average annual growth rate of 9.2 per cent compared with 1.4 per cent for capture fisheries. While aquaculture has considerable potential for meeting local food needs and for poverty alleviation, it also has potentially serious environmental consequences including genetic pollution of wild stocks, disease transmission and the human risks posed by antibiotic use (FAO, 2004). All of these sources of pollution involve market failures. That is, the markets for the goods and services associated with the production of pollution do not reflect the cost to society of that pollution. It

means that people whose activities on land have unintended (but not unforeseeable) consequences at sea have no incentive to take the external costs of their activities into account.

The two main issues with shipping are the effects of pollution, especially oil, and the movement of species in ballast water. Agreements exist to phase out single hull oil tankers¹, but pollution events remain a common occurrence. Regulations also exist to reduce pollution from sewage discharges at sea, but this too is a source of localised pollution with potentially adverse effects on marine biodiversity. Of more concern is the role of ballast water in the redistribution of marine organisms, including a range of pests and pathogens. The problem of alien invasive species is increasingly recognised to be one of the main environmental consequences of globalisation, the closer integration of world markets and the growth of trade. While most attention has been paid to human pathogens and the risks of global pandemics, the redistribution of organisms through the transport of goods and services has already resulted in biological invasions that have had major consequences for both terrestrial and aquatic systems. The zebra mussel in the Great Lakes and the Mississippi and the comb jelly in the Black Sea are two amongst many examples of invasive species introduced via ballast water discharges that have transformed a local ecosystem, with severe consequences for the economic activities dependent on that system. Once again, it reflects a market failure. Although there are no good estimates of the economic costs of invasive alien species introduced in this way (Perrings, Williamson and Dalmazzone, 2000).

The general problem of fisheries is discussed in section 3 below. Much of the impact on marine biodiversity of fishing activities occurs with the EEZs of nations states, and therefore within areas under national jurisdiction. So far as areas beyond national jurisdiction is concerned, a particular problem is the effect of bottom trawling on marine habitats, especially seamounts and cold-water and deep-water corals. This concern is strong enough that a number of countries have been pressing for a global moratorium on bottom trawling or at least for time-limited regional bans (UN, 2004b).

Seamounts are also affected by the mining of cobalt-rich ferromanganese crusts that cover the hard rock substrates both on seamounts and submerged volcanic range. This is expected to affect the communities that depend on those habitats. Hydrothermal vents and cold seeps are localised 'hotspots' of highly endemic species dependent on chemosynthesis for their nutrition including micro-organisms living off the carbon provided by the petroleum within deep-ocean sediments, tube worms, mussels, sponges, snails, eels, crabs, fish and especially bivalves (clams). Their depth, typically more than 2000m means that they are not directly affected by bottom trawling, but are susceptible to the effects of seabed exploration and mining activities (UN, 2004b).

3. The economic value of marine ecosystems

¹ Under the International Convention for the Prevention of Pollution from Ships, 1973, category 1 tankers (pre-MARPOL tankers) should be phased out by April 2005, and category 2 and 3 tankers (MARPOL tankers and smaller tankers) from 2015 to 2010. UN, Oceans and the law of the sea: Report of the Secretary-General, Fifty-ninth session Item 51 (a), UN A/59/62.

While the oceans are infinitely valuable as a crucial element of the life support system, they have historically also been the basis for a range of economic activities of which fisheries is the most significant. In addition, the oceans have supported the development of the world trade system through the development of marine transport. The relative economic importance of fisheries and marine transport may have declined over the last century as other forms of transport and other sources of food supply have been developed, but they are still important elements in some national economies and a primary source of protein in the human diet in many low income food deficit countries, including China (Borgese et al, 2001). For some developing economies fish exports are a significant source of foreign currency earnings, and fish production is a significant source of employment and food security. In the Faeroe Islands, the Federal States of Micronesia, Greenland, Iceland, the Maldives and Saint Pierre and Miquelon, for example, fish and fish products contribute more than half of the total value of exports. Fish currently provide 2.6 billion people with at least 20 percent of their average per capita animal protein intake, and the share of fish proteins in total world animal protein supplies stands at around 16 per cent (FAO, 2004).

Fisheries are both the main source of stress on marine biodiversity both within and beyond the limits of national jurisdiction, and the main source of direct market value of marine systems. Newer activities – especially mining of the seabed, aquaculture and ocean dumping – that have added to the direct market value of marine resources, have also increased levels of stress on marine biodiversity, especially in deep waters. It is technologically possible to exploit oil reserves up to 2000m below the seabed, and with many as yet unexploited petroliferous basins within abyssal zone or deep waters, there is scope for commercially viable production of oil from deep waters. Once again, while this increases the economic value of such resources, it also increases the likelihood of localised damage to biodiversity. Similarly, while the potential for deep seabed mining for polymetallic nodules, polymetallic sulphides and cobalt-bearing ferromanganese crusts increases the value of seabed resources, it also damages marine organisms in the abyssal plains, hydrothermal vents and seamounts (UN, 2004b).

Aside from the direct value of the ocean's biological resources, marine organisms have an indirect value in the support they offer to a range of ecosystem services. A large part of the value of the biodiversity, for example, derives from the fact that it helps to protect the resilience of ecological systems. In many systems, a change in the composition of species that affects key processes will simultaneously change both the ecological dynamics and the economic value of the system. Whether the 'mining' of some species disrupts key processes depends on whether there are other species that can take over its ecological functions. Evidence from freshwater aquatic ecosystems suggests that the most sensitive components of food webs, energy flows and biogeochemical cycles are those where the number of species carrying out that function is very small (Schindler 1990). It has long been thought that this is not the case in open oceans where pelagic organisms cannot control the structure of the system (Steele, 1989), but it is the case with any aquatic systems dominated by substrate, such as near-shore ecosystems, coral reefs or the benthic communities of the open oceans. In these systems the

conservation of biodiversity is an important means of reducing uncertainty. So long as the depletion of ecological resources and the generation of ecologically significant waste lies inside the carrying or assimilative capacity of the system, local effects tend to remain local and the dynamics of ecological systems tend to remain predictable.

While there have been numerous efforts by economists to value terrestrial biodiversity (e.g. Pearce and Moran, 1994; Heywood 1995), there have been a few attempts to value the contribution of marine biodiversity. Nor have there been many attempts to value ecosystem services as distinct from biological resources (Heal, 2000). Perhaps the best known is the exercise by Costanza et al (1997) which extrapolated from a range of socio-economic studies of the value of particular components of marine ecosystems to assign a global value to marine systems. Local estimates were obtained for a range of alternative uses for 17 ecological functions. These were used to define values for ecosystem services per unit area in each biome. Aggregation then proceeded by multiplying the estimate by the area of biome, and summing across biomes. First, it found that ecological services such as gas regulation, disturbance regulation, waste treatment and nutrient cycling account for the bulk of the estimated value of ecosystems. These services are largely outside of the market system. Second, it found that marine systems contribute around two thirds of the total value ecological services. Something over half of this derives from estuaries, coastal wetlands, beds of sea grass and algae, coral reefs and continental shelves. But although it indicates that coastal and estuarine systems contribute a disproportionate share of the value of the world's ecosystem services, it also showed that the areas beyond national jurisdictions are have a very significant role to play. The exercise is crude, but it nevertheless offers some information about the relative importance of components of the biosphere. It also says something about the capacity of the market to signal resource scarcity in different biomes.

Ecosystems can be thought of as a set of assets in the same way that we think about other assets. That is, the stock of assets available to us includes not only produced capital, and human capital but also natural or environmental capital. Most existing measures of capital neglect the latter. The most inclusive of all SNA measures, Net National Product (NNP), still excludes depreciation of both human and natural capital along with transboundary environmental flows. One attempt to capture the depreciation of environmental assets is the genuine savings index (GSI) due to Hamilton and Clemens (1999) and now referred to as Adjusted Net Savings. Dasgupta (2001) has developed the same idea, calling it genuine investment. It is a measure of the change in a country's wealth. Estimates of adjusted net savings are generally lower than other savings measures, reflecting the depreciation or degradation of many environmental assets. Particularly worrying is the case where positive net savings turn into into negative adjusted net savings, implying that the countries concerned are eating into their natural capital. When the effect of population growth is taken into account, the position is even worse. Dasgupta (2001) showed that inclusive wealth has in fact declined in many countries in the last three decades.

Of course there are no estimates of changes in the value of common capital stocks – including the high seas and the seabed. At present the best economic data relate to the direct use value of fisheries. There is some uncertainty about fisheries data, particularly relating to China whose recorded production has increased dramatically in the last decade. Elsewhere, the general trend is for per capita fish production from all sources to have stabilized over the last decade. The continued growth in aggregate production that this implies is largely accounted for by aquaculture, of which inland aquaculture accounts for more than two thirds. Aggregate exports of fishery products amounted to some \$58 billion in 2002, an increase of 45 per cent over the value ten years earlier, but the quantities traded have remained more or less the same since 2000 (FAO, 2004). Marine capture production has been reasonably stable (allowing for natural fluctuations in anchoveta and similar species), and the FAO reports that allowing for the reduction in by catch due to improved gear selectivity, fishing management practices and the adoption of zero discard policies in some countries, marine capture levels have been reasonably stable for two decades (FAO, 2004).

The main species caught remains the anchoveta. Catch of this species, along with other Clupeoid species (such as Atlantic herring, Japanese anchovy and European sardine), is extremely sensitive to environmental conditions, and is highly variable. Catches of the Gadiforme species (cods, hakes and haddocks) continue to decline and in 2002 were at the lowest level since 1967. However catches of tuna and related species are increasing, particularly tropical species such as skipjack and yellowfin tuna caught in the central Pacific and western Indian oceans. Catches of other pelagic species (capelin, Chilean jack mackerel and chub mackerel) are also increasing. Like the Clupeoids, catches of cephalopods is highly variable but this appears to reflect catch-population dynamics rather than environmental conditions. Catches of at least some species (Eastern Pacific jumbo flying squid) are currently increasing sharply, but catches of other species that had increased sharply in the late 1990s (Japanese flying squid and Argentine shortfin squid) are now in decline (FAO, 2004).

In areas beyond national jurisdiction, the most important developments in capture fisheries concern the epipelagic and deep-water species. In the most recent update of the FAO data base, an additional 35 mostly deep water species were added to the list of oceanic species being caught partly reflecting an increasing awareness of these species but partly also reflecting an increase in effort in deep water fisheries following technological developments that have made more of the mesopelagic and bathypelagic zones exploitable. The use of satellite-based geographical positioning systems, acoustic telemetry and seabed swath mapping have all made it possible to set trawls with great accuracy in both vertical and plane coordinates at depth (FAO, 2004; Garibaldi and Limongelli, 2002).

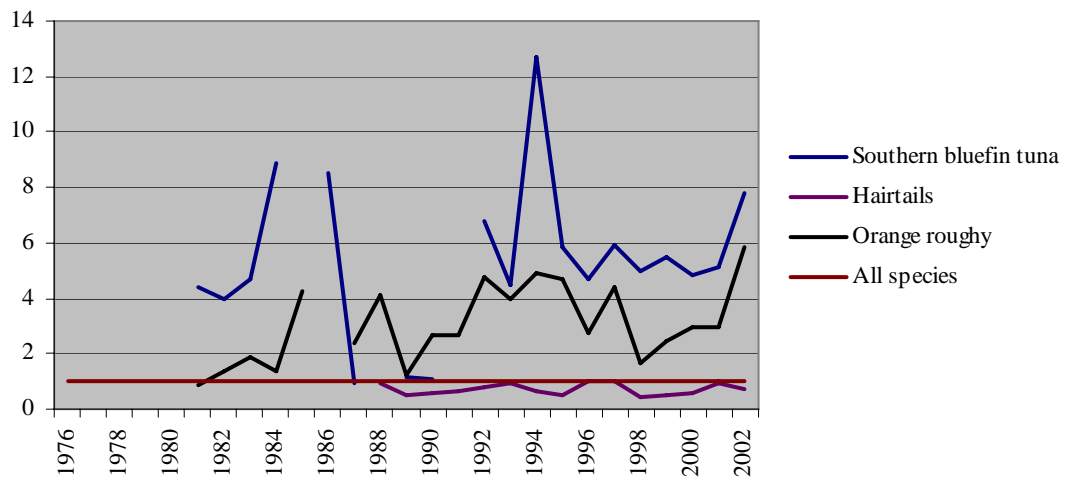
In 2002, all ocean species accounted for 11 per cent of the global catch, and catches of both oceanic tuna and oceanic squids were both higher in that year than at any time in the past. Deep water catches from countries excluding China accounted for 4.7 per cent of total marine fish catches, and catches from China alone, almost all largehead hairtail accounted for a further 1.5 per cent. Other commercially exploited deep-water species include orange roughy, oreos, alfonsinos, cusk eels and brotulas,

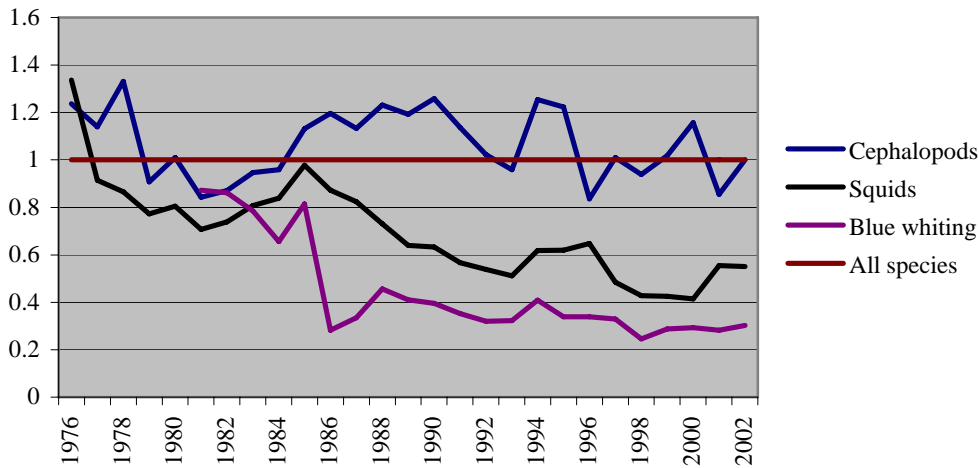
Patagonian toothfish, Pacific armourhead, sablefish, Greenland halibut, morid cods and various species of *Scorpaenidae*. Away from seamounts, Gadiformes are the most commonly exploited deep-water species. A number of deep-water species, such as blue whiting – which accounts for around half of all deep water catches – are caught for reduction into fishmeal. All are characterised by slow growth rates and late age at first maturity which implies low sustainable yields (Garibaldi and Limongelli, 2002).

Part of the driving force behind the increase in deep water catches is the growth of the international market in fish and fish products. In 2002, exports of oceanic species accounted for 10 percent of the value of total exports of fish and fishery products. While the physical quantity of exports of oceanic species has increased by a factor of five since 1976, the real value of exports has increased by a factor of more than 10 (FAO, 2004). This is largely driven by rising prices for particular high valued species such as southern blue finned tuna and orange roughy (see Figure 1). Export prices for many other oceanic species, particularly low-valued industrial species like blue whiting, have fallen relative to average export prices.

A second factor is the declining productivity of other fisheries. Between the 1960s and the 1990s, for example, catch per unit effort in the East China Sea declined by a factor of three, and within the coastal fisheries there had been a switch from large, high-valued, predator fish to smaller, low valued planktivorous fish, and from mature to immature fish (FAO, 1997). This is reflected in the FAO's report on the number of fish stocks exploited at or above maximum sustainable yield (Figure 2)

Figure 1: Export prices of oceanic species prices relative to all species caught, 1976-2002, US\$

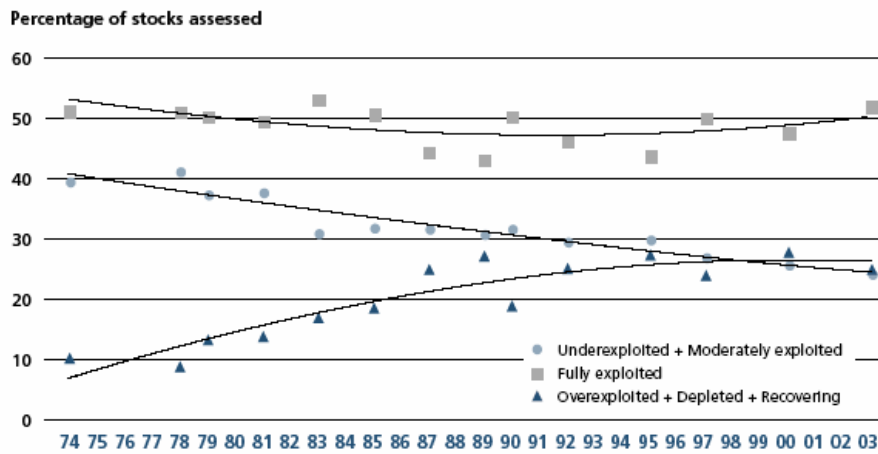




Source: Fishery Information, Data and Statistics Unit, Food and Agriculture Organization of the United Nations (FAO). 2005. FISHSTAT Plus: Fisheries commodities production and trade 1976-2002 dataset. Rome: FAO.

At the same time the tightening of regulations within national jurisdictions has increased the attraction of fishing in the high seas where international law and management mechanisms are unable to operate effectively. The freedom to fish on the high seas means open access to deep water fisheries, while the lack of any supranational authority means –despite the Compliance Agreement – that there is no body with a mandate to enforce compliance with agreed conservation measures (FAO, 2004).

Figure 2: FAO estimates of number of stocks overexploited, 1974-2003



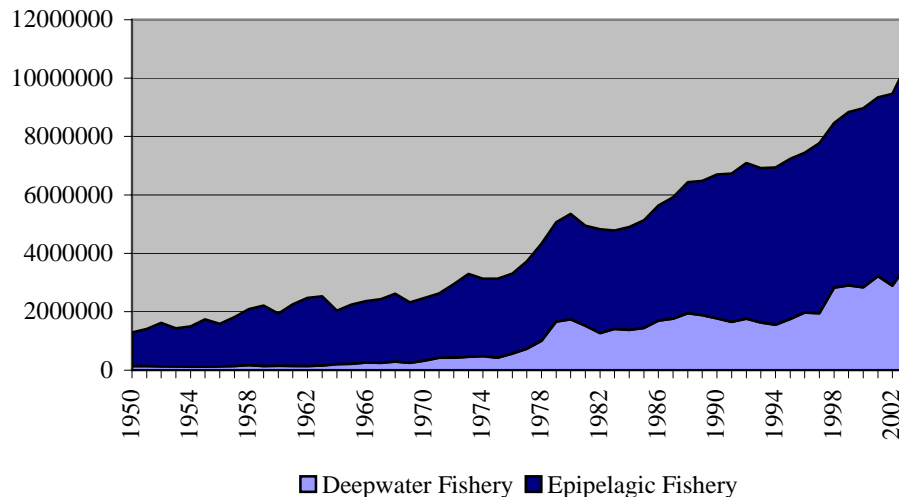
FAO (2004)

The net effect is that the level of fishing effort committed to oceanic species, and to deep water species in particular, has increased relative to the level of effort in other capture fisheries. The growth in output of oceanic fisheries in the last half-century is summarised in Figure 3.

The epipelagic fisheries are more important in terms of both quantity and value, but the deep water fisheries are expanding more rapidly. Indeed, while the deep water fishery represents only 5 per cent of the total capture fisheries (Table 1), it is one of the fastest growing sectors. Figure 4 shows indices

of deepwater catches relative to the total marine catch over the last five decades and shows that the rate of growth of deep-water fisheries considerably exceeds that of marine capture fisheries as a whole.

Figure 3: Growth in output of epipelagic and deepwater fisheries, 1950-2002



Source: Fishery Information, Data and Statistics Unit, Food and Agriculture Organization of the United Nations (FAO). 2005. FISHSTAT Plus: Capture production 1950-2003 dataset. Rome: FAO.

Table 1: Growth of deep water fisheries, 1952-2002

	1952	1962	1972	1982	1992	2002
World excluding China	232574	360125	870693	1726181	2348990	3325006
World including China	468174	759125	1366193	2219554	2971233	4613684
Fraction of total marine catch	0.02	0.02	0.03	0.03	0.04	0.05
Total marine catch	20724990	37349510	53511237	65787067	78878019	84132582

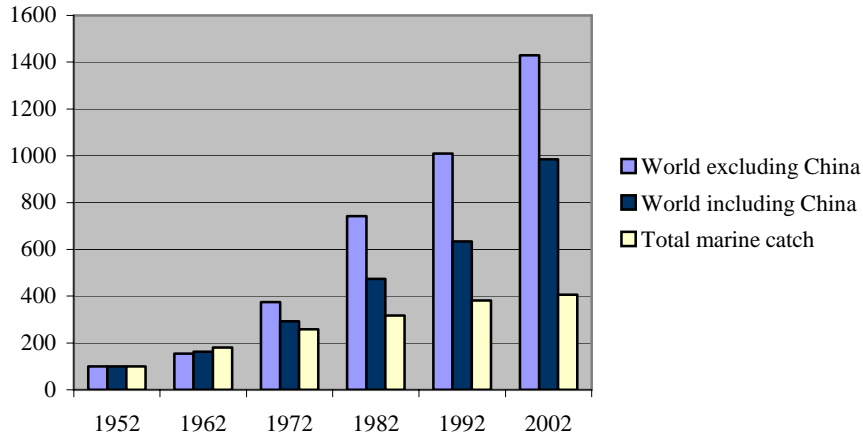
Source: FAO (2004).

Deep-water fisheries have developed largely in the Pacific and the Atlantic, most of the growth occurring in the Atlantic (Figure 5). There are two issues associated with deep water and epipelagic fisheries. The first concerns the overfishing of the stocks themselves due to the open access nature of the resource. There are a number of well documented examples of overexploitation followed by collapse in epipelagic and deep water fisheries. The general picture is that while overall catches are still increasing in some sea regions, they are declining in twelve regions, and in four the decline has been very sharp. In the Northwest Atlantic, for example, total catches have declined by 50 percent since 1968. In the Southeast Atlantic, they have fallen by 47 percent since 1978, and in the Southeast Pacific by 31 percent since 1994. In most cases this is ascribed to overfishing (FAO, 2004).

Amongst oceanic species there are numerous examples of fisheries that have collapsed following a sharp increase in fishing effort. Japanese flying squid and Argentine shortfin squid have already been mentioned. Another example is the Pacific pelagic armourhead fishery on the Emperor Seamount chain and the Northern Hawaiian Ridge. This was fished by Russian and Japanese vessels from 1969 and

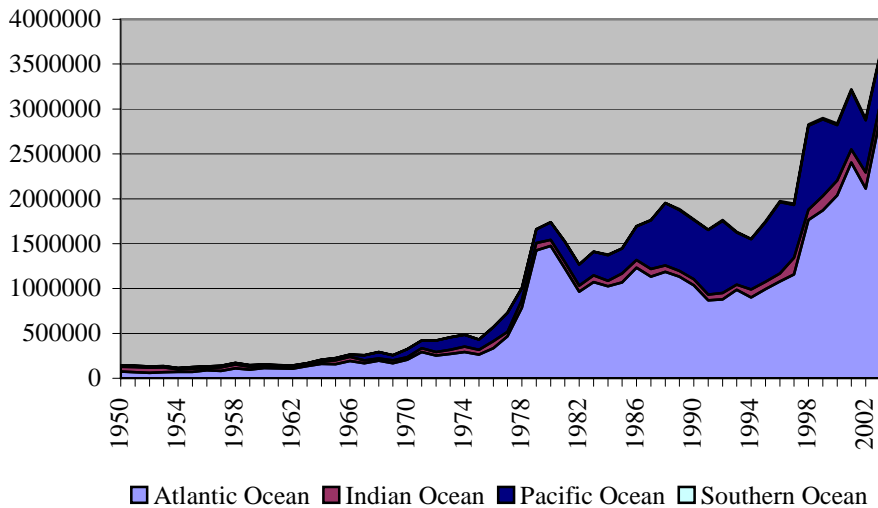
yielded catches up 48000 tonnes per year for eight years. In the next five years catches fell to less than 10000 tonnes, and now the fishery no longer exists (FAO, 2004).

Figure 4: Production indices of deepwater and global fish catches, 1952-2002



Source: Fishery Information, Data and Statistics Unit, Food and Agriculture Organization of the United Nations (FAO). 2005. FISHSTAT Plus: Fisheries commodities production and trade 1976-2002 dataset. Rome: FAO.

Figure 5: Landings of deepwater species by ocean, 1950-2002, (tonnes)



Source: Fishery Information, Data and Statistics Unit, Food and Agriculture Organization of the United Nations (FAO). 2005. FISHSTAT Plus: Capture production 1950-2003 dataset. Rome: FAO.

Other important marine communities that are vulnerable to bottom fishing include slow growing cold water corals that are associated with a rich diversity of flora and fauna, including molluscs, sponges and crustaceans, that may be abundant in the corals but are extremely rare elsewhere. Although the science is very sketchy at the moment, many species of fish identified in particular deep water corals appear to have an extremely limited distribution elsewhere.

An understanding of the economic implications of the impacts of economic activities on biodiversity in deep waters awaits an improvement in the science of these systems, and their interactions with more directly exploited systems. There are still a paucity of systematic data on most benthic organisms, on the effect of different types of pollution on marine organisms, on the functional diversity of micro-organisms, on the structure and dynamics of deep-water food webs, on the biological and other pathways for pollution in deep-water ecosystems, on the links between biodiversity, productivity and other ecological processes, the indirect ecological impacts of the overfishing of top predators, and the effect of alien species on different ocean ecosystems (UN 2004). Without such data it is impossible to calculate the value of the indirect consequences of bottom trawling in deep waters, and there is currently no economic literature on this problem.

4 Current solutions

The obstacles to biodiversity conservation in areas beyond national jurisdiction are formidable. They include the open access to fisheries that comes with freedom of the high seas, the weakness of the incentive to comply with the terms of the main multilateral environmental agreements and the lack of a supranational authority to enforce compliance, the persistence of national subsidies, the dearth of information about the physical and biological systems involved, the incompleteness of markets for marine goods and services along with the public good nature of conservation activities. All of these militate against effective conservation of marine resources. They mean that those who exploit the high seas and the sea bed have no incentive to take account of the effects of their activities on marine biodiversity.

Current solutions to the problems posed by open access include multilateral environmental agreements to protect the global commons; specific agreements to protect fish stocks on the high seas; the development of regional groupings to address specific conservation and management issues (of which the Regional Fishery Management Organisations (RFMOs) are the most important; the development of Marine Protected Areas (MPAs), and measures to address particular externalities such as oil pollution and invasive species in ballast water. All are designed to mitigate the effects of access open: i.e. to solve the problem posed by non-exclusive use of marine resources in areas beyond national jurisdiction. An additional solution – the removal of subsidies – addresses the open access equilibrium rather than the problem of open access itself.

Multilateral environmental agreements

The institutional environment within which sea areas beyond national jurisdiction are exploited is given by the set of multilateral agreements governing both marine organisms and the seabed. The most encompassing of these are the Convention on Biological Diversity (CBD), the UN Convention on the Law of the Sea (UNCLOS) and its instruments, the International Seabed Authority and the International Tribunal for the Law of the Sea. But there are many other agreements dealing with the conservation of marine biodiversity, ranging from species-specific instruments such as the North

Atlantic Fur Seal Treaty or the International Commission for the Conservation of Atlantic Tuna (ICCAT), through instruments dealing with groups of species such as the International Whaling Commission, to framework agreements such as the Antarctic Treaty which provides a framework for regulating the use of all marine and terrestrial resources south of the 60° latitude. Despite the existence of these agreements, however, the high seas are regarded as effectively unregulated (FAO, 2004).

Why? Beyond areas of national jurisdiction the Convention on Biological Diversity has nothing to say about particular species or assemblages of species. Instead it refers to activities and processes carried out under the jurisdiction or control of a signatory that have an impact biological diversity. Because they have no jurisdiction over biodiversity located in areas beyond the limits of national jurisdiction, the signatories to the convention have no direct responsibility for its conservation and sustainable use. In these areas, therefore, the CBD requires signatories to cooperate to achieve the goals of the Convention, but there are no penalties for non-cooperation and no incentives to cooperate.

Because the vast majority of marine organisms occur in benthic ecosystems, and because the seabed is the focus of the UNCLOS, the CBD secretariat has requested UNCLOS to consider what can be done within its provisions to enhance the protection of benthic biodiversity. A major difficulty with this is that Article 87 of the Convention affirms the principle of the “freedom of the high seas”, and specifically refers to the “freedom of fishing”. There is a qualification to this – that freedoms should be exercised with due regard to the interests of others – but the implication of “freedom of the high seas” is that open access is enshrined as a fundamental principle the Convention. The qualifications to the freedoms affirmed in Article 87 include a number relevant to fisheries. Specifically, they include a duty to cooperate with other states in the conservation and management of living resources (Article 118) and a duty to maintain or restore populations of harvested species at levels consistent with maximum sustainable yield (Article 119a). These obligations have not, however, been implemented, and freedom to fish on the high seas implies that many epipelagic and deep water fisheries are effectively unprotected (FAO, 2004).

Agreements to protect fish stocks on the high seas include the 1993 FAO Compliance Agreement, the 1995 UN Fish Stocks Agreement, the 1995 FAO Code of Conduct for Responsible Fisheries, and an International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing. The Compliance and Fish Stocks Agreements are both notionally binding, and do affect some heavily stressed fisheries. The Fish Stocks Agreement, for example, now extends over the high-seas areas adjacent to the EEZs of 51 countries (UN, 2005b). The Code of Conduct and its Action Plans, on the other hand, are voluntary. There have been no studies of the effectiveness of the incentives involved in these instruments, but experience with analogous instruments in terrestrial systems suggests that they are seldom effective in conditions where the incentive to defect (the gains from non-compliance) are significant (Barrett, 1994; 2003).

Regional groupings

There are currently twelve regional seas programmes, each involving a specific convention and action plan. They reflect a regional seas strategy that has a number of objectives, including the use of regional partnerships to achieve conservation goals, to strengthen national property rights, to translate regional seas conventions into national legislation, to coordinate management actions at the regional level (UN, 2004b). The most important manifestation of regional coordination is the RFMO, and much has been made of the potential role of RFMOs in addressing a range of problems. From an economic perspective, RFMOs and regional groupings generally are the appropriate level at which to manage environmental resources wherever the ecosystems concerned are regional in extent. In the case of straddling or migratory stocks, for example, the appropriate regional grouping will cover the sea areas within which those stocks move. The conservation of such stocks is a regional public good, and subsidiarity indicates that the right level of governance is the regional level (Sandler, 2005).

In principle, matching political, economic and environmental domains should promote efficiency. This is because the marginal benefit the public good supplied by the regional body, summed over regional members, can be equated to its marginal cost (Sandler, 2004). At the same time it minimises transaction costs by reducing the number of participants to those with a real stake in the public good, and builds trust by allowing repeated interaction between members over time (Sandler, 2004).

Under UNCLOS, it was envisaged that regional grouping would assume a substantial role in the protection of fish stocks, especially in areas beyond national jurisdiction, in providing information and advice on the conservation needs in those areas and on the outer limits of the EEZs, and in implementing agreements. Yet, as the FAO points out, UNCLOS does not confer any management authority on regional fishery bodies, and FAO considers many RFMOs are little different from open access regimes (FAO, 2004). Nevertheless, the RFMOs are still the preferred instrument for the regulation of fisheries in the high seas. The UN has urged states, through RFMOs, to prohibit destructive practices by vessels under their jurisdiction that have an adverse impact on marine ecosystems in areas beyond national jurisdiction, to address the impact of deep sea bottom trawling, to comply with existing obligations and to implement the International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing adopted by the Committee on Fisheries of the FAO (UN, 2004b).

While the RFMOs address at least some of the problems of international coordination identified in the literature – in particular they offer scope for repeated negotiation amongst a relatively small number of parties – they cannot effectively establish exclusive rights for member states (Barrett, 2003, 2004). Some RFMOs have developed policies for non-members, but they do not have the capacity to deal with unregulated fishing by non-members. For example, the Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean (1992) bans fishing for anadromous fish (six species of salmon and steelhead trout). It includes agreements to prevent reflagging of vessels of contracting states and to prevent, where possible, fishing of anadromous fish by non-contracting states. But the

contracting parties have no legal capacity to do this as long as the Compliance Agreement has not entered into force. Moreover, the only sanctions open to them are trade sanctions, and these are only effective if the markets for anadromous fish all lie within the contracting countries (Barrett, 2004).

Despite the practical difficulties associated with them, regional groupings are still the preferred solution to the open access issue in areas beyond national jurisdiction. A recent interdisciplinary review of the problem of the Arctic, for example, proposes that the Arctic Council take the lead in identifying the most important changes expected to occur, to establish whether it is possible to prevent or mitigate these changes if society acts now before the changes occur and to evaluate the costs and benefits of mitigation and to propose coordinated policies for arctic countries for mitigation (or adaptation to projected changes where mitigation is not a viable option (Chapin et al, 2005).

In the Arctic case, though, the forces that are driving local change are global in nature, and hence mitigation actions need to take place at a global level if they are to be effective. Indeed, the same paper notes that the global community has a vested interest in enhancing arctic resilience precisely because the Arctic is biologically connected to the rest of the world through annual migrations of marine mammals and fish (Chapin et al, 2005). A similar concern has been expressed by the FAO over the effectiveness of regional approaches – that regional solutions may merely shift the problem from one marine area to another. This indicates the need for a global approach of the kind envisaged in the FAO Compliance Agreement (FAO, 2004). Indeed, some have argued that it implies the need for a Global Environmental Organisation analogous to the WTO (Esty, 2004).

Marine protected areas

The third preferred solution to the open access problem is the establishment of MPAs or Particularly sensitive sea areas (PSSAs). Indeed there is a strong trend towards the declaration of PSSAs, possibly as the precursors to the establishment of MPAs. Recent examples include a large sea area off the western coast of Belgium, France, Ireland, Portugal, Spain and the United Kingdom from the Shetland Islands in the north to Cape Vicente in the south, together with the English Channel and its approaches. There are also proposals to designate the Baltic Sea, the area of the Canary Islands and the Galapagos Archipelago as PSSAs. For areas beyond the limits of national jurisdiction, MPAs can potentially complement regional management agreements. The Conference of the Parties of the CBD has agreed to promote development of a global network of MPAs, building upon national and regional systems and including a range of levels of protection. In marine areas beyond the limits of national jurisdiction, it recognises that the establishment of MPAs depends upon UNCLOS for the legal framework. One candidate for this is the Arctic Ocean, and it is proposed that an arctic MPA should be zoned for specific uses, but that a substantial proportion should be in fully protected reserves (Chapin et al, 2005).

Overcapacity

The fundamental cause of overcapacity in the exploitation of common pool resources is open access. This has long been recognised to induce fishers to add capacity up to the point at which total costs are

equal to total revenues, i.e. up to the point at which rents are exhausted. It follows that subsidies that reduce total costs will further increase capacity. Current subsidies to the fishing industry take various forms, including grants towards the cost of vessel construction or the cost of increasing the capacity of vessels, direct subsidies on the cost of production and marketing, price support on fish and fish products. In all cases the effect is to exacerbate the overfishing induced by open access. The removal of subsidies is to be preferred to buy-back programmes.

The problem of externality

The problem of externality lies in the incompleteness of markets – which leaves some effects of economic activities unaccounted for. It is due in part to ignorance about the incidental impacts of particular activities, to the lack of property rights in those impacts and often to policies that exacerbate rather than alleviate the problem. It is not therefore surprising that the solutions explored by economists have tended to focus on the assignment of property rights and the provision of information to make markets more complete, together with the elimination of policies that compound the problem.

However, in the case of the external effects of shipping, mining, exploration and fisheries in sea areas beyond national jurisdiction, the scope for market solutions to externalities is strictly limited. Not only does open access to the high seas, enshrined in UNCLOS, make it impossible to assign rights to those resources, but the markets involved are international and are therefore subject to the General Agreement on Tariffs and Trade. This makes it difficult for individual nation states to take any action that may be interpreted as a restriction on trade, unless authorised by the environmental provisions in Article XX of the GATT, or the Sanitary and Phytosanitary Agreement.

There is a considerable literature on the impact of trade liberalisation on transboundary environmental externalities generally, and this literature shows that liberalisation of international markets that involve environmental externalities may not be welfare-enhancing unless the environmental externality is addressed at the same time. This means that it is not desirable to further liberalise trade in goods and services that have undesirable side effects, such as the introduction of invasive species, unless there are specific parallel measures to address the externality (Deere, 2001; Copeland, 2000; Margolis et al, 2005).

Some recent work by economists has explored the potential use of trade measures to deal with the particular problem of invasive species. Costello and McAusland (2003) have explored the use of tariffs on imports to reduce the damage costs from accidental introductions. They show that import tariffs will always reduce import volumes of risky species. They also show that a combination of port inspections together with tariffs on imported goods could be effective in reducing invasive species risks. Importers should apply a tariff that covers inspection costs plus the potential damage costs from outbreaks of pests undetected during inspections. The optimal level of tariffs in each case depends on the risk of invasion and any resulting damage (McAusland and Costello, 2004). While these instruments represent an effective way of addressing many of the biodiversity externalities of the growth in trade (Perrings et

al, 2005), they may not be appropriate to deal with effects that occur with the oceans, simply because the introduction of species to new ecosystems occurs before the vessel docks.

The proposed solution is an international agreement specifically on the problem of ballast water organisms. In 2004, the International Convention for the Control and Management of Ships' Ballast Water and Sediments was adopted to prevent the potential threats from marine organisms carried in ships' ballast water. The Convention establishes rules designed to prevent or at least to minimise the risk of invasive alien species in ballast water. It requires that the discharge of ballast water should only be conducted under an approved management plan, and that ports where cleaning or repair of ballast tanks takes place have facilities for receiving sediments (UN, 2005). As with other international agreements its effectiveness is likely to depend on the incentive to defect from the terms of the agreement.

If effective the agreement would go a long way to addressing the problem, but as with many other instruments in this area, it is hard to be confident that it will do what it is intended to do. Indeed, there is general concern about the ineffectiveness of agreement-based conservation and management of the biodiversity in sea areas beyond national jurisdiction. It is currently impossible to offer estimates of the social opportunity cost of damage to benthic habitats in the high seas, but the more that is understood about the richness of seabed habitats, and the relationship between the species in these habitats, the abiotic resources of the seabed, and pelagic fisheries, the more valuable seamounts appear to be.

5. Conclusions

The extension of national property rights over an increasing proportion of the sea area has brought the majority of the world's capture fisheries under national control. While this has led to an improvement in the management of fisheries in those areas – for the most part – it has also increased pressure on the remaining sea areas. This is reflected in the increasing volume and value of the world's oceanic fisheries. At the same time, improved scientific understanding of marine ecosystems has led to an awareness that overfishing and the incidental damage caused by bottom trawling and a range of mining and exploration activities is increasingly damaging to important marine systems, particularly seamounts and deepwater corals in sea areas beyond the limits of national jurisdiction. There are clearly no easy fixes to this problem. The fact that open access to the high seas is enshrined in UNCLOS remains a fundamental source of difficulty. Open access is an appropriate rule wherever natural resources are genuinely non-scarce. While the high seas were legitimately regarded as a non-scarce resource for centuries, it is no longer the case that marine resources are non-scarce, and open access is no longer an appropriate rule. The fact that there is no authority with responsibility for the high seas is also a fundamental source of difficulty, and one that is at least as intractable.

There are, however, at least three areas in which there is scope for improvement: (a) the commitment of resources to the provision of marine biodiversity conservation and the provision of information on the

consequences of biodiversity loss as global public goods; (b) the commitment of resources to regional conservation efforts, and the strengthening of incentives to comply with regional agreements; (c) the development of MPAs that protect both benthic marine biodiversity and the fisheries they support.

Resources for the global public good

Marine fisheries generate exports of around US\$60 billion. This represents one part of the ‘interest’ on the set of natural capital stocks, including the world’s marine ecosystems. Many other benefits derive from these ecosystems, but fisheries are the most direct. The mechanism for funding conservation as a global public good is the Global Environment Facility (GEF). It is the only mechanism by which the global community invests in this set of natural capital stocks. Recent spending by the GEF on both biodiversity conservation and international waters has declined since 1999 (Table 2). Spending on international waters is largely accounted for by pollution clean up, but the line item also includes projects that benefit marine biodiversity. In 2003 it stood at under US\$80 million.

Table 2: GEF funding of global biodiversity conservation and international waters, 1999-2003 (\$ million)

	Biodiversity	Biosafety	International Waters	Total
1999	181.48		96.28	473.06
2000	182.75		47.43	453.20
2001	185.30		74.53	469.59
2002	79.35	7.19	80.11	340.98
2003	120.79	2.00	79.60	514.36

Source: Clemencon (2005)

The GEF’s budgeted funding for projects affecting sea areas beyond national jurisdiction has been increased to \$398 million for the period 2003-2006, restoring funding to the level of 1999, and it is projected to increase to \$189 million for the year 2007 (Clemencon, 2004). This is not currently based on any assessment of the global risks of damage to marine systems in waters beyond the limits of national jurisdiction, but by any criteria it is a very low level of investment in a resource that supplies the nutritional needs of a substantial part of the world’s population.

One reason that global investment in marine biodiversity conservation is so low is the paucity of information on the economic importance of the goods and services deriving from marine ecosystems. The CBD’s Clearing House Mechanism and the FAO’s Fishstat facilities are important contributions to the conservation and sustainable use of marine biodiversity, in that they provide a best shot solution to the information public good. However, few resources have been committed to developing a data base on the derived value of ecosystems that are at risk, or that are proposed for MPAs. An expansion of the data generated or provided by these bodies to include estimates of the opportunity cost of damage to seamounts, deepwater corals and similar benthic systems would help both to prioritise MPAs and identify the value of the resource to be protected through GEF resources.

Seamounts are a case in point since they have a number of direct and indirect links with commercially important deepwater and epipelagic species. For example, many deep-water species form spawning aggregations in seamount habitats leading to much higher catch rates in those habitats relative to other areas. Seamounts also induce upward convection currents that bring nutrients from the aphotic bathypelagic and mesopelagic zones into the photic zone, so increasing biological production of epipelagic species. Moreover, many seamounts are associated with 'Taylor's columns' – zones above the seamount that retain larvae in the zone, leading to highly localised populations (FAO, 2004).

Regional public goods and regional coordination

Regional cooperation and coordination is a helpful way of addressing some of the least tractable issues in the provision of international public goods or the exploitation of international common pool resources, in that it addresses both the problem of large numbers of contracting parties and allows for repeated renegotiation (Barrett, 2005). But regional public goods have their own problems. One is the difficulty of funding regional initiatives. National public goods are funded by nation states and the multilaterals and the GEF exists to fund global initiatives, but regional initiatives are frequently ignored (Sandler, 2005). In principle, the GEF funds only the incremental cost of providing global public goods – that is, the difference between the cost of provision of the public good and the local benefits it offers. In practice GEF funding covers more than just the incremental costs of conservation projects, but it does not apply to conservation whose benefits are largely local or regional. Hence marine conservation efforts whose benefits largely accrue exclusively to a particular group of countries are not eligible. This would not be a problem if funding were available from other sources, but it is not.

To address this problem it is important to identify the different levels at which conservation benefits accrue, and to use this information to develop a hierarchical funding structure. Application of the incremental cost principle implies at least three levels of funding: national, regional and global. Nation states should carry a share the cost of conservation projects with wider benefits, and the GEF and other global sources should cover the global costs. At the regional level Sandler has suggested both that regional development banks be engaged in the provision of regional public goods, and that regional trade pacts be engaged in the process (Sandler, 2005).

A separate problem at both regional and global levels is enforcement and compliance. The FAO Compliance Agreement is intended to commit contracting parties to the terms of the Fish Stocks Agreement in particular. The FAO notes that the RFMOs are playing an increasing role in this, particularly in respect of illegal, unreported and unregulated (IUU) fishing. Yet the existence of the problem is itself evidence of weaknesses in the design and enforcement of the FAO Agreement on Stocks (Barrett, 2005b). RFMOs are being asked to deal with the management of fleet capacity, the effect of the payment of subsidies and the reduction of bycatch, effort reduction, gear restrictions, inspection and enforcement. However, their capacity to act is limited. Sanctions can only be levied

against free-riders amongst the contracting parties. There is nothing that can legally be done to constrain non-contracting parties.

Taking ICCAT as an example, although countries have agreed to conserve the tuna pass through their EEZs, none has an incentive to do so. Moreover, the conservation incentive is even weaker in the high seas. Not only does a reduction in fishing effort that raises the return to fishing effort leave more fish for others to catch, it also provides non-signatories to the Fish Stocks Agreement with an incentive to enter the fishery. At the same time the vessels of compliant countries themselves have an incentive either to withdraw from the agreement or to ignore the agreed catch levels. ICCAT has adopted trade restrictions as penalties against both non-participants and non-complying states, but since there are fewer than 40 signatories those who are not in compliance are easily able to evade those sanctions (Barrett, 2005).

Although many common pool resource problems are in the nature of prisoner's dilemma, if cooperation and coordination are capable of yielding a net benefit to the contracting parties to an agreement, then it may be possible to design the agreement such that it is self-enforcing. This is not always true, and the form of the agreement will be sensitive to the particular conditions of the resource, the markets and the institutions within which the contracting parties operate. Many agreements have failed to deliver net benefits. Although the dominant reason is that the agreement is negotiated to deliver the non-cooperative outcome (Sandler, 1997), it is frequently the case that it simply fails to include an appropriate set of incentives to comply with its terms – that it is not self-enforcing. An important element of the research needed to support marine biodiversity conservation is accordingly an evaluation the incentives offered by the agreements governing the conservation of both fish stocks and the resources of the seabed.

Marine Protected Areas

A major element in the development of an ecosystem based approach to the management of marine resources is the development of MPAs. The developing literature on MPAs emphasises the potential benefits they have to offer not only to the resilience of vulnerable marine systems, but also to the productivity of fisheries. By siting MPAs in spawning areas of high species richness, for example, it is possible to enhance catches in adjoining areas. The location of marine reserves is critical to their effectiveness as both conservation and fishery protection measures and the location criteria accordingly include both biophysical and economic elements. Examples are representativeness, vulnerability, threats, connectivity, the presence of economically valuable species and ecosystem services (Roberts et al, 2005). The design and location of MPAs differs depending on whether the primary objective is biodiversity conservation or fishery support (Hastings and Botsford, 2003), and is sensitive to currents (Gaines et al, 2003). Roberts has argued that all deep-water habitats should be protected from fishing to protect particularly vulnerable habitats such as maerl beds and deepwater reefs, both of which are vulnerable to damage from bottom trawling. The economic case for MPAs would seem to be strongest for deep-water coral and seamount habitats that directly or indirectly support both deepwater and

epipelagic fisheries. Since regeneration rates are so low, he claims that no system of licensed or regulated fishing is going to be effective (Roberts, 2002).

There do not appear to be any economic studies of the costs and benefits of MPAs in areas beyond national jurisdiction, and the motivation for establishment of MPAs in deep waters currently appears to be quite variable. Deep-water corals have been protected in Norwegian waters since 1999 on biological and conservation grounds, but the establishment of MPAs prohibiting bottom fishing around seamounts in Australian, New Zealand and US waters effectively supports pelagic fisheries in the water column above the seamounts (Roberts, 2002). Economists have investigated the general problem of spatial fishing strategies where metapopulations include source areas, and these studies support the optimality of fishing in sink areas (Sanchirico and Wilen, 1998), as does the empirical evidence on the benefits to fisheries of the establishment of MPAs in source areas (Roberts et al, 2005).

An important factor in the economic analysis of MPAs protecting deepwater fisheries is that recovery from the overfishing of long-lived species with low growth rates and episodic recruitment may take several generations (FAO, 2004). Indeed, if growth rates are low enough, such fisheries may be regarded as exhaustible resources to be mined, and if the removal of particular slow-growing species has no implications for the abundance of other species this would be optimal from the point of view of both the individual fishing firm and society as a whole. However, if the removal of one species does impact the growth and abundance of other species in the system, this needs to be taken into account. Application of the ecosystem approach to the management of such fisheries requires that the indirect ecosystem effects of the removal of target species and bycatch be evaluated. Where there is insufficient knowledge to undertake such an analysis, then there is a case for precautionary action to limit stress on the resource while it is being evaluated (FAO, 2004).² The main point to make, however, is that this remains an area where data are sparse. It is accordingly an area where research into both the ecological and the economic dimensions of the problem should be a high priority.

The bottom line is that open access to the high seas and the public good nature of conservation activities in the high seas and on the sea bed make it hard both to coordinate and enforce conservation efforts in areas beyond national jurisdiction. The brightest signs currently lie in two things. The first is the fact that many countries have a direct interest in the conservation of biodiversity within their own jurisdiction, and that the effectiveness of these efforts can be significantly enhanced if there is coordination of effort in areas beyond national jurisdiction. This provides a positive incentive to explore the benefits of coordination. It does not solve the problem of illegal, unreported and

² Costanza et al (1998) argued that a precautionary approach to the governance of the oceans means the following. Where there is uncertainty about potentially irreversible environmental impacts, decisions should 'err on the side of caution', and that the burden of proof should lie with those whose activities are the source of damage. An application of the principle may be found in the decision to reduce polluting inputs to the North Sea by an arbitrary 50% by 1995. The moratorium on commercial whaling imposed by the International Whaling Commission in 1982 falls into the same category. The precautionary principle is thus a statement both about socially acceptable levels of risk, and about the onus of proof. Restating the principle as defined by the North Sea Ministerial Conference, it asserts that action will be taken to avoid serious potential damage from emissions to the North Sea unless there is 'proof' that emissions will have no such effect.

unregulated fishing by private interests, but it provides countries with significant marine resources adjacent to high seas to coordinate actions regionally. Given this, there is scope for development of agreements whose net benefits to members make them self-enforcing. The second source of hope is that marine biodiversity conservation in areas beyond national jurisdiction may be a threshold public good, implying that the effectiveness of individual conservation efforts depends on a minimum level of collective conservation. Certainly, the fact that there appears to be a consensus amongst marine scientists that marine biodiversity conservation requires that around 30 per cent of sea areas be protected supports the notion. The reason that this is a source of hope is that it reduces the problem posed by free-riding, and increases the incentive for those with the deepest pockets (the US in the Pacific and the EU in the Atlantic) to underwrite conservation activities beyond their national jurisdictions. Taken together these two things give reason to believe that it is possible to develop both self-enforcing regional agreements to coordinate conservation actions that go beyond the RFMOs, and the resources to make regional coordination effective.

Appendix 1: Export value of fisheries by region, 1976-2002 (US\$ million)

	Asia (excluding Middle East)	Central America & Caribbean	Europe	Middle East & North Africa	North America	Oceania	South America	Sub-Saharan Africa	
1976		2285	401	3060	135	1029	173	521	252
1977		2821	398	3651	150	1337	269	645	268
1978		3335	712	4229	162	1956	312	821	302
1979		4021	719	5167	211	2295	413	1045	384
1980		4150	879	5691	244	2247	545	1248	392
1981		4501	795	5511	313	2578	535	1265	468
1982		4461	779	5047	286	2479	578	1403	471
1983		4586	734	5361	362	2448	606	1299	463
1984		4922	735	5190	373	2385	672	1415	457
1985		5093	734	5666	388	2669	640	1489	512
1986		7015	897	7650	528	3460	751	1876	707
1987		8777	1055	9557	626	4228	870	2070	711
1988		10582	880	10423	750	4968	1099	2310	699
1989		10206	944	10561	751	4928	1045	2553	744
1990		10788	754	12947	875	5691	1044	2546	831
1991		12169	897	13566	937	5806	1239	3196	870
1992		12838	785	13896	864	6009	1381	3517	911
1993		14222	947	13708	835	5525	1399	3661	959
1994		16459	1108	15756	960	5679	1553	4457	1471
1995		17429	1396	17150	1152	6044	1788	5066	1685
1996		17005	1543	18667	1135	5779	1765	5151	1663
1997		17668	1644	18097	1143	5393	1779	5978	1694
1998		16117	1623	18994	1150	4907	1554	4953	1857
1999		16766	1446	19387	1107	5830	1747	4860	1646
2000		19106	1585	18562	1356	6142	1825	5006	1657
2001		18843	1527	19037	1263	6358	1741	5544	1828
2002		19203	1463	20469	1445	6536	1815	5145	2101

Source: Fishery Information, Data and Statistics Unit, Food and Agriculture Organization of the United Nations (FAO). 2005. FISHSTAT Plus: Fisheries commodities production and trade 1976-2002 dataset. Rome: FAO.

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