Economic and socio-cultural priorities for marine conservation

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Summary

1. Much of the marine environment is relatively natural and is generally regarded as wilderness, whereas it is in fact significantly impacted by fishing activities. However, the alien, remote and hidden nature of the marine environment reduces the priority that society attaches to these impacts even though they can damage sources of socio-cultural and economic value.
2. A variety of important resources are derived from the marine environment which could be damaged by the incidental impacts of fishing. There is a risk that fish stocks themselves could potentially be damaged through trophic feed-back mechanisms at considerable cost to society. However, concern over this potential risk is largely restricted to ecologically enlightened fisheries managers and the relevant research community. Marine wildlife of importance for coastal tourism could be damaged. With the exception of marine mammals, this is a relatively low priority as the attraction of coasts to tourists is largely related to coastal landscapes, sandy beaches and clean bathing waters, rather than healthy marine wildlife. Populations of marine organisms that might yield biotechnologically important compounds could also be damaged, but this is a very low priority as the degree of this potential is indefinable.
3. The marine environment is an important provider of ecosystem services, but whether the impacts of fishing will endanger the delivery of these services at a given regional scale is uncertain. It could be argued that there is a risk that any significant impacts will reduce the resilience of marine ecosystems and could lead to major ecological perturbations, but it difficult to predict the outcome of fishing impacts owing to the complexity of marine trophic relations. Again, such risks are a relatively low societal priority.
4. The value that society attaches to the existence of certain marine species and of marine wilderness is a fairly high priority, and has been used to great effect in certain publicity campaigns. The decision not to dump the *Brent Spar* in the deep sea west of the Hebrides was driven by the societal value attached to this marine wilderness, but the fact that nearby areas were subject to increasing fishing exploitation was largely ignored. The European Commission's decision to ban drift nets was largely driven by the impacts of these 'walls of death' on intrinsically appealing species such as sea birds, dolphins and turtles. There is a danger that focusing on the conservation of such flagship species can neglect the wider, ecosystem impacts of fishing.
5. In order to raise the priority that society attaches to the non-target impacts of fishing, it is argued that: a) greater efforts need to be focused on raising public awareness of the risk that the non-target impacts of fishing could lead to potentially serious ecosystem perturbations; b) more resources and efforts need to be focused on reducing the uncertainty concerning the functional value of habitats and species that are regionally endangered by fishing activities; and c) relevant scientists should become more involved in wider deliberations concerning the non-target impacts of fishing in order to guide their research efforts in a manner that increases the potential potency of their findings, and to maximise the extent to which their findings constructively inform such deliberations.

Introduction

Marine habitats and communities are relatively natural in that they are rarely the result of positive anthropogenic intervention, whereas terrestrial environments are, to a degree, intentionally developed and modified. Even those terrestrial areas considered to be of high conservation value, e.g. woodlands, moors, pastures and meadows, are generally semi-natural in that positive management through the maintenance of certain human activities is required to preserve them. Fishing in the marine environment is an exceptional activity in the modern world in that it involves the capture of uncultivated populations and is sustained by naturally productive and diverse ecosystems. In contrast, terrestrial agriculture relies on the enhanced productivity of ecologically and genetically modified, low diversity systems (Cole-King 1994). Marine environments are subject to direct human impacts that result from activities such as waste disposal and fishing that lead to significantly modified habitats. However, it is very rare for arguments to be made that such activities should continue in certain marine areas because the impacted habitats are considered to be of importance and value in themselves.

Despite the widescale nature of fishing and pollution impacts, a large proportion of the marine environment remains relatively unaffected. As such the sea is perceived by many people as being the last wilderness in their region. However, neither fishing nor its impacts are readily visible, i.e. they are 'out of sight, out of mind'. If they were more apparent, it might be argued that there would be greater pressure to establish areas closed to fishing to match nature reserves that exist on land which are closed to development, farming, *etc*.

The alien and mysterious nature of the marine environment may be its undoing in that it is perceived as an adversary and the cold-blooded, slimy life that inhabits it does not evoke public inspiration and empathy in the same way as many charismatic terrestrial animals (Kenchington 1990). Furthermore, conservation priorities in Britain, for example, have historically been focused on the aesthetication or taming of terrestrial nature (Lowe 1983), in a manner which might be termed 'conservation by gardening'. This technique is clearly not appropriate to the marine environment.

These factors reduce the priority that society attaches to the impacts of fishing. However, there are a number of economic and socio-cultural priorities that society attaches to marine conservation that are particularly relevant in the context of the impacts of fishing on non-target species and habitats. These relate to the value of marine resources for fishing, tourism and as sources of biotechnological compounds, the service values of marine ecosystems and the existence values of marine wilderness and of certain intrinsically appealing species. Each of these values will be explored in this chapter, and issues concerning the relationship between science and societal concerns about marine conservation will be considered.

Marine resource values

IMPACTS OF FISHING ON FISHERIES THROUGH ECOSYSTEM PERTURBATIONS

In keeping with the observational, alienation and perceptual hurdles discussed above, it has been argued that society's relationship to the sea is largely defined in terms of the resources it provides, particularly in relation to the importance of sea fish (Cole-King 1995). Fishing is of very high economic importance and provides many livelihoods, particularly in rural coastal communities. Internationally, people rely on fish for 16% of their animal protein needs, but in many developing countries 30% of people's animal protein needs are derived from fish, whilst in certain countries such as North and South Korea, Ghana, Indonesia, Congo, Japan, Malawi, and the Philippines, this figure rises to over 50% (McGinn 1998). Society's relation to the sea is also defined in terms of the services it provides, particularly as a place to dump solid wastes, dilute and disperse liquid wastes, and undertake marine navigation. By contrast the land is conceived as a tangible entity in itself the uses of which can be spatially divided, including the set-aside of areas for landscape and nature conservation (Cole-King 1995).

Traditionally marine environmental concerns have been focused on high profile sectoral issues such as the over-exploitation of whale stocks, the use of seas as a dumping ground for industrial wastes, the impacts of oil spills as a result of tanker accidents, and the direct impacts of fishing in terms of the exhaustion of target fish stocks. More recently, concern has been expressed over the impacts of fishing on non-target species. The repercussions of these impacts can feed-back to the fish stocks in question via food chain, habitat and ecosystem perturbations. These concerns have led to increased calls for an ecosystem-based approach to fisheries research and management rather than purely stock-based approaches. However, the understanding of the indirect impacts of fishing on trophic relations in the marine ecosystem remains poor, detailed studies being limited to a few well documented cases such as coral reefs and areas such as the North Sea (Jennings & Kaiser 1998). At present, it could be argued that this increasing concern is largely confined to ecologically enlightened fisheries managers, the relevant research community and their funding agencies, and certain environmental campaign groups.

There are examples of communities where this concern is a high priority, particularly those dependent on coral reef fisheries that have already suffered as a result of such indirect impacts, on which the majority of papers reviewing the ecosystem impacts of fishing have been focused. Although these cases are few and their applicability to temperate fish stocks is debatable, they might be regarded as cautionary warnings. Efforts have been made recently to raise societal awareness of the indirect impacts of fishing and to promote support for proposals to set-aside areas of the sea to protect both marine ecosystems and fish stocks, including an international campaign by marine researchers to set-aside 20% of the world's seas as areas closed to fishing (Holmes 1997). Fishing regulations often include partially closed areas which are critical to specific fish stocks at certain times of the year, and these are relatively acceptable to fishermen as the stock conservation benefits are relatively clear. However, gaining political acceptance for the closure of fishing areas on the basis of potential benefits which are relatively unclear from a fish stock conservation perspective can be extremely difficult, as fishing interests constitute a powerful political lobby. There is therefore a strong presumption that even in areas designated as marine nature

reserves, fishing will continue to be allowed in most if not all areas, despite the fact that this undermines many of the objectives of such reserves (Jones 1994). Gaining political acceptance for closed areas on the basis of the potential for ecosystem impacts to feed-back to fish stocks is also made particularly difficult by the fact that societal awareness about this issue is very low and it remains a relatively low priority, although it is potentially of very real concern.

IMPACTS OF FISHING ON TOURISM

Coasts are a very important attraction for tourists therefore any potential for the non-target impacts of fishing to reduce the tourism earning potential of coastal seas could have significant economic consequences. However, most studies have been confined to the impacts of tourism on tropical ecosystems, particularly the impacts of recreational SCUBA diving on coral reefs, which is a rapidly growing component of the tourism industry (Davis & Tisdell 1995).

Whilst coastal tourism in Europe is not dependent on healthy marine wildlife to the same extent as diving-based tourism in coral reefs areas, there has been considerable growth in recent years in marine wildlife-oriented ecotourism. This is related to activities such as whale, dolphin, seal, seabird and wader watching, and SCUBA diving. The marine wildlife on which these activities depend is potentially vulnerable to the impacts of fishing. A few research projects have been undertaken on the impacts of fishing on, for example, vulnerable rocky reef populations, and the potential impacts on marine-wildlife oriented tourism (e.g. Rayment 1998). However, suffice to say that whilst the potential exists for fishing to impact coastal tourism, this potential is relatively small as the majority of temperate coastal tourism is dependent more on coastal landscapes, beaches and clean bathing waters, with only a minority sector being dependent upon healthy marine wildlife. Therefore, once again, this issue is currently a relatively low priority in the context of societal concerns about marine conservation.

IMPACTS OF FISHING ON POTENTIAL SOURCES OF BIOTECHNOLOGICAL COMPOUNDS

Marine organisms are recognised as being potential sources of compounds that could be of potential biotechnological and pharmaceutical use, and increasing attention has been focused on the marine environment as the search for useful compounds from terrestrial species has become less rewarding (Grant & Mackie 1977). This attention is particularly focused on biodiversity 'hotspots' in tropical seas where intense competition among species has led to the evolution of complex toxins that may be of pharmaceutical use, for instance, in fighting cancer. However, colder water species are also screened and have yielded potentially useful compounds. For instance, promising anticancer compounds have been isolated from a newly discovered species of the temperate sponge *Lissodendoryx* spp., found on deep rocky reefs off the coast of New Zealand (Pain 1996). The temperate bryozoan *Bugula neritina*, found from California to Europe, yields a drug that could eventually form the basis of a market worth $1 billion a year (Pain 1998). It has also been argued that deep bathyal seabed environments, such as those in the North-East Atlantic, may contain huge genetic resources that might be of interest to drug companies (John Lambshead quoted in Pearce 1995).

It is therefore clear that marine species have the potential to yield useful compounds, though the degree of this potential is very uncertain and the risk of its loss due to fishing impacts is a relatively low societal concern. However, any irreversible losses caused by the impacts of fishing on the future but as yet unknown value of this potential resource could have considerable economic impacts through drug revenues foregone as well as considerable impacts on humanity through the loss of potential medical treatments.

Ecosystem service values

As this volume illustrates, there is increasing evidence that fishing has wide indirect impacts on marine ecosystems. However, there is considerable uncertainty surrounding the significance of these impacts in terms of the reduction of the potential of marine ecosystems to provide certain 'ecosystem services':-

Ecosystem Service	Ecosystem function	Examples
Disturbance regulation	Capacitance, damping, resilience and integrity of ecosystem in response to environmental fluctuations	Coastal defence value of marine habitats, particularly in the face of climate change
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	N and P and other elemental or nutrient cycles
Biological control	Trophic-dynamic regulations of populations	Keystone predator control of prey species
Habitat/refugia	Habitat for resident and transient populations	Fish nurseries, habitats for migratory waterfowl and harvested fish

Adapted from Costanza *et al* 1997

It has been estimated that the total global value of such services from marine ecosystems is approximately $\$20,949 \times 10^9$ per year, where the total value from terrestrial ecosystems is $\$12,319 \times 10^9$ per year, and that coastal ecosystems, where fisheries are concentrated, have the highest total global value of all at $\$12,568 \times 10^9$ per year (Costanza *et al* 1997). Whilst it is accepted that these are crude estimates, they do give a good indication of the relatively high importance of coastal ecosystems in providing services on which humans depend.

A key issue is whether the impacts of fishing will undermine the potential of marine ecosystems to deliver these vitally important services. At a wider trophic level, there are a number of indirect impacts that have raised concerns that fishing may have important impacts on ecosystem structure and function (Jennings & Kaiser 1998). Pauly *et al* (1998) have highlighted the somewhat worrying trend that the fishing industry is targeting trophically lower levels in marine food webs as fish stocks at higher trophic levels become depleted. The significance of these impacts in terms of the extent to which they might reduce the delivery of vital ecosystem services is uncertain.

There are also growing concerns amongst conservation biologists that any significant reductions in biodiversity could undermine the stability (Polis 1998), predictability (McGrady-Steed *et al* 1997) and reliability (Naeem and Li 1997) of ecosystems. Clearly this is a potential concern where non-target marine species may be threatened with extinction by fishing impacts. There are two schools of thought in relation to such concerns. Some argue on a precautionary basis that it would be unwise to render any species extinct and thus reduce ecosystem resilience, especially in the light of uncertainty about the degree of redundancy of species and the size of future stresses. Others argue that efforts should be focused on conserving critical functional groups of 'driver' species that underpin ecosystem structure rather than on trying to conserve all species, many of which are redundant in terms of their contribution to maintaining ecosystem functions and might thus be regarded as 'passengers' which are expendable.

Ehrlich & Walker (1998) point out that these views are not necessarily diametrically opposed. Those that argue for a precautionary approach recognise that not all species are equally important in maintaining ecosystem functioning, but they emphasise our ignorance about which species are redundant. Those that argue on the basis of species redundancy recognise that the extinction of a given species would often not lead to observable negative impacts on the delivery of ecosystem services, and that it makes sense that current conservation initiatives should place the highest priority on those species that are known to be the sole representatives of their functional group. However, they also argue that redundancy is likely to be important in the long term in the face of emerging ecosystem stresses, such as climate change. A species that is presently regarded as a might well be the only one in its group that is able to adapt to new environmental conditions and may thus become a driver species. Conserving redundant species is therefore important as it contributes to ecosystem resilience. Ehrlich and Walker thus conclude that considering the uncertainties and complexities between biodiversity and ecosystem services, policy decisions should take a precautionary approach to biodiversity protection in order to try to increase or at least maintain redundancy in ecosystems and thus maximise ecosystem resilience.

The significance of fisheries impacts on marine biodiversity is not confined to whether species, be they drivers or passengers, are rendered extinct, which is unlikely given the wide distribution of many species and the patchy nature of fishing. It is also important to consider whether regionally important populations of species might be wiped out, undermining the delivery of services at that geographic scale. Thus the disturbance of ecosystem dynamics at a regional scale by the non-target impacts of fishing could significantly reduce the potential delivery of services in that region without the species in question ever being globally endangered.

It is also important to remember that it is not only the impacts on non-target species that that need to be considered. The depletion of target fish stocks can also have impacts on ecosystem functions that may be of significance but the pathways and outcomes of which are difficult to predict due to the complex and non-linear relationships between species, particularly if important top predator species are involved. For instance, it has been reported that overfishing off the coast of Alaska was one of the principal factors which led to the collapse of populations of Steller sea lions and harbour seals, and that these were an important food source for killer whales, which have in turn been forced to seek alternative prey, including sea otters around the Aleutian Islands. The resulting decline in sea otters has set off a cascade of effects, as populations of sea urchins on which sea otters normally prey have exploded, leading to the overgrazing and collapse of kelp beds which are at the base of the coastal food web and provide an important habitat for many marine species (Estes *et al* 1998).

Overall it is clear that fishing can directly and indirectly lead to ecosystem perturbations that could undermine the potential of these ecosystems to deliver important services at a considerable cost to society. However, wider societal perception of this risk is arguably relatively low as is the priority that is attached to it. This is related to the fact that amongst relevant research communities there is a great deal of uncertainty concerning the risk that these perturbations will occur and the severity of their impacts. Consequently, many argue for a precautionary approach that provides society with sufficient environmental insurance against the impacts of overfishing through measures such as the designation of areas closed to fishing (Lauck *et al* 1998 and Lindeboom, this book), but for the reasons previously discussed, gaining acceptance for such closed areas is extremely difficult.

Existence values

Existence values are derived from an appreciation of simply knowing that undisturbed natural areas and the species they support are there, and are considered by economists to provide one of the main justifications for wilderness preservation (Krutilla 1967). This might be considered in terms of vicarious or symbolic existence values.

Vicarious existence values are based on the 'second-hand' aesthetic appreciation of the marine environment through wildlife documentaries, magazine articles, books, *etc*, this being particularly important in the marine environment due to the extreme difficulties in observing it first-hand. They can also be based on the altruistic appreciation that other people can derive values from preserved marine areas.

Symbolic existence values derive from the "moral conviction that it is right" to preserve natural areas and the species they support (Leopold 1964) on the basis of their intrinsic value, regardless of any present or future use values. Pearsall (1984) considers that the likelihood of use values, such as the resource and ecosystem service values discussed above,

accruing from any given species is very small and that public support for species protection must therefore be largely founded on such moral convictions of which preserved natural areas are an important symbol.

EXISTENCE VALUE OF WILDERNESS: THE BRENT SPAR CASE

The priority that is attached to the existence value of marine wilderness in relation to the non-target impacts of fishing is arguably relatively low due to the alien, remote and hidden nature of the marine environment. However, such existence value in relation to other activities can be evoked with potent effect as the high profile public controversy over the decision to dump the decommissioned *Brent Spar* structure illustrated. Shell's proposal to dump this structure in one of three deep-water locations west of the Hebrides, which had been approved by the British Government, caused widespread public protests in 1995 stimulated by Greenpeace's publicity campaign. This was centered on the argument that the deep sea marine wilderness should not become a dumping ground for redundant oil industry structures, and the protests led to a dramatic U-turn by Shell. The options appraisal stage was re-opened and a wide consensus building exercise was initiated in order to identify an option which was acceptable to environmentalists and the wider public.

A notable feature of this case was that the deep sea 'wilderness' to the east of the dump sites has been subject to increasing exploitation by deep sea trawlers, particularly on the continental slope at depths of 200-1800 m (B. Bett, Southampton Oceanography Centre, personal communication). However, no major campaign was mounted by Greenpeace over this exploitation of sensitive deep sea species. It is not certain whether this was because the fishing industry is relatively diffuse and therefore less of a target for campaigns, whereas the oil industry is seen as a 'Goliath' against which Greenpeace wished to pitch itself, or because it was considered that the public would be less sympathetic towards an oil company than they might be towards fishermen. What is clear is that Greenpeace's campaign evoked great public concern which stemmed from the high priority that was attached to the existence value of this deep sea wilderness, whilst the much wider impacts of deep sea fishing were not considered to be a priority in this 'landmark' campaign. This also illustrates the malleability of such societal priorities in the face of campaigns whose profile is not necessarily proportionate to the environmental impacts of the activity in question. In this respect Side (1996) comments that it is unfortunate that it is the marketing of stakeholder goals in such symbolic contests that provides the vehicle for society to form its values, rather than such values being formed through a closer relationship with the natural world.

EXISTENCE VALUE OF CERTAIN SPECIES: THE 'WALLS OF DEATH' CASE

The existence values that society holds for certain intrinsically appealing marine species have had a potent effect on many fisheries policies, relating to the by-catch of sea birds, dolphins, turtles, *etc* (Hall 1996). For instance, the European Commission's decision to ban drift nets from most of its waters by the year 2002 was largely driven by concerns about the impacts of drift nets on marine wildlife. Greenpeace's campaign on this occasion highlighted the thousands of dolphins, whales, turtles, *etc*, that were killed in these 'walls of death' every year. Clearly, the existence value that society holds for such 'charismatic megafauna' can be evoked by arousing public interest and sympathy, and can have a potent effect on fishing policies. However, it has been argued that such flagship species may not be the most appropriate indicator or umbrella species by which wider ecosystem health can be measured or ensured, and that it may be more appropriate to move towards an ecosystem or 'landscape' approach to conservation rather than one based on species (Simberloff 1998). There is thus a danger that focusing campaigns to reduce the impacts of fishing on flagship species can neglect the more important wider ecosystem impacts of fishing, though it is understandable why campaigns focus on species the existence value of which is relatively easy to evoke.

Discussion

It is clear from the above review that the non-target impacts of fishing can damage the ability of the marine environment to be of value to society through damages to existing or potential resources, to ecological service provision, or to wilderness areas or intrinsically appealing species. Whilst there is a growing scientific awareness of the potential significance of the impacts of fishing on marine ecosystems, there is a strong tendency for public awareness raising efforts to be focused on flagship species as a means of supporting specific campaigns, and it is likely that such campaigns may miss important wider ecosystem issues. Greater efforts might therefore be focused on raising public awareness of the wider ecosystem impacts of fishing, particularly with regards to the potentially serious consequences of ecosystem perturbations, but also with a view to promoting general interest in the marine environment as a means of raising the priority that society attaches to such impacts.

The relatively low priority that society attaches to the non-target impacts of fishing is also attributable to the considerable scientific uncertainty concerning the present and potential significance of such impacts. Many 'scientific' claims about the potential pharmaceutical or ecosystem service values of species and habitats which may be endangered by fishing at a certain regional scale are often extremely difficult to back-up with rigorous scientific evidence, and may thus be regarded more as scientifically informed opinions, wider public support for which is based more on belief than fact-driven concern. This tendency is not restricted to the issue under discussion as the fact that environmental decisions must often be made in the face of considerable uncertainty is becoming accepted in the context of many pressing issues. However, it is clear that the scientific rationale behind such decisions must be maximised. Whilst the scale, connectivity and complexity of marine ecosystems presents major obstacles for robust empirical research concerning the ecological service value of

endangered species and habitats, it is clear that more resources and effort needs to be focused on overcoming these obstacles and increasing the scientific basis of arguments to reduce the non-target impacts of fishing.

Decisions concerning measures to reduce fisheries impacts will often involve major socio-economic trade-offs, and are unlikely to be based solely on scientific rationale as appropriately sound analytical foundations rarely exist. More often they will largely be based on deliberations which are not restricted to scientists, but that also include political actors and other stakeholders that act as much on the basis of values as on science (Dietz & Stern 1998). As such, there is considerable scope for increasing the constructive involvement of scientists, who it must be accepted are also motivated by values and judgments, in broadly based deliberations. This will serve to guide their research efforts in a manner which increases the potential potency of their findings, and to maximise the degree to which their findings constructively inform these deliberations.

However, increasing the profile of scientists in such debates and in raising public awareness of the ecosystem impacts of fishing does raise the critical issue of whether the role of scientists is one of communicating value-free scientific evidence, or whether it should be extended to being advocates or even campaigners for increased marine conservation measures. This is a particularly difficult issue given the problems of achieving scientific certainty about wider impacts on marine ecosystems. In the face of uncertainty, marine scientists may have to go beyond what they can empirically prove when arguing for increased marine conservation measures, but this leaves them open to criticisms that they have abandoned science in favour of values. For instance, one of the authors of a paper (Elliot and Norse 1998) which compared bottom trawling to the clearcutting of forests and strongly argued for the precautionary establishment of closed areas, has been accused of having 'left his scientific credibility at the door' and of publishing controversial one-sided statements (Oceanspace 1999).

In the face of the generally low priority that society attaches to the ecosystem effects of fishing, and the problems of proving their potentially major significance, it could be argued that concerned scientists have a legitimate right to adopt the role of advocates or even campaigners. Of course, the quest for scientific evidence to underpin fisheries management must continue, as this book demonstrates. However, if we are to progress from a stock-based to an ecosystem-based fisheries management approach, it must be accepted that a balance will need to be achieved between scientific opinions to inform management decisions and scientific certainty. Concerned scientists may wish to become involved in efforts to raise societal awareness about related issues in order to drive political decision-making processes, which this chapter indicates is relatively low, and it is argued that this can be achieved in a manner which does not necessarily involve abandoning science. To this end it is important that the distinction is made clear between scientifically provable statements and scientifically informed opinions.

References

Cole-King, A. (1994) Coastal and marine conservation in Britain: ecology and aesthetics, land and sea. *Environmental Values*, **3**, 139-153.

Cole-King, A. (1995) Marine Protected Areas in Britain: a conceptual problem? *Ocean and Coastal Management*, **27**(1-2), 109-127.

Costanza, R., d'Arge, R. & van den Belt, M. (1997) The value of the world's ecosystem services and natural capital. *Nature*, **387**, 253-260.

Davis, D. & Tisdell, C. (1995) Recreational scuba-diving and carrying capacity in marine protected areas. *Ocean & Coastal Management*, **26**(1), 19-40.

Dietz, T. & Stern, P.C., 1998. Science, values and biodiversity. *Bioscience*, **48**(6), 441-444.

Ehrlich, P. & Walker, B. (1998) Rivets and redundancy. *Bioscience*, **48**(5), 387.

Estes, J.A., Tinker, M.T., Williams, T.M. & Doak, D.F. (1998) Killer whale predation on sea otters linking oceanic and nearshore ecosystems. *Science*, **282**, 473-476.

Grant, P.T. & Mackie, A.M. (1977) Drugs from the sea: fact or fantasy? *Nature*, **267**, 786-788.

Hall, M.A. (1996) On bycatches. *Reviews in Fish Biology and Fisheries*, **6**, 319-352.

Holmes, B. (1997) Dreams as big as an Ocean. *New Scientist*, **155**(2097), 20.

Jennings, S. & Kaiser, M.J. (1998) The Effects of Fishing on Marine Ecosystems. *Advances in Marine Biology*, **34**, 201-351.

Jones, P.J.S. (1994) A Review and Analysis of the Objectives of Marine Nature Reserves. *Ocean and Coastal Management* **24**(3), pp 149-178.

Kenchington, R. A. (1990) *Managing Marine Environments*. Taylor and Francis, 37-38.

Krutilla, J. (1967) Conservation Reconsidered. *American Economic Review*, **57**, 777-786.

Lauck, T., Clark, C.W., Mangel, M. & Munro, G.R. (1998) Implementing the precautionary principle in fisheries management through marine reserves. *Ecological Applications*, **8**(1) Supplement, S72-S78.

Leopold, A.S. (1964) Wilderness and culture, in (Brower, D. *ed*) *Wildlands in Our Civilisation*, Sierra Club, San Francisco.

Lowe, P. (1983) Values and Institutions in the history of British nature conservation, in (Warren, A. & Goldsmith F.B. *eds*) *Conservation in Perspective*, John Wiley, Chichester, 329-352.

McGinn, A.P. (1998) *Rocking the Boat: conserving fisheries and protecting jobs.* Worldwatch Paper 142, Worldwatch Institute, Washington, DC.

McGrady-Steed, J., Harris, P.M. and Morin, P.J. (1997) Biodiversity regulates ecosystem predictability. *Nature*, **390**, 162-165.

Naeem, S. and Li, S. (1997) Biodiversity enhances ecosystem reliability. *Nature*, **390**, 507-509.

Oceanspace (1999) Oceanspace Electronic Newsletter, Issue 101, Article 4.

Pearce, F. (1995). Rockall mud richer than rainforest. *New Scientist*, **147**(1995), 8.

Pain, S. (1996) Hostages of the Deep. *New Scientist*, **151**(2047), 38-42.

Pain, S. (1998) Foul medicine. *New Scientist*, **157**(2120), 11.

Pearsall, S.H. (1984) *In absentia* benefits of nature preserves: a review. *Environmental Conservation*, **11**(1), 3-10.

Polis, G.A. (1998) Stability is woven by complex webs. *Nature*, **395**, 744-745.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. & Torres, F. (1998) Fishing down marine food webs. *Science*, **279**, 860-863.

Rayment, W. (1998) *The Conservation of the Lyme Bay Reefs*. Unpublished M.Sc Thesis, Dept of Geography, University College London.

Simberloff, D. (1998) Flagships, umbrellas and keystones: is single-species management passé in the landscape era? *Biological Conservation*, **38**(3), 247-257.

Watling, L. & Norse, E.A. (1998) Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. *Conservation Biology* **12**(6), 1180-1197.

Recommendations

Greater efforts need to be focused on raising public awareness of the wider ecosystem impacts of fishing, particularly with regards to the potentially serious consequences of ecosystem perturbations.

More resources and efforts need to be focused on overcoming the obstacles posed by the scale, connectivity and complexity of the marine environment in order to increase the scientific basis of arguments to reduce the non-target impacts of fishing.

Scientists need to increase their constructive involvement in public and political deliberations concerning ecosystem-based approaches to fisheries management and marine conservation issues, provided that a clear distinction is made between scientifically provable statements and scientifically informed opinions.