CHAPTER 2

MARINE MAMMALS AND FISHERIES: THE ROLE OF SCIENCE IN THE CULLING DEBATE

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INTRODUCTION

Wherever the distribution of a marine mammal population overlaps with that of a commercial fishery, there exists the potential for various interactions between them. Such situations frequently result in calls for culling the marine mammal population, ostensibly to benefit fish stocks and commercial fisheries. Calls for culling then almost invariably lead to conflicts between groups of humans, pitting those who advocate the culling of marine mammals against those whom advocate for their protection.

The notion that certain pinniped (fur seals, sea lions, walrus and true seals) populations need to be culled to protect fisheries has been around for a long time (e.g. Merriam 1901; Anonymous 1928). There are also some longstanding examples where coastal cetaceans have been the subject of culling proposals. One case, dating from the 1920s, involves the beluga whale (*Delphinapterus leucas*) in the St. Lawrence River estuary, Canada (Anonymous 1927). As the twentieth century unfolded, this population was reduced to a few hundred individuals and, in 1983, it was listed as an endangered species in Canada (Pipard 1985). Despite its continued endangered status (it is also listed as 'Vulnerable' by the International Union for Conservation of Nature and Natural Resources (1996), concerns about its consumption of fish nonetheless persist. In 2001, for example, when three belugas from this population became trapped in the St. Paul River, the view was expressed that they might be destroying the recreational salmon fisheries in the region (CBY-AM/CBC 2001).

A much more recent phenomenon involves calls for culling large cetaceans – including some baleen whales (suborder Mysticeti, e.g. minke whales, *Balaenoptera acutorostrata*; Komatsu and Misaki 2001), and the largest of the toothed whales (suborder Odontoceti, e.g. killer whales, *Orcinus orca*, and sperm whales, *Physeter macrocephalus*) – because they too are now seen by some as a threat to the world food supply (Anonymous 1996).

By the mid-1980s, it had become clear that proposals to cull marine mammal populations would only increase with the rising demand for food from the seas to support the ever increasing human population (e.g. Gulland 1986, for an update, see Anonymous 1999a), the antiquated view that the oceans provide an unlimited food supply having long since been overtaken by reality. As anticipated, calls for culling marine mammals have continued to increase into the twenty-first century (Anonymous 1999a; also see Table 1), and a number of culls have actually occurred (Table 2).

Table 1 Calls to cull marine mammals 2000–2002

Country	Species	Sources
Pinnipeds		
Canada – East Coast	*Pagophilus groenlandicus* *Halichoerus grypus* *Phoca vitulina*	Fisheries Resource Conservation Council 2000, 2001, 2002; Keen *et al.* 1999; Dwyer 1999; Sharratt 2000
Canada – West Coast	*Phoca vitulina* *Zalophus californianus* *Enhydra lutris*	Anonymous 2002a; Hume 2002; Wilson 2002
United States	*Zalophus californianus* *Enhydra lutris* *Phoca vitulina*	Anonymous 1999b, 2000a; Polakovic and Macgregor 1998
Scotland	*Halichoerus grypus*	Anonymous 2000b; Seenan 2000
Ireland	*Halichoerus grypus* *Phoca vitulina*	Anonymous 2000c; O'Keeffe 2001
England	*Halichoerus grypus*	Barron 1999; Seenan 2000
Australia	*Arctocephalus pusillus* *Arctocephalus forsteri*	Titelius 2001; Anonymous 2000d, 2003
New Zealand	*Arctocephalus forsteri*	Anonymous 2000e
Germany	*Phoca vitulina*	Ananova 2001
Denmark	*Phoca vitulina*	Haddow 2001
Cetaceans		
Iceland	*Balaenoptera acutorostrata* *Balaenoptera physalis*	Anonymous 2001b, c
United States	*Orcinus orca*	Collier 1998; Anonymous 2000f

Tellingly, the contemporary calls for culling marine mammals come at a time when some 65% of world fisheries are either fully or overexploited and another 10% are 'depleted' or 'reduced' (Food and Agriculture Organization of the United Nations 2000). They come at a time when aquaculture facilities (frequently built in coastal areas occupied by marine mammals) are growing by leaps and bounds (estimated at about 11% per annum during the 1990s; Chapter 11, this volume). They come at a time when there are few remaining commercial seal hunts (Lavigne *et al.* 1999), and when there is a global moratorium on commercial whaling, a time when some people simply (and erroneously) *assume* that all marine mammal populations are consequently increasing, in some cases, 'exploding' (Efford 1999; Anonymous 2000a; Canfield 2001). They also coincide with a time in history when many individuals, organisations, and governments, are promoting the commercial consumptive use of wildlife under the rubric of 'sustainable utilisation' (e.g. Lavigne *et al.* 1996) or 'sustainable development' (e.g. United Nations Conference on Environment and Development 1992; Lavigne 2002).

Over the past twenty years there has been much discussion at conferences, symposia and workshops on the subject of interactions between marine mammals and fisheries, and the possible consequences of marine mammal culls (e.g. Anonymous 1981a, b, 1992a, 1997; Beddington *et al.* 1985). In this chapter, I will leave the discussion of individual case studies largely to others. Here, I will attempt to put the subject of marine mammals and fisheries into broader perspective, explain why the culling debate is so controversial, and why it is unlikely to go away any time soon. I will also try to explain why scientists' endeavors over the past two decades to assess the effects of culling have met with only limited success. Finally, I will focus in on what science can (and cannot) contribute to the question: Is culling marine mammals the solution to resolving conflicts between marine mammals and fisheries?

Marine mammal/fishery conflicts

The potential for conflicts between marine mammals and fisheries undoubtedly arose the moment that humans first began to live and fish on seacoasts frequented by seals or whales. But it was not until the second century AD, so far as I can determine, that such a conflict was actually recorded for posterity. The Greek writer, Oppian, describes an ancient encounter involving the Mediterranean monk seal, *Monachus monachus* (Johnson and Lavigne 1999): '…when the fishermen have unwittingly enclosed a seal among the fishes in their well-woven nets', he writes, '…it will easily break them and prove…a great grief to

Table 2 Marine mammal culls 2000–2002

Country	Species	Sources
Pinnipeds		
Canada	*Phoca vitulina* *Zalophus californianus* *Eumetopias jubatus*	Jamieson and Olesiuk 2001
Namibia	*Arctocephalus pusillus*	Anonymous 2000e, g, h
Sweden	*Halichoerus grypus* *Pusa hispida*	Associated Press 2001; Anonymous 2001d
Norway	*Pagophilus groenlandicus* *Cystophora cristata*	Norwegian Ministry of Foreign Affairs 2001
Cetaceans		
Japan	*Balaenoptera acutorostrata* *Physeter macrocephalus* *Balaenoptera edeni*	Reuters 2001; Tamara and Ohsumi 1999
Norway	*Balaenoptera acutorostrata* *Lagenorhynchus acutus* *Lagenorhunchus labirostris*	Norwegian Department of Fisheries nd. Thoring 2000; Anonymous 2002b

the hearts of the fishermen'. But for the language, his account sounds remarkably contemporary.

The fishermen's response sounds quite familiar too. '[The fishermen] bring it near the land; there, with trident and mighty clubs and stout spears', Oppian continues, 'they smite it on the temples and kill it, since destruction comes most swiftly upon seals when they are smitten on the head'.

The situation described by Oppian represents but one of several potential conflicts between marine mammals and fisheries. For convenience, these conflicts are usually divided into two categories: operational conflicts and ecological conflicts (Anonymous 1981a; Lavigne 1982; Fertl 2002; see Table 3). *Operational conflicts* involve physical encounters between marine mammals and fishing gear, broadly defined. They arise, for example, when marine mammals damage fishing gear or aquaculture facilities, and when they damage fish caught in the gear or cause the fish to escape (either from fishing gear or from aquaculture facilities), resulting ultimately in economic losses to commercial enterprises. They also arise when marine mammals are taken incidentally in commercial fisheries resulting in their injury or death (Woodley and Lavigne 1993; Perrin *et al.* 1994) or become entangled in discarded fishing gear, including 'ghost' nets (Gulland 1986; Laist *et al.* 1999). Those conflicts that are perceived to damage fisheries or aquaculture facilities typically result in calls for culling the marine mammal population(s) involved (Table 3). Those that potentially harm marine mammals do not, and will not be discussed further in this chapter.

Ecological conflicts include those that arise because of predation by marine mammals on commercially important fish stocks or their prey. While attention has tended to focus on the potential effects of marine mammals on commercial fisheries (Fertl 2002), there is another side to this coin: the potential effects of commercial fisheries on marine mammals, particularly endangered species (Northridge 2002). Such suspected interactions have been a source of conflict, for example, in the case of the endangered Steller sea lion, *Eumetopias jubatus*, in western Alaska (National Research Council 1996; National Marine Fisheries Service 2000); and of the Hawaiian monk seal, *Monachus*

Table 3 Potential conflicts between marine mammals and fisheries (modified after Anonymous 1981a; Harwood 1983; Gulland 1986). Those conflicts that give rise to calls for culling marine mammals are marked with an asterisk (*).

Operational conflicts	
	Damage to fishing gear or aquaculture facilities*
	Damage to (or loss of) catches or aquaculture stock*
	Incidental catches of marine mammals in fishing gear or in aquaculture facilities
	Entanglement of marine mammals in marine debris, including discarded gear
Ecological conflicts	
	Transmission of parasites*
	Predation and competition
	Effects on fisheries (direct effects and indirect effects)*
	Effects on marine mammals (direct effects and indirect effects)

Table 4 Attitudes toward animals (adapted from Kellert 1980, 1993).

Term	Definition
Naturalistic	Affection for wildlife and the outdoors; satisfaction from direct experience/contact with nature
Humanisitic	Affection for individual animals; emotional attachment, 'love' for nature
Aesthetic	Interest in the physical appeal and beauty of nature
Symbolic	Interest in the use of nature for metaphorical expression, language, expressive thought
Moralistic	Concern about the treatment of animals, with strong opposition to exploitation or cruelty toward animals; strong affinity, spiritual reverence, ethical concern for nature
Scientistic	Interest in the physical attributes and biological functioning of animals
Ecologistic	Concern for the environment as a system, for interrelationships between wildlife species and natural habitats
Utilitarian	The practical and material exploitation of natural resources including animals or their habitats
Dominionistic	The mastery and control of animals and their habitats
Negativistic	Fear, aversion, and alienation from nature
Neutralistic	Passive avoidance of animals due to indifference or lack of interest

schauinslandi, in the North-western Hawaiian Island chain (Lavigne 1999; US District Court 2000). In both cases, concern has been expressed that commercial fisheries are contributing to the decline, or preventing the recovery, of depleted marine mammal populations. But once again, the latter conflicts do not result in calls for culling marine mammals, so they will not be discussed further here.

The effects of ecological conflicts involving predation (or competition) may be either 'direct' (e.g. marine mammals eat commercially important fish stocks, or a commercial fishery reduces the availability of an important marine mammal prey species) or 'indirect' (e.g. marine mammals eat the prey of commercially important fish stocks or commercial fisheries reduce the availability of food for marine mammal prey).

Ecological conflicts of a different sort arise where marine mammals are the definitive hosts of parasites that also occur in commercially harvested fish species (e.g. cod worm, also known as seal worm, *Pseudoterranova decipiens*, and herring (or whale) worm, *Anisakis* sp.; Malouf 1986; Bowen 1990).

There has been a tendency for scientists to focus mainly on ecological interactions between marine mammals and commercial fisheries, arguing that solutions to operational interactions are largely technological in nature (e.g. Anonymous 1981a). Nonetheless, science and scientists have important things to say about both operational (Northridge 1984; Pemberton and Shaughnessy 1993; Wickens 1995; Hutchinson 1996; Read 1996) and ecological (Earle 1996; Anonymous 1997; Northridge and Hofman 1999) interactions.

From the outset, however, it is important to recognise that the debate over culling marine mammals, like the debate over culling mammals generally, actually has more to do with values, attitudes, and societal objectives, and therefore politics, than it has to do with science *per se*.

THE NATURE OF THE CULLING DEBATE

Different individuals and groups in society attach different values and hold a variety of different attitudes toward animals generally and toward marine mammals in particular (Table 4). They also have different objectives for marine mammals and their wild populations, objectives that in many cases are mutually incompatible (Table 5). It is because of these differences in values, attitudes, and objectives, that calls for culling marine mammals give rise to a variety of conflicts among different segments of society (Anonymous 1981a).

Such conflicts involve, on the one hand, fishermen, sealers and whalers, and their respective organisations, as well as governments and government agencies, and international bodies primarily concerned with sustaining or enhancing the productivity of commercial fisheries, sealing or whaling. The attitudes they express generally are *utilitarian*, *dominionistic*, and *negativisitic* in nature (see Table 4). Their objectives for marine mammals are, understandably, largely socio-economically oriented (Table 5).

On the other hand, these conflicts involve individuals and organisations, national and international, concerned with the wellbeing and preservation of marine mammals. The attitudes they express are generally *naturalistic*, *humanistic*, *aesthetic*, *symbolic* and, most importantly, perhaps, *moralistic* (Table 4). Their objectives for marine mammals tend to be largely ethically oriented (Table 5).

As Donovan *et al.* (1981, p. 4), pointed out, such conflicts are 'the stuff of politics'. They generally take place 'not only among people and groups and nations, but also among alternative values, or to put it more precisely, competing visions of what is "good"'.

With that as background, let us briefly examine the evolution of a typical culling debate. In the past, calls for culling almost invariably originated from fishing interests, commercial or sport fish-

Table 5 Objectives of marine mammal management

Socioeconomically oriented objectives	
1	Providing commodity yields (including food, industrial products, luxury items, etc.)
	a from marine mammals
	b from competitors of marine mammals (e.g., upper trophic level fishes)
	c from prey species of marine mammals (fish, invertebrates)
2	Providing recreation and tourism
	a oriented toward hunting and fishing for sport
	b oriented toward nature observation, ecotourism (e.g., whale watching)
3	Providing employment and cash income
4	Maintaining cultural diversity (e.g., survival of traditional and subsistence economies)
5	Providing for distribution of benefits to all levels of society
	a locally
	b regionally
	c nationally
	d internationally
6	Providing for scientific uses and increased knowledge
7	Providing educational benefits
8	Providing for human health
9	Providing for domestication (e.g. as sources of food and other commodities, for captive breeding programs)
Ecologically oriented objectives	
10	Maintaining ecosystem diversity (biodiversity)
11	Maintaining ecosystem stability
12	Maintaining gene pools and genetic diversity
13	Maintaining the ability of populations to survive fluctuating environmental conditions
Ethically oriented objectives	
14	Minimizing human impacts on marine mammal populations
15	Avoiding inhumane or cruel practices involving marine mammals
16	Enhancing survival chances of marine mammals, especially threatened and endangered species
17	Not killing animals at all
18	Maintaining options for future human generations

There are no clear boundaries between the three main headings; various objectives clearly overlap and, in some cases, objectives are either in conflict or mutually exclusive with others under the same or different heading. All objectives must be considered in relation to both long-term sustainable benefits and intermediate or short-term benefits (modified after Food and Agriculture Organization 1978). For completeness, a fourth category, politically oriented objectives, could be included in this list. Because it was not in the original, I have not added it here.

ermen or the operators of aquaculture facilities, who see marine mammals as a threat to their operations or livelihoods. But, today, with increasing frequency, they also originate from those who promote the commercial exploitation specifically of marine mammals (individual sealers and whalers, government agencies, and even certain governments), or of wildlife in general (e.g. World Conservation Trust Foundation 1999; and from other members of the 'wise use' movement, see Lavigne *et al.* 1999).

The typical culling controversy begins when bold statements about the need for a cull are transmitted (almost always uncritically) by the popular media (e.g. Dwyer 1999; Seenan 2000). Thus, the stage is set for a 'political' conflict of the sort described above. Those opposed to a particular culling proposal mount their opposition and both sides attempt to generate public pressure on those who make policy and management decisions regarding marine mammals and fisheries. The media dutifully record the controversy, giving weight to virtually any claim, regardless of its merit, all in the name of 'balanced' journalism.

Public pressure from various constituencies eventually reaches the attention of politicians who, ultimately, are responsible for making management decisions regarding both marine mammals and fisheries. The situation is further complicated, in a number of countries – Canada and the United States come immediately to mind – because the responsible politicians and their associated bureaucracies (the Department of Fisheries and Oceans in Canada and the National Marine Fisheries Service in the United States) are in a 'conflict of interest' situation. On the one hand they have a mandate to look after the interests of fish stocks and fisheries; on the other, they have responsibilities for the conservation of marine mammals. And, because the ultimate objective of a politician is to get re-elected, the deck is stacked against the marine mammal. The reality is: fishermen, sealers and whalers have a vote; marine mammals (and, for that matter, fish) do not! While it is evident that marine mammals have gained increasing numbers of advocates in some parts of the world in recent decades (Lavigne *et al.* 1999), whether that support actually gets translated into votes on their behalf in any particular election is not at all assured and will depend on many other variables.

Regardless, there is a history in wildlife and fisheries management, which dates back to the early 1930s (e.g. Leopold 1933) – in North America at least – of making management decisions based on science (or, more likely these days, paying lip-service to making decisions based on the best available scientific evidence). Thus, scientists are drawn into the debate and they are asked to provide answers to questions such as: what will be the effect of a marine mammal cull on commercial fish stocks and the fisheries that depend on them? In this way, questions about culling become scientific questions, and workshops (e.g. Anonymous 1981a, 1997), symposia (e.g. Montevecchi 1996), Royal Commissions (e.g. Malouf 1986), and even 'eminent persons panels' (Anonymous 2001a), are convened to examine the issues arising.

Before we get to the question of what science has contributed to the debate and what it can contribute in the future, let's first examine the question of values, attitudes and objectives, and the mechanisms we have for resolving conflicts in civil societies.

CONFLICT RESOLUTION IN MODERN SOCIETY

The culling controversy involves a debate over 'facts' and values (or attitudes, objectives). Since 'science' has little to contribute on the subject of values (Berry 1993), it begs the question: what can science contribute to resolving conflicts, such as the culling debate?

Berry (1993) provides some insights, 'based on sociology's enduring quandary of "fact/value conflicts"'. His conflicts matrix (Figure 1), while undoubtedly an oversimplification of the real world, is quite instructive.

Where there is social agreement on both the facts and the values surrounding a decision there is no societal conflict and all that remains is to find a 'computational solution'. If, for example, there is societal agreement that a fish population can and should be exploited at biologically sustainable levels, scientists can, in theory at least, estimate (or compute) the appropriate yield that will have an acceptably high probability of achieving that objective.

Most decisions in fisheries and wildlife management, however, involve situations where there really is a 'fact/value conflict'. There are, for example, situations where 'values' are in agreement, but the facts remain in dispute – the O.J. Simpson murder trial is a good example. There was little disagreement on 'values'- husbands should not kill their wives – but there was a disagreement over the facts – did he, or did he not do it? While such conflicts are frequently 'resolved' using the LEGAL system (see Figure 1, lower left box), they also may be viewed as being typical of scientific controversy arising from the existence of competing hypotheses. Hence, my modification of Berry's original matrix to include SCIENTIFIC conflicts (Figure 1). Scientists can test

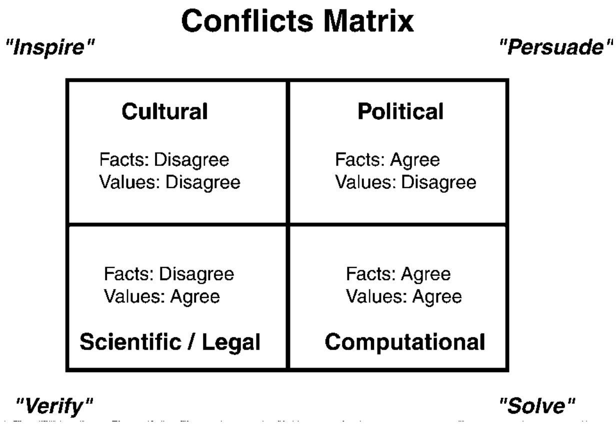

Figure 1 Berry's conflicts matrix (modified from Berry 1993; see text for detailed discussion)

among such competing hypotheses, reject those that do not withstand scrutiny and, with luck, move the debate into the COMPUTATIONAL box.

Science has less to contribute, however, when the 'facts' are not really in dispute and the conflict revolves largely around a disagreement over 'values'. For example, there might be agreement that species A is endangered but conflict over what, if anything, should be done about it. While 'science' might be used to persuade society to act in a particular way, ultimately, such conflicts are usually resolved by POLITICAL means (Figure 1).

The most contentious conflicts in society – including those in fisheries and wildlife biology in general, and the majority of culling controversies in particular – involve disputes over both 'facts' and 'values'. In such conflicts, Berry suggests that science is 'ineffective' and its solutions have 'little relevance to either the discussion or a decision'. Berry labels such conflicts 'CULTURAL' conflicts, the abortion debate being the classic example. Science can still 'inform' the debate (Berry 1993), educate the public (Lavigne 1996) and 'illuminate the political choices' (Butler 2000). But, more often than not, such conflicts, with their attendant scientific uncertainty, give rise to the spectacle of dueling expert witnesses, which does nothing to reinforce society's regard for the ability of science and scientists to resolve controversial issues.

There is really no mechanism in modern society for resolving cultural conflicts of the sort described above, and that includes culling debates that involve both facts and values. The only hope for resolution is that over time, some agreement can be reached, either on the facts or on the values, or both, thereby moving the conflict into another box in Berry's conflicts matrix (Figure 1). Once out of the CULTURAL box, we at least have mechanisms for resolving the conflict in question.

The message implicit in Berry's (1993) model is that science *per se* cannot be expected to resolve most culling controversies. But, as Berry's analysis also indicates, this does not mean that science and scientists have nothing to contribute. That being the case, what has science done thus far to 'inform' the culling debate, and what might it be expected to do in the future?

WHAT HAS SCIENCE CONTRIBUTED TO THE CULLING DEBATE?

Science and scientists have 'informed' the culling debate in a variety of ways and, on occasion, have been influential in 'persuading' or influencing decisions by management authorities. They have often been called upon to assess and quantify the nature of a presumed interaction between marine mammals and fisheries (e.g. Anonymous 1991, 1997). They have been asked repeatedly to predict the possible effects of increases or decreases in marine mammal populations on fish stocks or on yields derived from them (e.g. Anonymous 1981a, 1981b, 1991, 1997). In some instances they have been asked to recommend mitigation measures and to evaluate their potential efficacy (Northridge and Hofman 1999). Finally, they have been encouraged to develop and test new mitigation methods, including alternatives to culling.

In the following two sections I look briefly at what science and scientists have contributed to discussions of both operational and ecological interactions between marine mammals and fisheries.

Operational interactions

Despite the fact that a number of scientific workshops on interactions between marine mammals and fisheries have explicitly avoided any discussion of operational interactions (e.g. Anonymous 1981a), scientists have done considerable work on the subject (reviewed in Harwood 1983; Northridge 1984; Wickens 1995; Northridge and Hofman 1999; Fertl 2002).

From the outset, it seems apparent that each and every operational interaction must be examined on its own merits. This is because the species of marine mammal and the nature of the hypothesised conflict with a fishery or aquaculture facility vary both spatially and temporally. Nonetheless, a number of generalisations have emerged from studies conducted to date.

Whenever an interaction between a marine mammal and a fishery or aquaculture facility arises that is thought to impact on human activities, the initial reaction is to call for culling the marine mammals involved. Culling, defined as the directed reduction in the size of a local population to achieve some specified objective (Jewell and Holt 1981), may involve lethal or non-lethal methods. Culling using non-lethal methods invariably involves the removal of individual animals and their relocation elsewhere in the wild or their confinement in captivity (e.g. Fraker and Mate 1999). Lethal culling may involve the targeted removal of offending individuals or the indiscriminant killing of large numbers of animals (essentially, culling at the population level) with a view to reducing the number or severity of interactions between the marine mammal population and human activities.

Regardless of the type of cull proposed, there is little evidence to suggest that the removal of animals alone will generally provide a long-term solution to operational conflicts. If a species is abundant in the area, the culled individuals will likely be replaced by others and, in order to be successful, such culling programmes would require constant vigilance and continued effort to remove the marine mammals in question. Indiscriminant culling at the population level may not even remove the individuals that are implicated in the presumed interaction.

In instances where individual 'rogue' animals are causing the problem, their specific removal should eliminate the problem, so long as mitigating measures are put into place to discourage other animals from becoming problems in the future (National Marine Fisheries Service 1996). In the case of California sea lions, *Zalophus californianus*, at Ballard Locks, Seattle, for example, the removal of three troublesome sea lions to a captive facility (National Oceanic and Atmospheric Administration 1996) plus the use of acoustic alarms (Marine Mammal Commission 2000) appears to have reduced depredations by sea lions on steelhead trout passing through the locks on their way to spawning grounds up river (National Oceanic and Atmospheric Administration 1999).

Since culling rarely appears to provide a consistently effective means of solving operational interactions where marine mammals impact fisheries, much effort has been put into developing alternatives to culling (Fertl 2002). These alternatives, designed to keep marine mammals away from fishing operations and aquaculture facilities, include harassment techniques, aversive conditioning, exclusion, and relocation. Harassment has been attempted, for example, by means of acoustic harassment devices (AHDs; Johnston and Woodley 1998), acoustic deterrent devices (Mate and Harvey 1987), and through the playback of predator recordings (Wickens 1995). Aversive conditioning using lithium chloride treated fish has also been attempted (Pemberton and Shaughnessy 1993, Gearin *et al.* 1988).

Where existing aquaculture facilities are involved, exclusion of marine mammals from the area of interaction may be accomplished using models of predators or 'scarecrows', or by creating physical barriers through the construction of anti-predator fences (Pemberton and Shaughnessy 1993). Also, it has been suggested that some of the problems would not arise (or would be less serious) if the facilities were not placed in coastal habitats favoured by marine mammals, particularly pinnipeds (Würsig and Gailey 2002). Building such a facility within sight of a favoured haul-out site, for example, simply creates a problem that will be difficult to solve, resulting in frustration and economic costs to the facility operator, and the needless deaths of seals that will likely be culled as a result. These, and other problems related to aquaculture facilities, led an independent public examination of the salmon aquaculture industry in British Columbia, Canada, to recommend that net cages be replaced with onshore, closed-loop containment systems, thereby insuring no opportunities for conflicts with marine mammals, while at the same time reducing coastal habitat destruction and loss (Leggatt 2001).

Regardless, it seems clear that the attempts to develop alternative measures to reduce operational interactions have met with only limited success. The general consensus seems to be that further research is required to develop and test new technologies to reduce operational interactions between marine mammals and fisheries.

Ecological interactions

By their very nature, ecological interactions between marine mammals and fisheries give rise to a number of scientific issues. There was a time, early in my career, when the conventional scientific wisdom was that marine mammals had voracious appetites. The famous Norwegian biologist, E.J. Slijper (1962) actually called cetaceans 'gluttons'. Their large appetites were necessary, it was thought, to fuel an elevated metabolic rate that, it was assumed, would be required for a warm-blooded mammal to maintain a constant deep body temperature in cold ocean waters (reviewed in Lavigne *et al.* 1986). Some scientists also postulated (without any supporting evidence) that marine mammals were 'inefficient converters of fish flesh' (Sergeant 1973), another feature that, if it were true, would increase even further an already hearty appetite.

This is one area where scientists, particularly physiological ecologists, have made significant contributions to inform the debate surrounding proposals to cull marine mammals ostensibly to benefit fisheries. Although one still sees occasional references to the sorts of dated claims mentioned above (e.g. Komatsu and Misaki 2001; Winters and Miller 2001; Williams *et al.* 2001), scientific research has demonstrated that when measurements are made under standardised conditions, metabolic rates of marine mammals are not significantly different from those of other mammals (Lavigne *et al.* 1986; Hunter *et al.* 2000). Likewise, their digestive efficiencies are also similar to other mammals eating similar diets (Lavigne *et al.* 1982) and, consistently, their average daily food consumption (in terms of energy) is, for their size, not significantly different from those of other mammals, including humans (Innes *et al.* 1987).

The above evidence notwithstanding, the view that marine mammals are 'gluttons' has not been totally abandoned. Today, calls for culling marine mammals are routinely justified on the basis of a comparison between the biomass of marine organisms that marine mammals might take from the ocean versus that removed by humans (see Lavigne 1996). Take for example, the current push to cull whales ostensibly to benefit world fisheries (e.g. World Conservation Trust Foundation 1999; Komatsu and Misaki 2001).

In recent years, Japanese scientists have presented calculations which suggest that whales are removing 'between 280 and 500 million tonnes of marine life each year' from the world's oceans, 'three to six times the annual world harvest of fish for human consumption' (Tamura and Ohsumi 1999). These calculations, it should be noted, are not part of the mainstream primary scientific literature, but have been widely disseminated through advertising campaigns (e.g. World Conservation Trust Foundation 1999) and used extensively by proponents of whaling (e.g. Komatsu and Misaki 2001) to further their cause. They have also been uncritically reported by journalists and columnists (e.g. Kristoff 2002), who seem unable to distinguish pro-whaling advocacy from reliable scientific information.

The scientific reality is that estimates of food consumption by whales (e.g. Tamura and Ohsumi 1999), even if they were based on adequate data, would actually tell us very little about whether or not marine mammals are having direct or indirect effects on the abundance of various fish stocks or on the catches of commercial fisheries (Lavigne 1996).

Of course, whales must eat to survive and reproduce. In the case of the great whales, the bulk of the prey species consumed are invertebrates, including zooplankton (Euphausiacea) and squid (Teuthoidea) (Pauley *et al.* 1998). Many whales do eat fish, but a large proportion of the species they eat, whether invertebrates or fish, are of no current interest to commercial fishermen. In those situations where whales, like some seals, do eat commercially important species or their prey, it is not at all clear, as we shall soon see, whether a whale cull would be beneficial or detrimental to fishing interests.

Regardless, if someone insisted on trying to estimate the total amount of food eaten by whales in the world oceans, they would need to know the population size for the nearly 80 species of marine cetaceans (whales, dolphins, and porpoises), their daily energy requirements in the wild (see Leaper and Lavigne 2002), the amount of various prey species consumed, and the energy content of each. Since we do not know the population sizes for most cetaceans, nor their actual energy requirements in the wild, nor specific details about most of their diets, it quickly becomes evident that it is impossible to estimate accurately the total amount of food eaten by all whales.

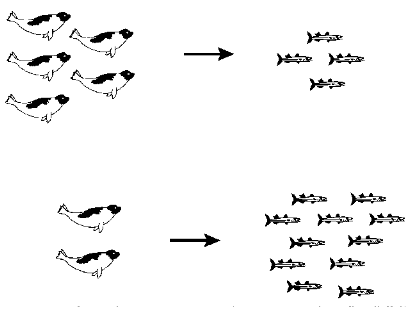

Figure 2 A simple, two-component model of marine ecosystems, where marine mammals eat commercially important fish (upper). A reduction in the number of marine mammals can only result in more fish for fishermen (lower).

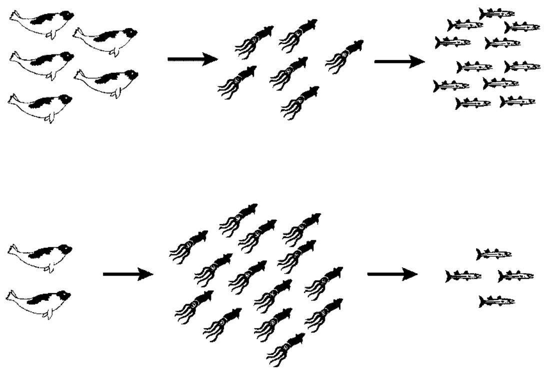

Figure 3 A simple, three-component model of marine ecosystems, where marine mammals eat the predators (or competitors) of a commercially important fish (upper). A reduction in the number of marine mammals results in fewer fish for fishermen (lower).

So, when proponents of culling whales suggest that these animals eat huge amounts of marine life, the actual numbers they provide are virtually meaningless. They do not tell us how much commercially important fish is actually eaten by whales. They tell us nothing about the effects of culling whales on the future abundance of commercially important fish stocks and catches that might be obtained from them. And, they obscure the fact that the major predators of commercially important fish are not marine mammals, but other fish (e.g. Young 2000).

The view that fewer marine mammals would mean more fish in the ocean, and more fish for human consumption is often said to be based on 'common sense'. According to that particular 'common sense', a reduction of whale stocks would 'release' millions of tonnes of fish to fill the nets of fishers for years to come. In reality, such a view is based implicitly on an overly simple model of the world, where the oceans contain only two groups of animals: marine mammals and fish (Figure 2a). Since marine mammals eat fish, then fewer marine mammals must mean more fish for humans (Figure 2b).

Scientists have informed this particular debate by pointing out that an equally 'common sense' argument tells us that in those situations where a marine mammal eats the predators or competitors of commercially important fish (Figure 3a), then fewer whales would actually mean fewer fish for fishermen (Figure 3b). Adding just one more component to the system changes the predicted outcome of a whale cull (Butterworth *et al.* 1988; Lavigne 1996).

Empirical evidence supports this possibility. In terrestrial systems, for example, the removal of top predators may sometimes result in an increase in smaller predators, a process termed mesopredator release (Soulé *et al.* 1988). As a result, levels of predation may actually increase and have a negative effect on prey populations, including those 'of human economic concern' (Palomares *et al.* 1995).

Regardless, both of the above 'common sense' scenarios are overly simplistic. Ocean ecosystems have many more than two or three components. When one looks at even a simplified food web for the Northwest Atlantic (Figure 4), for example, it becomes obvious that predicting the outcome of a whale cull based on either 'common sense' argument would be foolish. Feeding relationships in the oceans are complex (see Yodzis 2001a, for another example) and it is extremely difficult to predict what the effect would be of reducing one component, such as whales, on the rest of the system.

As early as 1981, scientists participating in a meeting of the Northwest Atlantic Fisheries Organization (NAFO) concluded that the effects of increasing or decreasing the size of a seal population on fish stocks and fishery yields was unknown. In other words, the effects of seals on fish stocks and fishery yields was not sufficiently well understood at the time to offer a scientific opinion on the likely outcome of a seal cull. More than ten years later, Canadian government scientist, Dr Don Bowen (1992) would reiterate much the same conclusion, regarding harp seals (*Pagophilus groenlandicus*) in the Northwest Atlantic. 'We do not know', he noted, 'what the effects of a change in seal numbers would have on commercial fisheries'. Several years later, an international scientific workshop on interactions between harp seals and fisheries in the Northwest Atlantic (Anonymous 1997) would come to a similar conclusion. 'It is not yet possible', the report notes, 'to predict the effects of an increase or a decrease in the size of the harp seal population on other ecosystem components, including commercially exploited fish populations, or on the yields obtained from them' (Anonymous 1997, p 28).

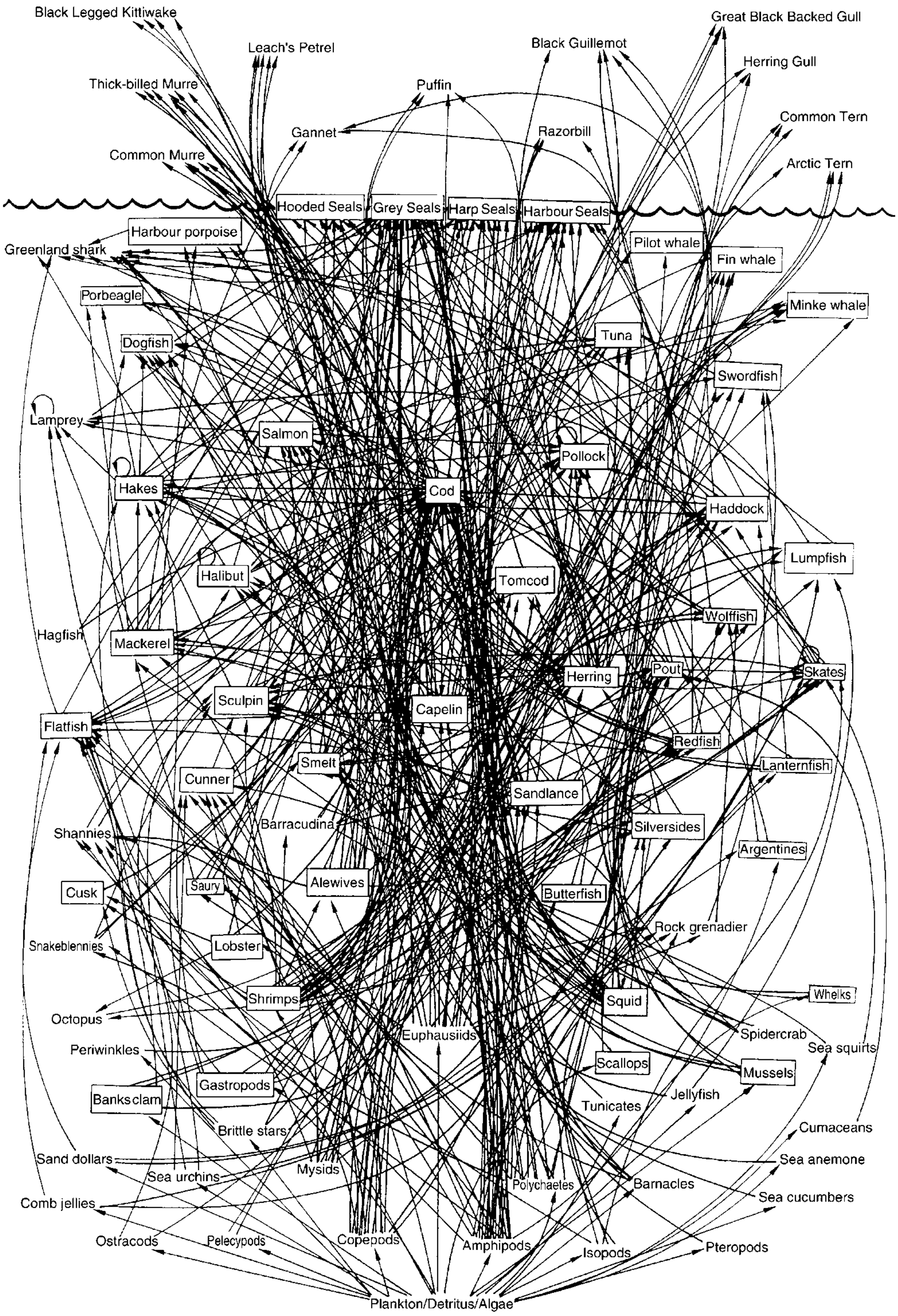

Figure 4 A partial food web for the Scotian Shelf in the Northwest Atlantic off eastern Canada. Species enclosed in rectangles are also exploited by humans. This food web is incomplete because the feeding habits of all components have not been fully described. Further, all species – including some of the marine mammals – do not spend the entire year in the area (compiled from a variety of sources by D. Huyck and reprinted from Lavigne 1996).

The failure of scientists to come to more definitive conclusions about the nature of interactions between marine mammals and fisheries and even about the possible benefits of culling marine mammals simply underscores the complexity of marine ecosystems (remember Figure 4) and our lack of precise understanding about how they function (e.g. Yodzis 2001a, 2001b; Boyd 2001). But to conclude that no scientific progress has been made in recent years would also be wrong.

Some real progress has been made, particularly in the last 15 years, and it is interesting, in the context of this book, that some of the most significant advances have occurred as a result of work done in the Southern Hemisphere, specifically in South Africa.

In the late 1980s and early 1990s, fishers and politicians in South Africa began to call for a cull of Cape (South African) fur seals, *Arctocephalus pusillus pusillus*, because it was perceived that the fur seals were competing with important commercial fishery for hake, *Merluccius* sp. (Anonymous 1991). Calls for a cull were followed, as usually happens, with an international outcry that there was no scientific evidence to support a reduction in the Cape fur seal population.

South Africa's initial response was typical of countries faced with a culling controversy. As others had done before (Anonymous 1981a), and still others have done since (e.g. Anonymous 1997), it convened an international workshop on the biological interactions between Cape fur seals and fisheries. The workshop produced a consensus report, which included a number of recommendations for further scientific research (Anonymous 1991).

At this stage, South Africa deviated from the norm. It immediately called upon its scientists to implement the workshop recommendations (to the extent that they were able) and, two years later, the government reconvened a sub-set of the original workshop participants to review their findings (Anonymous 1994).

In short, the South African scientists found that while a Cape fur seal cull might provide some minor benefits to fisheries, it was more likely to have a detrimental impact on the hake fishery (Punt and Butterworth 1995). This was because the fishery actually involved two hake species, *Merluccius capensis* and *M. paradoxus*, that, in addition to being eaten by fur seals, also eat each other. Because of the differential feeding rates of the fur seals on the two hake species, and the fact that the hake species of lesser importance to the fishery eats more of the more important hake species, a cull of fur seals was likely to result in increased depredation on the more important hake and, hence, have deleterious impacts on the fishery (Punt and Butterworth 1995; Yodzis 2001a).

Following the international review of the findings, and consistent with its policy of basing fishery management decisions on the best available science, the Government of South Africa dropped its call for a seal cull in 1993 (for further details see Chapter 6, this volume).

The South African case provides a good example where science can make a significant contribution to resolving a culling debate. In this instance, there was *de facto* an agreement on values: management of the hake fishery should be based on the best available science, but a disagreement over the facts (the SCIENTIFIC/LEGAL box in Berry's conflict matrix; Figure 1). Science was then used to test whether a cull of Cape fur seals would be beneficial or detrimental to the hake fishery. The hypothesis that a cull would benefit the fishery was subsequently rejected (Punt and Butterworth 1995) and the conflict was effectively moved into the COMPUTATIONAL box in Berry's matrix (Figure 1). With sufficient agreement on both values and facts, the South African government introduced a moratorium on culling Cape fur seals that remains in place today.

Shortly after the 1991 meeting in Capetown, the United Nations Environment Programmes' Marine Mammals Action Plan convened a Scientific Advisory Committee to begin the development of a protocol for the scientific evaluation of proposals to cull marine mammals. That committee, with representatives from both the Northern and Southern hemispheres first met in 1992 (Anonymous 1992b), and again in 1994 (Anonymous 1995), and eventually submitted the results of its labours to UNEP in 1999 (Anonymous 1999a).

The protocol describes the steps required to make a proper scientific evaluation of a proposal to cull marine mammals. It makes heavy reading, even for most scientists, and therein lies an important message. The scientific evaluation of proposals to cull marine mammals requires considerable data and sophisticated scientific analyses, reinforcing once again the message implicit in Figure 4. The first steps entail the identification of the relevant components needed to conduct the evaluation. These include: the marine mammal population(s) involved, the target fish species, the relevant fisheries and existing fishery management system, other predators of the target species, and other important species in the system. The next steps include: defining the measures of gain or loss to the fishery, constructing simulation models of the components identified above, examining a range of alternative scenarios, running replicates of each scenario and, using the information generated, to compute frequency distributions of gains and losses (for details, see Anonymous 1999a).

Despite the continual appearance of proposals to cull marine mammals (Tables 1 and 2), no jurisdiction (besides South Africa) has yet attempted to subject a culling proposal to the sort of rigorous evaluation procedure outlined in the UNEP culling protocol.

Suppose a jurisdiction disregards all the obvious problems and uncertainties and proceeds with a marine mammal cull regardless.

An obvious question is whether all the fish that the culled marine mammals would have eaten would end up in fishers' nets? According to the scientific community, the answer is clearly no (Lavigne 1996). Any increase in the number of fish resulting from a marine mammal cull is much more likely to be eaten by other predators, including predatory fish, sea birds, and other marine mammals, than it is to be caught by fishers. Still others of the 'saved' fish will simply never be encountered by a commercial fishing boat and will eventually die from other forms of natural mortality. Any possible benefits of a marine mammal cull to a fishery could, therefore, only amount to some small proportion of the benefits originally implied simply by calculating, no matter how imprecisely, the total amount of food consumed by the marine mammal population. Without adequate assessment, such as that described in the UNEP protocol, there also remains the troublesome possibility that a marine mammal cull might actually be detrimental to fishing interests.

Until other jurisdictions apply methods similar to those employed in South Africa and described in the UNEP culling protocol, controversies will continue to rage. In the interim, we will continue to consult the historical record and the past musings of scientists to inform the current debate.

In centuries past, the world's oceans were home to more marine mammals, including whales, dolphins, porpoises, fur seals, sea lions, walruses and true seals, manatees and dugongs, than they are today (Jackson *et al.* 2001). At the same time, many fish stocks were also more plentiful. Remember, for example the anecdotal reports from John Cabot's early ventures to the Northwest Atlantic, off the East coast of North America. Marine mammals were numerous and not commercially exploited on any major scale, and Atlantic cod, *Gadus morhua*, were purportedly so abundant they could be scooped out of the sea in wicker baskets.

Today, there are fewer species of marine mammals in those waters. In the eighteenth and nineteenth centuries, the Atlantic gray whale (*Eschrichtius robustus*) was hunted to extinction and the walrus (*Odobenus rosmarus*) was extirpated from the Gulf of St. Lawrence and the North-eastern United States (Lavigne and Kovacs 1988). Although protected since 1972 (Lavigne *et al.* 1999), a number of other great whale populations have yet to recover from the effects of commercial whaling. Meanwhile, those once abundant cod stocks that had supported a commercial fishery for centuries, finally collapsed in the early 1990s, due to over-fishing (Hutchings and Myers 1994) and there has been a moratorium on Canada's commercial cod fishery since 1992.

A similar pattern is seen elsewhere. Most large whale populations used to be far more numerous than they are today; there were obviously enough fish and plankton to support them, and enough left over to support the huge global fish stocks that have since been exploited by commercial fisheries (Young 2000). While the possibility exists that cetaceans could reduce commercially important fish stocks, scientists have yet to find any substantive evidence that they have done so (Katona and Whitehead 1988), and the partial recovery of some whale populations over the past 30 years cannot begin to explain the decline in fisheries worldwide (Young 2000).

As far as the prospect of gaining benefits from culls of marine mammals, one might reflect on Montevecchi's (1996) observation that 'There is no scientific evidence that the culling of large marine predators has ever benefited a commercial fishery'. Such a conclusion might have been predicted from Larkin's (1979) warning that we should not, in fact, 'expect long-term benefits to the prey from predator control'. And now, '…there is a considerable body of current opinion that fisheries should be managed in such a way as to avoid harm to natural populations, rather than the other way round' (Yodzis 2001a). This latter opinion, of course, arises more from ethical (rather than scientific) considerations, but it is noteworthy that such sentiments have become entrenched in a number of international conventions including the United Nations Convention on the Law of the Sea and the Convention for the Conservation of Antarctic Marine Living Resources. Both conventions recognise the importance of 'dependent species' and require those who wish to exploit fishery resources to make sure that enough fish remain for other predators, including marine mammals.

Conclusion

If there is one take-home message in this chapter it is this: Science will never put an end to calls for culling marine mammals. There will always be segments of society that will, because of their values, attitudes or objectives, continue to call for culls of marine mammal populations. In some of these cases, culling proposals will arise out of a genuine belief that there is a real conflict. In many others, marine mammals will continue to be used as scapegoats for failures in fishery management (e.g. Holt and Lavigne 1982). In still other situations, calls for culling marine mammals will simply be part of a political strategy to promote commercial consumptive use of marine mammals, including both seals (e.g. Lavigne 2002) and whales (Komatsu and Misaki 2001).

Each new call for a marine mammal cull will be accompanied by calls for more scientific data and analyses, and better models, maintaining the impression that culling controversies eventually will be resolved by the weight of scientific evidence. Scientists in turn will capitalise on the situation and apply to granting agencies and governments for more money for further research on the issue. The resulting scientific research undoubtedly will continue to answer some of the questions posed. It will continue to reject untenable hypotheses, and inform the debate over proposals to cull marine mammals, at least for those prepared to read or listen to the evidence. In a few instances (as in the South African example above), it will actually contribute to a resolution of a culling controversy, at least for a time. More globally, and despite the best efforts of the scientific community, however, proposals to cull marine mammals, and the actual culling of marine mammals, will continue largely unabated.

For those who think such a conclusion is overly pessimistic, I would like end this chapter by returning to the beginning. Remember Oppian's Mediterranean monk seals? Now, move the clock forward from the second century AD to the early years of the twenty-first century. Today, only about 500 Mediterranean monk seals survive worldwide, perhaps 350 maximum in the Mediterranean Sea. The remainder resides precariously in the Northeast Atlantic off the coast of the Western Sahara (Forcada *et al.* 1999). The species is described as highly endangered (IUCN 1996). Yet, remarkably, those monk seals remaining in the Mediterranean are still killed by fishers, who remain convinced that the seals really are competing with them for depleted fishery resources in the sea. No amount of science will end this (and other) interactions, perceived or real, between marine mammals and fisheries. No amount of science will stop some fishers and others from culling marine mammals they perceive to be competitors or pests. Nothing short of a major change in global human attitudes will accomplish that.

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