Seal-Fisheries Interactions

PROBLEMS, SCIENCE AND SOLUTIONS

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Executive summary

- The aim of this report is to consider both sides of the seal-fisheries conflict and to seek solutions. The report focuses on the harbour and grey seal in UK waters, but also considers other seal populations worldwide where studies may contribute to the debate (Introduction).

- The fishing industry's collective view is that seals are competitors for economically valuable fish (biological interactions) and damage both fishing gear and catch (operational interactions). Seal numbers should therefore, according to this view, be controlled by culling. The grey seal is the fishing industry's principal target, since it is the more numerous species in UK, its population has been increasing for several decades, and it appears to be more opportunistic than the harbour seal in its predatory habits (The Debate, §1–2).

- Until 20 years ago, the UK government scientists recommended culling of grey seals based on the theory that the fewer seals there are, the fewer fish they eat and the more will be available to commercial fisheries. Government sponsored culls of grey seals were attempted between 1977–1982. However, these culls were vigorously opposed by international and UK national conservation bodies, who urged a precautionary approach to seal management until adequate scientific studies of seal diet and impact on fish stocks had been carried out. The UK government reluctantly agreed to carry out further research before authorizing any further culls. That research is still ongoing and does not so far support culling (The Debate, §3–4).

- Since the early 1980s, more realistic models of interactions between seals and commercial fish stocks have been developed. These are 'multi-species' models of the marine food web, which include all marine fish predators, including other fish and birds as well as seals, dolphins, porpoises and whales. Figures from ecosystems studied indicate that predatory fish are by far the greatest predators of fish. In the North Sea, commercial fisheries consume 36% of all fish, while all marine mammals together consume only 0.8% of the total. Moreover, the whitefish and flatfish eaten by seals in the North and Irish Seas are mostly juveniles, i.e. of a size discarded by fishermen. Even if every grey seal in UK waters was removed, therefore, any possible 'surplus' of any kind of fish liberated to the industry would be extremely small and any discernable benefit would be short-lived with the present level of fishing. There is no evidence that seals have had any part to play in the collapse of the cod fishery, either here or in eastern Canada. Nor is there any evidence that seal predation would inhibit the recovery of cod stocks (The Debate, §5).

- Computer modeling studies to predict the outcome of seal culls indicate the amount of commercial fish liberated for fisheries would be negligible. Implementation of any future cull proposal would have to comply with the internationally agreed UNEP protocol, which requires clear objectives and scientifically evaluated biological data relating to any proposed cull (The Debate, §6–11).

- Salmon fisheries claim that seals threaten the survival of their industry by preying on salmon entering or leaving rivers, as well as attacking salmon caught in nets, traps or held in cages. They claim that seal diet studies reporting that salmon are not part of the seals' diet conceal the real truth, because seals eat only the soft parts of salmon and not the head, and therefore that salmon remains, including earstones (otoliths) are not detected in diet studies using seal scats. This latter assertion seems to be incorrect, because salmonid hard parts, including otoliths, have been detected in some major studies of seal scats, including several in the NE Pacific and one in the UK. Where salmonid remains are found to be absent from a large sample of seal scats, therefore, probably signifies a genuine absence of salmon in the diet. This appears to be the case for most major colonies of both species in the UK (The Debate, §12).

- Seals in estuaries are often legally shot to protect salmon fisheries. However, studies have indicated such shootings are almost certainly of little or no benefit - seals near salmon river estuaries have been found not to feed exclusively on salmon, and to consume much fewer salmon than those caught by anglers. Seals have also been exonerated of much scar damage to fish, and seals shot near nets will in any case be replaced by others. There is an additional concern that many seals assembling at river estuaries are actually harbour seals, whose local population size may be relatively small; shooting these seals may therefore endanger local populations (The Debate, §13).

- The increasing use of inshore set nets (Drift, tangle and gill nets) in various fisheries during the past three decades, and also the new practice of setting creels with fresh fish bait during the past 2 decades, has been accompanied by an increase in the incidence of seal damage to gear and catch. The cost of this damage may be significant to individual fishermen, possibly averaging about 10% of the catch. However, in some cases the loss to seals may be reduced by modifying the fishing methods, e.g. by reducing the soak time of bottom-set nets and by patrolling surface-set nets frequently to remove fish as they are caught. Any culling operation would have to be on a large scale to have any effect, since all members of a grey seal population may be equally likely to try to prey on nets. Since the cost of such a cull would be enormous in relation to the cost to the fishery (and would also pose serious ethical and animal welfare problems), it would be neither a rational nor humane solution. In the UK, fishermen may shoot seals legally around their nets, but this is probably ineffective in reducing damage, might endanger local populations, and raises ethical problems (The Debate, §14–22).

- Some fish cages and traps may be made seal-proof, for example by a net tensioning system for fish cages and by strengthening the twine and using a grating for the fish entrance in traps. For fish growing cages a new type of acoustic deterrent, triggered only by a predator attack, has proved highly successful when used as a preventative in conjunction with a net tensioning system. For set nets no successful deterrent has been developed. For all types of fish cages, traps and set nets, probably the best solution to seal damage is to set the gear away from known seal haul-out sites, foraging hot-spots and travel routes. Exclusion zones for set nets might be considered in conservation areas for seals (The Debate, §23–24).

- The role of seals in the cycle of the codworm (a nematode parasite of cod and other whitefish) is an additional reason for calls for seal culling by the fishing industry. However, the relationship between seal numbers and cod infestation is complex; infestation in North Sea cod has not risen along with grey seal numbers, for example. In fact the number of fish, the average age of the cod population and the movements of the cod all appear to have a greater effect on infestation levels than the number of seals. Culling, unless on a very large scale, would therefore not be effective (The Debate, §25–26).

- By-catch of seals in fishing nets is an enormous problem world-wide. All ages of grey and harbour seals die in set nets (tangle and gill nets), but yearlings seem to be most vulnerable. Seals drowning in nets are not necessarily trying to feed from those nets. It is thought that seals foraging on the seabed do not detect the nets until they have swum into them and been caught. A study on the Norwegian coast estimated a minimum of 6% of yearlings of each species are by-caught annually. The solution to this problem, similarly to that for seal damage to nets and catch, may lie in setting the nets away from major areas of seal use. (The Debate, §27–38)

- Entanglement of seals in pieces of discarded netting is a very major problem for some seal species in some parts of the world. A seal may drown, or carry a neck ligature of net, which causes constriction, wounding and eventually death. The extent of this problem for seals in the UK and Ireland has yet to be assessed on any quantitative basis, but in any case, deliberate or negligent discarding of netting should be prevented and dedicated efforts should be made to retrieve lost pieces of netting (The Debate, §39–40).

- It is known that some commercial fisheries are having a negative impact on some fish stocks. There is also evidence that seals are susceptible to malnutrition or starvation resulting from declines in stocks of particular staple prey items. Where commercial fishing reduces the abundance of a particular species or alters the dominant fish species in the food web, therefore, commercial fisheries may have an indirect impact on seal populations, resulting in altered distribution of seals and in some cases population declines or mass migration. (The Debate, §41–43).

- In some areas the careful development of wildlife tourism, with both species of seal featuring prominently, might help fishing communities to diversify, encourage tourism and offset losses. The large cuts in commercial whitefish quotas and consequent redundancies will cause great hardship in fishing communities. However, in 1996 the revenue from 0.5 million visitors watching seals in the UK and Ireland was estimated at more than £36 million and generated 193 full-time and 322 part-time or seasonal jobs. (The Debate, §44–47).

- For the future it should become possible for scientists and the fishing industry to cooperate in developing a sustainable fishing industry, which can co-exist in harmony with natural populations of seals and other marine mammals. Fishermen can work together with scientists to minimize seal-fisheries conflict. During the period of the present serious cuts in commercial fisheries, the industry may take the opportunity to restructure future fishing so as not to result in irreversible food-web instability and loss of species (The Debate, §48).

Introduction

The protagonists in this debate are seals and fishermen.

The most publicized problem, as perceived by fishermen, is that seals constitute a rival fishing fleet, which directly competes for available fish stocks and thereby reduces the potential profit of the industry. Representatives from the fishing industry regularly call publicly for a cull of seals large enough to reduce the alleged competition. The other side of this coin is that over-fishing by commercial fisheries may have an impact on seal populations by altering the amount of food available to them. Both of these types of clashes between fishermen and seals are known as 'biological interactions'.

A less publicized problem in the UK is known as 'operational interactions'. This involves seals attempting to feed from fishermen's nets, traps or cages and in so doing damaging both the fishing gear and entrapped fish.
The other side of this coin is that seals become entangled in fishing gear and drown or are killed by fishermen. Also, seals become entangled in floating debris resulting from discarded fishing gear. The salmon fishing industry (including netting, trapping, angling, farming) is particularly antipathetic to the presence of seals.

Seals are the final host of a nematode parasite known as the 'codworm' or 'sealworm', which infects cod and other whitefish in its larval stage. These worms have to be removed from the flesh before the fish can be sold. This earns the seals another black mark from the fishing industry.

The aim of this report is to consider carefully both sides in the seal-fisheries conflict and debate. Information relating to all aspects of the conflict will be presented and synthesized. Finally, feasible routes to long-term solutions will be suggested; these will have the ultimate goal of creating a situation whereby seals and fishermen may live in harmony. This report focuses in detail on interactions between seals and fisheries in UK and Irish waters, but interactions in other countries and with different species of seal will also be considered where they contribute to a better understanding of the problem.

Since the ultimate aim of this report is to seek solutions, this report should be viewed as a dynamic instrument for improving the seal-fisheries relationship. The report takes the form of a debate in which a seal biologist responds to typical questions and complaints by fishermen. The answers to the questions are summarized from key points from published reports and scientific papers, which in turn are summarized in Tables I–XIX, referred to in the text. In the tables, paraphrased summaries are presented in ordinary type, while direct quotes from the authors are italicized. It is also hoped that the tables (which will be updated regularly) may be used as quick reference background material for current and future debate, while the summary report may be a starting point for a forum where new constructive and creative ideas by different contributors may be incorporated in future editions.

There are two seal species native to the British Isles.

The harbour seal (sometimes known as the common seal), Phoca vitulina. is a relatively small seal (adults weighing about 100–130 kg), with males generally only slightly larger than females. The harbour seal comes ashore to rest, pup and moult on inter-tidal ledges and sandbanks, but spends most of its time in the water.

Clockwise from top left: adult male, adult (non-pregnant) female, pregnant female lying beside juvenile male, and juvenile. Note variation in pelage and, even in adults, the rounded shape of head.

Note shape of face and nostrils compared with grey seal (below)

2. Newborn harbour seal pup – note shape of face and nostrils compared with grey seal (right)

It sheds the white fluffy coat, usually so characteristic of seal pups, before birth and is able to swim and follow its mother through the water within minutes of being born. The pups nurse for about four weeks, immediately after which pups swim and learn to feed independently.

There are approximately 30–40,000 harbour seals altogether in UK and Irish waters, constituting about 40% of the European harbour seal stock and about 7.5% of the global population in the north Atlantic and Pacific oceans.

3. Harbour seal pup riding on its mother's back.

The grey seal (sometimes known as the Atlantic seal), Halichoerus grypus, is a larger seal, females weighing about 150 kg and males larger, about 230 kg. Like the harbour seal, the grey seal hauls out on intertidal ledges and sandbanks to rest, but it also tends to favour more exposed coastlines and offshore islands.

4. Grey seal haul-out group

Pups are born in late Autumn and early winter, usually at a spot above the high tide mark. The white fluffy coat is not shed until the pup is about 3 weeks old, and so the pup is maladapted to an aquatic existence until then, although (as illustrated below) pups in some areas do venture into the water close to the shore. The pups nurse for 2½ – 3 weeks and then usually spend a few days alone on or close to the shore before finally going to sea and starting to swim and feed independently.

5. Grey seal mother nursing pup and close-up of same pup in water. Note shape of face and nostrils compared with harbour seal

6. Grey seal pup riding on mother's back.
Note: the more aquiline profile of the mother's head compared with the harbour seal.(left)

The most recent estimate for the UK grey seal population is about 120,000, of which about 80% are in Scottish waters. Irish waters hold approximately another 10–15,000. The grey seal occurs only in the north Atlantic. The British Isles stocks constitute about 85–90% of the European stock, and about half of the world population, estimated at about 250,000.

Fishing industry representatives regularly use the press to articulate their collective view that seals in the UK, particularly in Scotland, pose a threat to the fishing industry. Scottish politicians from all the main political parties have supported their view in statements to the press (Table1). The reason always given is that their increasing numbers mean they have a significant and ever-increasing effect on fish stocks and altogether catch as many or more fish as the fishing industry is allowed to land. Fish assumed to be eaten by seals are considered to represent a loss of catch, and hence of profit, to fishermen. From these reports, therefore, it appears that 'biological interactions' are the industry's main concern. The industry favours culling seals as a solution to this perceived problem. Some reports refer just to 'seals', although in one report the industry called for 50,000 grey seals to be culled in one season followed by an annual cull to keep the numbers down (Table I).

However, when individual fishermen in the UK and Ireland were given an opportunity to respond to survey questionnaires, problems with operational interactions were highlighted (Table II). The main concern was damage to trapped fish rather than damage to nets (which many fishermen regard as a general occupational hazard). The most serious level of complaints in surveys in Cornwall and SE Ireland (home to grey seals) concerned inshore tangle net and gill net fisheries. A survey of creel fishermen in Orkney (home to both grey and harbour seals) revealed a problem since 1989 of fresh bait being removed by seals (Table II). The majority of respondents (though not all) to these questionnaires recommended seal culling as a solution to the problem (Table II).

Representatives of the salmon fishing industry have claimed significant damage by seals (Table III). The claim is that consumption of salmon by seals has been a major factor in the recent decline in salmon returning to their home rivers and that many caught are damaged by scars from attacks presumed to be by seals. They also claim that seals only eat some soft parts of salmon, and therefore

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salmon consumption is not detected by scientists looking at for hard parts as evidence (Tables I and III).

1. Is the UK government responding to the fishing industry's constant pleas for a major seal cull to reduce their effect on fish stocks?
Not any more. UK government scientists used to recommend culling based on the theory that the fewer seals there are, the fewer fish they eat, and less of the potential profit to the fishing industry is lost to seals (Table IV). In the 1960s it was recommended that seal stocks should be 'substantially reduced and thereafter maintained at a level which will not interfere unduly with fisheries'. Culling of both grey and harbour seal pups was carried out in the 1960s and 1970s with the object of protecting salmon fisheries (Table XI) as well as selling skins. In the late 1970s, UK government scientists considered it 'of paramount importance' to fisheries to reduce the UK grey seal population and maintain it at its mid-1960s level. A total of 1,800 females and 131,750 pups were to be killed over a 5-year period 1977–82. The effects of these planned culls were to be monitored and procedures adjusted every year to maintain the population at its desired level (Table IV).

2. So, what happened?
The first planned culling was carried out in the Western Isles in the grey seal autumn breeding season of 1977, but fewer seals were killed than intended because of bad weather and other logistical factors (Table V). The serious disruption due to the killing caused breeding adults to abandon the pupping grounds and 40% did not return during the next two years. The following year saw the celebrated Greenpeace Rainbow Warrior protest and outcry by the public and major international and UK national conservation bodies against the culling (Table IV), but the programme nevertheless continued until 1981.

7. The Kvitungen, the Norwegian sealing vessel hired for the cull.

However, of the cull originally intended, only 3.9% of the pup cull and 15.9% of the adult female cull was actually carried out (Table V), and no monitoring of the effects nor procedural adjustment were actually implemented.

8. Grey seal carcases lie about after a cull of adults and associated pups

9. A grey seal 'moulter' pup is shot during the cull (left) and moulter carcases being removed and taken to the ship for skinning

The statements by Greenpeace UK and IUCN in October 1978 explained that their principal reason for opposing the scientific basis for the cull was that although there was data on grey seal population sizes and individual seal energy requirements, data on fish species consumed and impact on fish stocks was totally inadequate to predict any benefit to fisheries of a cull. They, and other conservation bodies, therefore urged a precautionary approach and a stop to any culling until the appropriate research had been carried out. Scientists who had supported the culling lamented that the bodies opposing the cull were unqualified and unprepared to do so and predicted that they would lose scientific credibility over the affair. By contrast, history would vindicate the pro-culling position as being scientifically justified (Table IV). Nevertheless, the UK government agreed to carry out further research before authorizing any further culls.

3. That was more than 20 years ago. Meanwhile the grey seal population has continued to grow at about 5% a year with their fish consumption increasing accordingly, while the North Sea whitefish industry is close to collapse. Surely they have done enough research now to be able to back the fishermen's plea for a major cull?

Yes and no. Yes, the research has been carried out — but no, it doesn't support a cull.

4. But why not? If the link between increasing seal populations and declining fish stocks was self-evident in the 1970s, surely it is even more obvious now with the expanding grey seal population?

Quite the opposite, in fact. The simplistic idea of seeing fish populations collectively as a 'cake' having to be shared between seals and fishermen, with more for one resulting in less for the other, was widely accepted by UK government seal scientists until the early 1980s (Table IV). Criticism of this naive idea was articulated in 1978 by Greenpeace UK and IUCN, who both opposed the grey seal cull then (Table IV) on much the same basis as it is opposed now, based on research since carried out (Table IV & VI). Far from being discredited, as predicted by the UK government scientists at the time, therefore, the precautionary approach articulated by the bodies opposing the cull was eventually shown by modern research techniques to have been the wisest approach after all.

The sea-change in scientific thinking began in the early 1980s. Sidney Holt and David Lavigne, writing in the *New Scientist* (Table VI) in 1982, explained why perceived problems of seal-fisheries biological interactions could not be considered and solved only by reference to seals and fisheries, i.e. to the population size and appetites of seals on the one hand and the size of commercial catches on the other. They explained that because fish are eaten by many predators besides seals, such as other fish and other marine mammals, all co-existing in a highly complex 'multi-species' web, it is simply naive to imagine that a reduction (by culling) in the seal population would mean that more fish would become available to commercial fisheries. Figures from ecosystems so far studied indicate that predatory fish are by far the greatest predators of fish. In the North Sea, commercial fisheries were estimated to consume 36% of all fish while all marine mammals together consume only 0.8% of the total (Table VIIb). Any surplus fish 'liberated' by a seal cull would therefore be expected to be small, and fishermen would only secure a small fraction of that. At worst there might even be a reduced availability to fisheries of some valued species owing to multi-species interactions. The authors concluded by stating that there is no justification for making scapegoats of seals for the failure of fisheries management and making a plea to scientists not to allow government strategies for seal 'management' culls to misrepresent their advice.

5. Isn't this just 'fudging' the inescapable fact that seals are allowed to breed freely and eat whatever fish they want, while fishermen are subject to crippling cuts and quotas?

Since the early 1980s fisheries and marine mammal scientists, from Beverton in 1985 to Yodzis in 2001 (Table VII), have been devising ever more sophisticated models, for marine ecosystems worldwide, of the complex and dynamic web of interactions involving valued fish species and all their potential prey and predators. These models are tested and developed in conjunction with real data on fish and marine mammal population dynamics, and on the diet and energy needs of all marine creatures in the web, including valued fish species and seals (Table VIII).

Early research on seal diet involved the analysis of stomach contents of seals that had been shot, mainly at salmon fishing nets, and therefore the results were thought to be biased. Since the mid-1980s the diet of seals has been studied principally by analysing fish otoliths in faecal samples. Although this has the disadvantage of a probable bias towards the inshore diet of seals (as opposed to their offshore diet), it is an entirely non-invasive and inexpensive technique. In the mid-1980s the UK Sea Mammal Research Unit (SMRU) published their first research on the energy requirements, diet and overall estimated amount of fish of different species eaten by grey seals in the North Sea (Table VIII). This study was considerably extended in the North Sea and to Orkney and the Hebrides in later years. The seals' principal prey was found to be sandeels followed by various whitefish (of which cod was the dominant species except for the Hebrides) and flatfish, and only for sandeels did seal consumption compare significantly with a large commercial catch.

The most recent SMRU estimates for cod consumption by grey seals is that they consumed less than 10% of the amount taken by the commercial fishery in 1995 and, despite the increase in grey seal numbers since then and the decrease in commercial cod quotas, cod consumption by grey seals in 2002 was still estimated to be only 25% of the commercial landed catch (Table VIII).

6. But 25% is a lot! If our profits went up by 25% we'd be much better off!

Even if every grey seal in UK waters was killed, only a small fraction of that 25% might be available to the fishing industry, and even that possible benefit would be short-lived with the present level of fishing. Furthermore, studies have shown that the whitefish and flatfish eaten by grey, harbour and harp seals and also fur seals are predominantly juvenile fish of less than 40 cm (Table VIII), i.e. the size discarded by fishermen and not included in the size of the landed catch. The 25% figure does not take that size discrepancy into account, and would be very much smaller if it did.

This preference of seals for juvenile fish and of the commercial fishery for adult fish is thought to reduce local competition where seals and the commercial fishery operate in the same area (Table VIII). In such cases, the fishery may even

benefit seals by catching the large fish, which would normally eat the seals' smaller prey. It is also possible that the abundance of sandeels in the North Sea in recent years is partly due to the commercial over-fishing of adult cod and other whitefish, which would otherwise be important predators of sandeels. By removing the majority of the top fish predators from the North Sea, NW and NE Atlantic ecosystems, therefore, commercial fisheries may have inadvertently encouraged the growth of grey and harp seal populations by providing them with a larger surplus of smaller fish and sandeels (Tables VIII and X).

7. But by eating small fish, seals are also eating the food needed by large cod. This has meant that in the last few years only a small amount of cod have grown to full size.

Small fish are eaten by many predators as well as by growing cod, and seals only take a very small fraction of these (Tables VI, VII and VIIb). There is no evidence whatever that predation by seals on small fish deprives larger fish of food! However, if concerned about this, the fishing industry might be equally concerned by the vast numbers of juvenile fish killed and discarded by fisheries as by-catch.

8. Another point, then. SMRU has stated quite recently that although grey seals may not be significant consumers of fish in the scale of the whole North Sea, their research shows that the seals may spend most of the time fishing close to the shore. Therefore they could be having important local effects, which could have economic significance for fishermen. Isn't this a hint that a local cull could benefit local fisheries?

The studies referred to were on the grey seals of the Farne Islands. Their local inshore foraging 'hotspots' were actually sandy gravel banks where the seals were believed to be feeding primarily on sandeels. These seals are therefore, so far as is known, not competing to any significant extent with local fishermen fishing for whitefish or flatfish. The information obtained from this study may, however, be fed into fine-scale multi-species fisheries models, which will enable the situation to be more accurately assessed.

9. So, are you telling us that the EU is threatening to close our cod fishery, the rampant increase in grey seals has nothing to do with the collapse, seal populations might actually be growing because of the collapse in stocks of adult cod - and that we should just quietly decommission our boats, watch the seals taking over the sea and do nothing about it?

That just about sums it up. There is really no evidence that seals have had any part to play in the failing fortunes of the cod fishery. This was also the case in NE Canada. It is now generally accepted that the collapse of the Newfoundland cod fishery was due to the unsustainable TAC and by-catch levels (VI) and nothing to do with harp seals, who were generally blamed by fishermen. Atlantic cod in fact has been found to be only a minor component of harp seal diet (2.8% by weight average from 12,5000 stomachs; Table VIII).

10. But the Canadian cod fishery was closed in 1992 and cod stocks still haven't recovered. The Canadians are allowed to shoot thousands of harp seals now because it is widely accepted that the increasing harp seal population is preventing recovery of the cod stocks. So why can't we do the same with grey seals? We could develop and market new seal meat dishes to compensate for the loss of fishery, just like they are doing in Canada.

It is true that the Canadians are once again killing huge numbers of harp seals, but this was a political decision and not a scientific one. The only tenuous scientific basis was a model which made an assumption that predator (i.e. seal) control would have an effect on recovery of the cod stocks, but failed to incorporate the long-term effects of the persistent removal of cod spawning stock by the fishery up to 1992. Cod do not mature until 5–8 years of age, and the more viable young are spawned by older females. Clearly, therefore, stock recovery will be slow and cannot be expected to have recovered yet. Despite allegations (Table II), there is no scientific evidence that harp seals will inhibit the recovery (Table VI). In fact, the reverse is likely to be true – a recovering cod stock will prey heavily on capelin, which is a principal prey fish of harp seals. Commercial over-fishing of capelin together with predation on capelin by a recovering cod stock in the Barents Sea resulted in a collapse of capelin stocks and large-scale starvation and migration of harp seals in the late 1980s (Table X).

11. Then wouldn't it be a kindness to have a cull of grey seals now, and keep the numbers down for when the cod recovers and sandeels decline? Wouldn't that save them from future starvation?

There are serious moral problems associated with any attempts to cull seals in order to mitigate potential 'natural' mortality (Table V) or seals' own 'welfare' (Table II). Culling is a blunt (and also inhumane) instrument, which may well disrupt the natural process of the seals' own intrinsic population control mechanism. For example, a recent SMRU survey of major British grey seal colonies has shown a marked decrease in the number of pups born, which is

probably the seals' own response to diminished prey availability (Tables IV and X). In any case, any future cull proposals in this country would undoubtedly have to comply with the UNEP protocol, which requires clear statements of the objectives of such a cull, backed up by a host of biological data, which would be subject to scientific evaluation (Table IV). Without such statements, the UK government would not therefore be in a position to authorize a cull in response to requests from the fishing industry.

12. What about salmon fisheries? It's been revealed that just under a million mature salmon return to Scottish rivers each year and about half of those are eaten by seals.

There is actually very little evidence that either grey or harbour seal predation has any significant impact on wild salmon populations. Diet studies of seals from major colonies in the UK and Ireland have found virtually no evidence of predation on salmon (Table VIII). An exception to this was a study of harbour seals in Loch Linnhe (a sea loch in the west of Scotland). Salmonids are resident here at certain times of the year; in the early summer of 1990, nine salmonid otoliths from adult fish were recovered from scat samples out of a total of 2729 otoliths (0.33%) and amounted to an estimated 9% of the diet by weight. A major study of harbour seal diet in British Columbia (BC) has also detected significant numbers of adult salmonid otoliths and identifiable bones in 451 of 2841 harbour seal scats (15.1%), which were estimated to represent 4% of the diet by weight. These authors recommended scat analysis for a broad overview of the diet. Other harbour seal diet studies from scats (in the Russian, Columbia and Rogue River systems on the west US coast) have shown frequencies of occurrence of salmonid remains of 20–60%, variously on hatchery fish, adults returning to spawn or smolts leaving the river.

These studies are important, since they indicate, contrary to the salmon fishery's general assertions, that otoliths from adult salmonids can be detected in seal scats, and harbour seals do, at least sometimes, eat the entire adult fish, including the head. This was also observed in harbour seals in Thurso in the spring of 2002 (Table XI). It is possible that detection rates for the relatively fragile salmonid otoliths may be less good than for the more robust otoliths of some other fish groups (such as gadoid fish), but nevertheless, where there is total absence of salmonid otoliths in large sample sizes of scats, it may be concluded with reasonable confidence that salmon are not part of the diet.

10. Grey seal eating salmon. ***Note that in this case the salmon head appears to have been eaten.***

13. Since the seal population is expanding so rapidly, soon the salmon will be virtually extinct unless we restore the balance of nature by culling seals.

This perception is a misapprehension. Grey seal numbers have been increasing in the UK, but not harbour seals. However, the seals most often found at the estuaries of important salmon rivers in the British Isles are harbour seals, and not greys. Moreover, the only diet studies of seals in which salmonid remains have been found in the scats are of harbour seals, not greys. Very few studies of these harbour seal colonies have been carried out, but their presence in the river undoubtedly reflects various aspects of their habitat, such as suitable haul-out site (often with high water access) and proximity to inshore foraging areas. In BC, salmon was found to be a relatively minor component of the diet (12% by weight) of harbour seals in salmon rivers, which fed primarily on other marine fish (Table XI).

The authors of the BC study nevertheless voiced their concerns over localized conflict between harbour seals and salmon fishermen in the estuaries of major salmon rivers, and suggested that detailed investigations, including direct observation should follow a study by scat analysis. In the study of harbour seals in the Don & Dee estuaries, seal predation on large salmon was found to be an order of magnitude less important than the number of salmon caught by anglers (Table XI). Even if seals were thought to be having a significant impact on numbers of salmon, SMRU has pointed out that localized killing of seals around the estuaries of salmon rivers will not be effective if all the animals in the local population may target salmon, since individuals killed will soon be replaced by others (Table XI). Since local harbour seal populations at river estuaries may be relatively small, shooting of harbour seals in estuaries in the UK and Ireland might make them vulnerable to local extinction and would raise ethical dilemmas. The small group of harbour seals in the River Thurso in Scotland, for instance, gives townspeople and visitors the opportunity to watch wild seals at uniquely close quarters.

14. Are you saying, then, that there is no real problem of seal-fisheries interactions and it's all just a figment of the fishermen's imagination?

No, there are real problems involving seals and fisheries. However, continuing calls by representatives of the fishing industry for culls still appear to be based on the old chestnut of increasing numbers of seals endangering the fishing industry by eating too many fish. This is a naïve theory that was already biting the dust by the early 1980s and which has been given a dignified burial by continuing research and developing scientific thought over the past 20 years

(Tables IV–VIII). Fisheries representatives need to leave this theory behind and move on to address the genuine problems of seal-fisheries interactions on the one hand and conservation of fish stocks on the other.

15. What, then, are the 'genuine' problems of seal-fisheries interactions?

The problems that undoubtedly occur to one extent or another in different areas include seal predation on fishing nets and on fish farms and also the other side of that particular coin – seals being either caught and drowned in nets or being deliberately killed in or near nets. The indirect biological effects of fisheries on seals due to the collapse of particular fish stocks or change in the dominant fish species are being increasingly documented.

16. Seal predation on fishing nets and fish farms cannot be denied by anyone. Culling the seal population as well as killing seals around nets would solve this problem too, would it not?

So far there is no evidence that killing seals, either around farms and nets, or in the wider regional population, will resolve this type of problem. If all members of the seal population are equally likely to prey on fish in nets, then only a large-scale cull would have any conceivable effect on the problem. If seals near nets are killed, they will soon be replaced by others – the problem will remain while a large proportion of the local seal population could be killed inadvertently. If research can show that particular 'rogue' individuals are involved, then killing these seals might alleviate the problem (Table XII). However, a trial cull in Sweden, in which grey seals sighted close to salmon traps were killed in experimental areas, but not in control areas, demonstrated that the cull did not reduce damage to the nets and catch, and therefore did not support the specialist 'rogue' theory (Table V).

17. So it has to be a large-scale cull then?

This would be unlikely. Apart from the ethical issues involved, a large-scale cull would not make economic sense. The actual costs of seal damage to gear and catch in any particular area would be small in relation to the expense of a large-scale cull in a given area (Table XII). Also, large-scale culls of grey seals would have to be carried out at haul-out sites, probably during the breeding season and in Ireland, for example, the actual population of grey seals causing damage to particular fisheries in SE Ireland is ill-defined. Also, in the NE of England seal damage to the inshore set net fishery is actually less in the vicinity of the major colonies at the Farne islands than in more northerly areas, where seals may be converging from different colonies. A cull might, therefore, be directed at the wrong group of seals (Table XII). Moreover, previous attempts at grey seal culling in Scotland and on the Farne Islands caused major problems of animal welfare without being successful in achieving the desired effects on the seal population (Table V).

18. But there appears to be general agreement among fishermen that the problem of grey seals attacking inshore set nets has greatly increased in the past decade. Surely this is because of the uncontrolled expansion of grey seal numbers, and would be solved by controlling their numbers?

Well, this is apparently a growing problem in the Celtic Sea, but there is in fact no indication that grey seal numbers have increased substantially in this region. It is much more likely that the increase in damage is related to the actual increase in the use of inshore set nets – both tangle nets and gill nets. This type of fishing only began in the 1970s and has increased greatly in recent years (Table XVI). Both complaints of damage by fishermen (Table II) and scientifically reported damage (Table XII) are much greater for these inshore nets than for nets set, for example more than 5 miles offshore.

19. Nevertheless, it is generally accepted, even in law, that the fisherman's best defence against individual seals raiding inshore tangle and gill nets is to shoot them.

Although shooting seals around fishing nets is permitted in the UK under the provisions of the 1970 Seal Conservation Act, as previously discussed, such shooting is not an effective solution to the problem. Apart from the ethical considerations of such action, such killing around nets might result in a large proportion of the local seal population being killed inadvertently (Table XII). It is believed that such killing of the Mediterranean monk seal is one of the main causes of this seal's population decline to the verge of extinction (Table XII). Scientists in Greece believe that deliberate killing by fishermen seems to be responsible for the animals' fear of man and their avoidance of much potential coastal habitat (Table XIV).

20. You say the costs of seal damage to fishermen's catch and nets are relatively small in relation to the cost of a cull, but these costs are significant to individual fishermen.

Yes – Damage of up to about 30% of catch has been reported, although average figures of about 10% damage from various inshore set-net fisheries have been reported (Table XII). In monetary terms, an example of the estimated loss to the tangle-net monkfish catch in SE Ireland was estimated at 667 kg, amounting to approximately IR£1,553 in 1998, or averaging approximately £50 per vessel per month (Table XII). Any attempt to solve problems of seal damage on this

relatively small scale must make economic sense as well as being ethically defensible.

11. Netted herring damaged by seals

21. So if there isn't going to be any seal cull, what is an effective solution to gill and tangle net damage?

There is no quick fix, but various non-lethal means have been tried. In the summer drift net fishery for salmon in NW Ireland, losses to seals from nets was reported to be < 2% when fishermen adopted a system of patrolling the nets regularly and removing each fish soon after it was caught, rather then leaving caught fish accumulate in the nets to attract seals (Tables XI, XIII and XIV). An extension of this system might be to experiment with reducing the soak time of bottom-set nets or adjusting the periods of night and day during which they are set. An automatic explosion simulator was reportedly successful in deterring sea lions from raiding bottom-set nets in Hokkaido, but since such devices may result in ear damage to marine mammals, their use may be ethically questionable (Table XIII). A successful method tried in bottom-set bag nets in Hokkaido was increasing the strength of net yarn (to 75 yarns) and use knotted webbing to prevent the spread of tears. Stronger nets have also reduced the level of damage in the Scottish stake net fishery (Table XIII).

One solution is to take great care in selecting the locations for inshore set nets. The inshore coast includes the natural breeding, resting and foraging habitat of many species of seal, including grey and harbour seals in the UK and Ireland. Setting nets near seal haul-out sites, near their established travelling routes or near their foraging grounds will cause predictable operational problems. If nets can be set so as to avoid the main areas of seal activity, then damage may be minimised. For example, nets set offshore in the summer resulted in much less damage by monk seals, because the main (inshore) foraging area of the seals was avoided (Table XIV). Similarly, fishermen in Barra (Scotland), working a new tangle-net fishery for crawfish, found that with experience they could minimise interactions with seals by being selective about where nets were laid (Table XIV). Recent tracking studies of seals are increasing our knowledge of where seals go and where the greatest areas of activity are. For example, studies of grey seals at the Farne islands were able to show that while the seals were feeding, they formed clusters at distinct locations – four inshore and four more distant. When seals are travelling from haul-out sites to foraging areas, they tend to go directly, and these travel paths may be charted. If this sort of information can be charted and shared with the fishing industry, it may help fishermen to locate nets away from seal 'hot spots' and thereby minimise damage.

22. But won't some seals find the nets anyway, and use them to get an easy meal?

The extent to which seals will be attracted to fish in the nets depends partly on the species and possibly also on the individual seal. Seals are generally natural predators of live fish either on the sea-bed or in the water column and naïve seals of any species are not normally attracted to dead or dying fish. All seals may, however, be attracted to live fish in cages, bag nets or trawls, since the message received by the seal from a group of trapped fish will resemble the message from a fish shoal.

However, seal species seem to vary as to how opportunistic they are in adapting their natural foraging behaviour to respond to dead or dying fish in tangle or gill nets, or to dead fish discarded by fishing boats. The more opportunistic species seem to include grey seals, monk seals and sea lions, while harbour seals, by contrast, are rarely found scavenging from nets or boats. Individuals of the more opportunistic grey seal may indeed quite readily learn to feed from nets or to open creels to remove fresh bait. They will, of course, also learn the locations of fixed nets. Studies of grey seal foraging behaviour indicate that once an individual has established a particular foraging location and pattern, it seems to repeat this pattern for extended periods (Table IX). The best advice to the fishing industry to minimise seal damage to the nets is to request studies of seal movements and seal 'hot spot' areas to avoid, to change the locations of nets frequently and to fish offshore whenever possible. Inshore set nets are a relatively recent growth industry, and perhaps should be subject to environmental impact assessment where further expansion of this type of fishing is being considered.

23. Well, how do we stop seals raiding fish traps, creels and cages – apart from trying to site them away from seal hot-spots?

For fish farms there is a new net tensioning system now being widely used and this has proved to be 95–100% effective in preventing seal predation on salmon cages. A newly developed acoustic deterrent device (ADD) - which emits sound at a non-injurious intensity and is triggered only when fish are panicked by a seal's approach - has proved to be 92% effective in trials in keeping seals well away

from cages in which a net tensioning system is already being used (Table XIII). The ADD not only further reduces fish loss, but also reduces the stress levels of caged fish and hence improves their welfare and growth rates. The ADD is most effective against seal predation if activated constantly before a problem has occurred rather than as a reaction to an attack.

The problem of seals predating on fish caught in bag nets in the Baltic was studied in experimental trials. The authors suggested using a seal exclusion grating at the trap entrance in combination with stronger 'seal-proof' 'dyneema' twine, and this was found to be successful (Table XIII). The very recent practice of baiting creels with fresh fish bait is evidently a problem in attracting seals (Table II); a return to the older practice of using non-fresh bait should alleviate this problem.

24. So in general you are saying that not only should seals not be killed, but fishermen should actually change their behaviour to accommodate seals?

Well, yes. We have to remember that seals have been in our coastal waters for many millions of years before human beings arrived and started to fish as well. Seals are supremely adapted to finding food in their environment, and to them fish in nets are just another source of food to be exploited. There is no point in hoping that seals will change their behaviour to suit human beings (and then shooting them when they don't), so the only logical way to reduce conflict and move forward is for fishermen to try to understand the way seals operate and use this knowledge to reduce deleterious interactions.

25. Well, what about the codworm, or sealworm as people now rightly call it? Seals are the final host of this worm, and if there weren't so many seals there wouldn't be so many of our fish infested with it. You can't disagree with that!

There is no doubt that seals ingest codworm larvae from the fish they eat and then recycle them back into the food chain by eliminating their eggs into the sea. However, the idea that worm infestation of cod (and other whitefish) is a simple function of the number of seals was based on superficial surveys in the middle of the last century. In fact there is no simple relationship between seal numbers and cod infestation, and the latter has not increased along with the rising grey seal population in the UK (Table XV). Modeling studies have shown, for example, that doubling the number of fish will have a much greater impact on the number of parasites present in the system than a doubling of the number of seals. If the commercial fishery reduces the average age of the cod population (as it has done in the North Sea), this will also reduce the number of worms. This has occurred in the North Sea, despite the increase in the size of grey seal colonies there. Also, it has been found that cod infestation levels are lower for cod going inshore only seasonally (as in the Moray Firth) than for cod remaining for a long time on nursery grounds close to grey seal colonies (Table XV).

26. Oh no – you're about to say that culling seals won't solve the codworm problem either!

You took the words out of my mouth! Humans, seals and cod all have to live with the codworm and there's not a lot can be done about it, apart from removing the worms from the cod as part of the processing. Think of it as creating employment!

27. It sounds as if there is nothing much left for us to say then. Discussion over?

Not quite. Thus far we have only discussed one side of the coin – the alleged damage seals do to fish stocks and fishing. We haven't yet considered the other side of the coin – namely, the damage that commercial fisheries may do to seals.

28. So far you've been telling me that seals aren't such bad guys after all, but just misunderstood and we shouldn't shoot them. Now you're going to try telling me that we're the bad guys. I don't believe it! What sort of damage are you talking about, anyway?

For a start there is the by-catch of seals in fishing nets

29. That's not a major problem, surely?

It's a huge problem, worldwide and affecting most populations of most species of seals (Table XVI). I didn't even realise the enormity of the problem until I started to research it. Did you know that up to 15,000 harp seals may be drowned every year in drift nets off Northern Norway!

30. Well, what is the scale of the problem for harbour and grey seals?

The problem is mostly with inshore gill, trammel and tangle nets. In California there is one harbour seal drowned for every 712m of trammel nets hauled. In Alaska over 2,000 harbour seals a year drowned. About a thousand or more harbour seals in northern Japan used to die annually in nets, and this is thought to be a main cause of the serious decline in this seal, which is now relatively rare. 37,000 harbour seals were reported to have died in Danish nets between 1889

and 1927. At the present time estimates for the percentage of grey seal yearlings dying in nets vary from about 1–2% in Scotland and the Farne Islands, 8% in Norway, 12% on the west of Ireland, 20% in the Baltic and 70% in Cornwall. Estimates for harbour seal pup by-catch in Norway is a minimum of 6% of yearlings, mainly in bottom-set nets (Table XVI).

12. Adult male grey seal accidentally caught in a fishing net

31. I don't wish to sound callous, but isn't it their just deserts for trying to feed from our nets? It's a sort of cull without us shooting them.

Seals that drown in nets are not necessarily trying to feed from those nets. For example, in the Barra crawfish fishery the nets are set flat and loosely on the seabed. It is thought that harbour seals foraging on the seabed do not see these nets until it is too late, on account of the dark background of the seabed and the absence of a float. They then cannot escape because of the thick multifilament mesh used. When this fishery was first begun on an experimental basis in 1980, 107 harbour seals were caught in two months. The majority of these seals were juveniles probably in their first or second year (Table XVI).

Norwegian scientists working on this problem think that harbour seals may be especially vulnerable to being tangled in bottom set nets because they swim quite rapidly along the seabed when searching for prey, whereas grey seals tend to dive directly to the seabed and then remain stationary there. They found that pups of both species were most vulnerable to being caught in the first three months after birth, but mortality remained high until the yearlings were 8–10 months old. They suggest that yearling seals may fail to escape because of their limited physical strength and less well-controlled diving responses when compared to adults. Naive curiosity may also attract them to investigate nets (Table XVI).

In some cases the seal by-catch level does not appear to be a threat to the conservation status of the seal population, and may be considered more of a problem of animal welfare. However, in some areas such as Cornwall, where about 70% of pups are drowned in nets and the population appears to be declining by about 8% per year (Table XVI), the problem is clearly of crucial importance to the conservation status of the population.

32. Well, some of them are feeding from the nets because one grey seal that drowned in a monkfish tangle net in Ireland had two monkfish tails in its stomach!

That may well sometimes be the case (Table XII), particularly for older grey seals who might be less likely than yearlings to blunder into a net by accident. As discussed above, grey seals appear to be very opportunistic in their development of feeding habits and therefore individuals may well readily develop a strategy of feeding from nets (Table XVI).

There may also be a point here for seal sanctuaries to be aware of, because seal pups that have been trained in captivity during their formative months to feed on dead fish will doubtless be highly likely to develop a feeding habit of taking fresh fish bait from creels or feeding from nets, and thereby adding to the problem of operational interactions and conflict with fisheries. In Cornwall, one fisherman reported catching three drowned grey seal pups within one week of their release from the local seal sanctuary (Table XVI). The creel fishermen in Orkney have stated that the seals they have seen diving on creels and raiding them for fresh fish bait seem to be mainly young animals (Table II), and that the problem started suddenly.

As suggested above for minimizing operational interactions, the best tactic against the problem of by-catch in UK and Irish coastal waters at present would probably be to try to site nets offshore as much as possible, and in any case, to try to locate them away from areas of seal activity. Where there is as yet no information on the locations of seal activity, fishermen may, by trial and error, find net locations with the lowest by-catch rate, as occurred in the Barra case (Table XVI). Seal sanctuaries may be able to help by using an alternative to training pups to feed on dead fish.

33. If scientists can provide the fishing industry with the necessary information on local seal hot spots and movement patterns, then this could well be an area in which everyone could work together to reduce this problem. Have scientists made any other suggestions for reducing by-catch?

Some suggestions have been made, and successfully tried, for reducing by-catch of harp and hooded seals and Hooker's sea lions in trawls, for example by setting and retrieving nets as quickly as possible (Table XVII). However, there don't seem to have been any other suggestions for mitigating the problem of seal by-catch in set nets. In inshore areas where by-catch levels of seals are high, one possibility might be to consider adjusting the height at which nets are set above the sea-

bed. For example, it is possible that nets set on or close to the sea-bed may be more likely to entangle grey and harbour seal pups than nets set a few metres above the sea-bed.

34. Isn't it just too bad, then, if seals drown in nets. It's simply too much to ask fishermen to relocate their nets away from seal hotspots or way offshore.

In the US fishermen are required to obtain a permit, without which marine mammal by-catch in fishing nets is illegal, and carries a jail sentence or fine up to $20,000 for each animal illegally by-caught. Such permits are not available for marine mammals in declining populations (Table XVI). If a similar law were to be enacted in the UK or Ireland, much of the present by-catch of both seals and dolphins in Cornwall, for example, would be illegal. In such cases there would be a considerable financial incentive for the fishing industry to cooperate closely with scientists endeavouring to chart seal hot spots, and even to sponsor such research. At present, the incidental capture of dolphins and porpoises must be monitored under Article 12 of the 1992 EU Habitats Directive, since they are listed in Annex IVa (strictly protected species of Community interest). Seals are listed in Annex V (species of Community interest whose taking in the wild…may be subject to management measures) and as such, under Article 14, monitoring of their taking in the wild should be carried out if the Member State deems it necessary under the surveillance requirements of Article 2, i.e. if a potential threat to their conservation status is identified. In some areas, therefore, such as Cornwall, monitoring of seal by-catch should evidently be undertaken along with monitoring of dolphin and porpoise by-catch, and management measures taken if deemed necessary. For seals, this could mean relocation of nets away from seal hot-spots or offshore.

Where the problem of by-catch of yearlings has not been able to be solved by adjusting fishing methods, special protection areas in which fishing is either prohibited or very limited have been established in some of the most sensitive areas in European waters under various domestic and multi-national agreements as well as under Article 3 of the Habitats Directive (Table XVIII). Such reserves have been set up in Lake Saimaa in Finland for the endangered Saimaa seals, in the Mediterranean for the endangered monk seals, in Norway for the harbour seal and in the Baltic for the grey seal (Table XVIII).

35. What sort of size are these reserves?

The Saimaa reserve is 300 km2 while the Northern Sporades reserve in Greece is 2,200 km2, with no human activities permitted within 3 miles of the island where the seals breed. The Froan nature reserve in Norway is 720 km2, while the Finnish Baltic reserve is 192 km2, which is 0.37% of Finnish coastal waters (Table XVIII).

36. Do they solve the problem of seal pup by-catch?

A tagging study of harbour seal pups in Norway found that none of the pups tagged within the reserve died, whereas 16% of pups tagged outside the reserve died, at least half of which were entangled in fishing nets (Table XVIII). The difficulty here is that seals outside the reserve (the majority, in the Norwegian case) have no protection. Because of this, also, such reserves may be less successful in protecting the more vagrant young of species like the grey seal.

37. So you wouldn't really support the introduction of such protected areas into the UK or Ireland?

They might make a significant difference in certain places where there is evidently a problem, which is serious enough to threaten the population. In Cornwall, for example, some fishing exclusion areas might help to reduce the appalling by-catch levels. However, telemetry research on grey seal foraging area 'hot spots' would be needed in order to establish the most effective reserve area or areas. However, I think the most comprehensive solution would, as suggested above, be for set nets in inshore areas to be subject to coastal planning control, which might involve prior environmental impact assessments and judicious location of nets with respect to seal 'hot spots' identified by seal scientists.

38. I imagine the fishing industry would vigorously oppose the introduction of such fishery exclusion areas for the benefit of seals.

Well, in fact such areas might actually be a help to fishermen in helping them to avoid fishing in areas where seal damage and seal by-catch is most likely. Such protected areas to prevent by-catch might well even become mandatory under the requirements of the EU Habitats Directive Article 14, under which Member States are required to take measures to ensure that the taking in the wild of Annex V species (which includes both grey and harbour seals) is compatible with their being maintained at a favourable conservation status.

There is another problem related to by-catch that we need to discuss, which is entanglement of seals in discarded pieces of netting.

39. A very minor problem, surely?

Unfortunately not. As for by-catch, it is a world-wide problem of marine animal welfare and for some seal species it is a key conservation issue. The principal problem involves small pieces of lost fishing gear, particularly trawl net, and gillnet and monofilament line. These 'ghost nets' can remain intact and catch marine life for well over a decade (Table XIX). For example, modeling studies suggest that one main reason for the decline in the once numerous northern fur seal may be that 50,000 were killed annually by entanglement in pieces of floating net. The endangered Hawaiian monk seal is known to particularly prone to net entanglement. Pups are particularly prone, since they tend to investigate and play with marine debris. Hawaiian monk seal entanglement rates vary according to the colony up to 7.5% per year. In 1998, 64–94 pieces of netting per km2 were found in the reefs surrounding the seal haul-out and breeding areas. Even following a partial clean-up, the National Marine Fisheries Service estimated that 38,000 pieces of ghost netting remained at each of the reefs (Table XIX).

40. But the problem can't be nearly as bad as that for grey and harbour seals in UK & Irish waters?

In the UK and Ireland it is certainly not a rarity to see seals at haul-out sites, or find seals stranded, with pieces of discarded netting around the neck (XIX).

However, the frequency of entanglement is not known. It is suggested that a survey should be carried out, in conjunction with seal sanctuaries, to define the extent of the problem.

Laist (1995) recommended that technology should be developed to reduce the likelihood of losing nets at sea, to help locate lost nets, and to cause lost netting to become disabled. There should also be dedicated efforts to retrieve lost pieces of netting (Table XVII). Legislation might be developed to create an offence of deliberate or negligent discarding of netting.

13. This grey seal pup's cry for help was answered in time

14. A grey seal pup being treated for neck ligature in the RSPCA Hospital, Norfolk

15. This adult male grey seal was not so lucky – he was found dead on the beach

41. I object to the direction this discussion is taking. We started off by discussing what action was going to be taken against the seal pest, which many fishermen rightly see as marine vermin and vandals. You're turning the whole thing round to make seals sound more like some sort of innocent victim and make fishermen seem like the bad guys. It's just typical of townies that know nothing about the realities and suffering of coastal communities.

The information collated in this report is certainly no 'townie' fantasy. Rather it is fact and scientific opinion based on it. And there's more to come.

It is increasingly recognized that commercial fisheries are having a negative impact on fish stocks – witness the reasons for the closure of the Newfoundland cod fishery and now a similar closure in the North Sea and Irish Sea. In some cases fish stock declines may have a negative impact on seal populations (Table X).

42. Do you have any evidence for this?

Quite a bit. For example, harp seals on both sides of the Northern Atlantic depend heavily on capelin. When capelin abundance declined due to intensive fisheries (in the 1970s in the NW Atlantic and in the late 1980s in the NE Atlantic), the body condition of harp seals in the NW declined significantly, while in the NE the food shortage was the apparent cause of a mass migration of harp seals into the coastal waters of Norway (X), where in 1987 alone more than 56,000 were caught in gill nets (XVI). On the Bering Sea the decline in Steller sea lion and harbour seal populations was associated with the decline in herring stocks in the late 1970s as a result of intensive fishing. Pollock subsequently became the dominant species and the dominant food of the sea lion. Further recent declines in sea lions have been attributed to a decline of pollock due again to intensive fisheries. Under US law, fishery management decisions now have to consider the potential impacts on Steller sea lion survival. The US National Marine Fishery Service stated that the Pollock fishery proposed for 1999–2002 was likely to jeopardize the continued existence of the Steller sea lion (Table X). In Hawaii, one monk seal colony is declining, with poor juvenile survival and underweight juveniles recorded. The reason appears to be limited prey availability, most probably due to these seal prey items being taken as by-catch in commercial lobster fishery (X).

43. These instances are all from faraway places. Is there any evidence from UK and Irish waters?

Studies of harbour seals in the Moray Firth have demonstrated poor body condition and anaemia in years of poor herring abundance. A decline in harbour seals in Northern Ireland has been attributed partly to limited availability of preferred prey species, particularly since local herring stocks were depleted by fisheries. A decline of seals, particularly grey seals, in the Clyde has been attributed to their prey abundance having been depleted by commercial fisheries. (Table X).

44. But where fish are in short supply, for whatever reason, we shouldn't have to compete with seals for what's left. Surely fishermen's livelihoods come before seals?

There is no example where it has been demonstrated that any marine mammal is competing (in an ecological sense) with commercial fisheries (Table VI). In an ecological sense, therefore, there is no reason to suppose that seal predation would affect fishermen's livelihoods, even in a situation where fish stocks are depleted. Predators - including both seals and fishermen - need, for survival, a concentration of food items above a certain mimimum level (Table X). For seals, depleted stocks of their prey species would most probably result in high juvenile mortality, poor reproductive success and dispersal away from the area of shortage.

45. Whatever you say, it's intolerable for us to contemplate thousands of seals out there, feeding freely on fish, when we are threatened with being effectively banned from fishing and face utter ruin.

But the threatened fisheries closure is quite unconnected with feeding by seals and other marine mammals. The collapse of fish stocks that have necessitated the huge cuts is due to excessive fisheries-induced mortality. Both fishermen and sea mammals experience the consequences of this in different ways. Some seal populations may benefit from a temporary glut of sandeels and juvenile whitefish because of the paucity of adult fish predators. Other seal (and other marine mammal) populations may suffer from the effects of malnutrition, particularly of juvenile animals (Table X). But whereas sea mammals have no alternative to eating fish, fishermen do have the possibility of diversifying, however unpalatable this may be.

46. Diversifying! The whole character and culture of coastal communities in many parts of the UK and Ireland will die.

Perhaps seals could even help here, if you could look upon them as an asset and an ally rather than as the enemy. Careful development of wildlife tourism, including educational seal-watching trips (possibly also participating in research projects) using modified fishing vessels, could help to sustain coastal economies without destroying their essential character. Nature-based tourism is currently a major growth industry. Whale watching in 1994 attracted 5 million people in 65 different countries and generated revenues of US$504 million. In 1996 there were already 117 seal-watch establishments in the UK and Ireland, visited by 0.5 million people; the total gross revenue of the industry was estimated at more than £36 million per annum and employment estimated at 193 full-time and 322 part-time positions (Table XIV). Tourism obviously depends heavily on scenic beauty, cultural heritage and wildlife. Seals are not only a major wildlife attraction, but are also an important feature in Celtic folklore and cultural heritage of coastal communities throughout the UK and Ireland. A seal-watching industry would, however, be incompatible with either systematic or sporadic seal culling. One survey of tourists in the Hebrides found that 65% of tourists were against seal culls and 15% said it would affect their decision to come to Scotland (Table X).

47. We were thinking more along the lines of diversifying into hunting seals for the dinner plate, with such delicacies as 'flipper pie' on the menu for both local people and tourists, as in eastern Canada.

The law in Northern Ireland, the Isle of Man and the Irish Republic would not permit such hunting at any time. At present, the 1970 Seals Conservation Act would usually permit such hunting in Scotland, Wales and England, but only outside the close season and only with an appropriate and licensed firearm. At the present time, however, most seal populations in Scotland and England are protected by a special conservation order under the 1970 Act because of the 2002 outbreak of seal distemper virus. Even when and if permitted by law, however, such hunting would probably be economically counter-productive. People in the UK and Ireland would be unlikely to be easily persuaded to eat seal meat. Furthermore, the social tensions and atmosphere created would divide the local communities, while the adverse publicity created would doubtless kill the local tourist industry stone dead. And I couldn't imagine a worse PR campaign for the fishing industry! My advice to you would be to not even think your way down that route.

48. What advice can you offer, then, apart from a few seal-watching trips?

During the period of the fisheries closure I would suggest that the industry takes a step back to reconsider it's long-term relationship with the sea and the entire ecosystem. The present attitudes, though sincerely held (Tables I and II), have been outdated by the rapid advancements in our knowledge of the biology of seals and modeling of marine ecosystems over the past 20 years. What is needed in the future is the development of a sustainable fishing industry, which can co-exist in harmony with natural populations of seals and other marine mammals. As discussed in this report, it should be possible with creative thinking and cooperation by scientists and the fishing industry, to consign seal-fisheries conflict to the Dark Ages and create a new eco-friendly industry worthy of the new millennium.

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Table I. Newspaper reports (Fishermen's representatives' opinions on seal-fisheries interactions

Author and date	Comment
Anon, in the Aberdeen *Press and Journal*, 8/1/98	*Leaders of the Scottish salmon fishing industry yesterday called for culls of seals and gooseanders to halt the annual destruction of thousands of tons of valuable fish….Chairman of the Tay District Salmon Fisheries Board, Mike Smith, said 'The number of seals, both grey and common, around our shoreline has expanded enormously and this must have had an impact on inshore fish as well as salmon and sea trout. Seals should be culled for that reason and also because they are a valuable crop in their own right, their skins are useful for sporrans, waistcoats and slippers and their carcases should be put to good use in these BSE-ridden times.'*
J.D. Allingham in the *Aberdeen Press and Journal*, 12/1/98	***An extrapolation of the figures in the report*** (Task Force headed by Lord Nickson) ***reveals that the total number of salmon available to return mature is about 937,043, of which 50.16% are eaten by seals, 9.69% are taken by commercial fisheries, 8.03% are caught by rods and 31.13% are other mortalities. The seal population is increasing rapidly and is expected to double in the next 10 to 12 years. The conclusion is obvious: wild salmon will soon become virtually extinct, along with some 3,400 jobs which are salmon-dependent. …..Practical men who live and work among salmon know what seals do to salmon, as the increasing number of salmon bearing seal marks proves. I do not want seals exterminated. I just want the see the balance of nature restored.***
S. English, in Times, 10/4/98 *'Licence to kill' fear as ban on seal hunting is lifted. Fishermen welcome decision*	Report cites Magnus Flaws of Shetland Salmon farmer's Association, said ***'It's good news, but there is no way that anyone will embark on wholesale slaughter. It means we will be able to protect our salmon from the odd rogue seal that attacks the nets and kills fish without eating them.'*** **He also said that** ***technological advances meant most fishermen had effective alternatives to protect their stocks, including acoustic seal scarers.***
Anon, in the Daily Mail, 01/3/99 *Bloodlust of Britain's seal killers*	***Fishermen are killing seals for fun, shooting them at point-blank range as they bask on rocks in the sun, according to Jim Cormack of the SSPCA.*** …Alexander Smith of the Scottish Fishermen's Association, ***..is demanding an organised humane cull….'Who do people care more for, seals or our fishermen?*** ***In a tactic which it thinks will strengthen the case for culling, the Fishermen's Federation is pressing MPs to explore the possibilities of seal meat. It says a pie made from seal flippers is a big hit in Canada, where culling is allowed, and could catch on here.***

C. Cairns, in *The Scotsman*, 5/3/99 *Sewell rules out any cull of seals*	***Scottish fishermen have been told by*** Lord Sewell, the Scottish environment minister, speaking at the opening of the Fishing 99 exhibition in Glasgow, that ***there is no chance the Government will bow to pressure and introduce a seal cull. 'There is no way we will return to a situation like that which existed until the early 1980s when thousands of seal pups were slaughtered.' He was responding to remarks made by Fergus Ewing, the SNP fisheries spokesman, who told a radio programme that jobs should not be sacrificed on the 'altar of political correctness'. Lord Sewell said: 'Labour is committed to maintaining a balance between the interests of conservation and those of the fishing industry; the SNP is committed to making Scotland a pariah nation by returning to the days of mass slaughter of seal pups along our coasts.'...'We trust the SNP will put science and reason before politics in the new Scottish Parliament,' he wrote, 'In our view it would be unwise for the newly created parliament to court international condemnation when video of seals being culled is flashed around the world.'*** ***A (SNP) spokesman, Peter Murrell, said: 'Any responsible administration would be looking for fresh ways to tackle the problem. The present Government has done nothing.'***
D. Perry, in the *Aberdeen Press & Journal*, 5/3/99	Peter Murrell (SNP's fisheries spokesman) ***...insisted...that 'it is no longer possible to ignore the population explosion in grey seals....a return to horrific scenes of clubbing is not an option', but believed there were humane alternatives. Mr Murrell said the number of seals had risen to the point where they could face starvation, adding: 'it could be as cruel to do nothing at all.'***
L. Kibby, in *The Express*, 19/3/99 *Fish-eating 'monsters' are just too cute to cull*	***Seals, which have been spotted as far as 15 miles up some of Scotland's premier salmon rivers, are said to be catching wild salmon at an alarming rate. William Crow of the Scottish Salmon Growers Association explained: Because the salmon is quite big, the seals tend to just suck the liver out and move onto another fish.'*** ***Craig Egner, of Scotland Fishermen's Federation, added,: 'Soon the grey seal population will become simply unsustainable, and that has to be addressed.'*** ***Professor John Harwood (SMRU)... has said that any cull would have to be of huge proportions to have any effect on the 120,000-strong seal population. He said: 'Here in St. Andrews, the fishermen feel their catches would increase if the local colony was removed. But evidence shows that seals from all over the country come here for food. ..'The British people love seals. The huge majority see it as a beautiful animal which symbolises wild nature. Politicians in a Scottish Parliament would find a cull desperately difficult to sell to the general public.'***

C. Watson, in the *Herald*, 26/3/99 *Tories back seal culls to help save fish stocks*	***Scottish Tory leaders favour the introduction of seal culls to protect the country's fish stocks, it has emerged. Deputy environment spokesman Alasdair Hutton told delegates at a Edinburgh conference on the marine environment this week that he backed such a policy. Mr Hutton explained yesterday that seal numbers plummeted in the late 1980s because of a deadly virus, but were now recovering. He said they were eating more fish at a time when Scottish fishermen were being forced to cut back on their catches. Mr Hutton added: 'That seems to me to be out of balance so we need to think seriously about a managed cull to get seal numbers back to a reasonable level. If I was in the Scottish Parliament, I would be asking for study on what would be the right number of seals to take out, because I don't have any doubt in my mind that we do need to take some out.'*** ***Dr Phil Hammond, director of SMRU, agreed (with Scottish New Labour's opposition to a seal cull) that there was no evidence that a seal cull would make any difference to fish stocks.***
Anon, in *Aberdeen Press & Journal*, 17/5/00 *Cull of seals not the answer*	***Deputy Minister for Rural Affairs John Home Robertson made a fact finding visit to SMRU yesterday and …said 'It appears that there are rogue seals which are contributing to the alarming decline in salmon stocks in Scottish rivers, so a widespread cull of all seals would not perhaps be the most appropriate solution to the problem.***
Anon, in *Edinburgh Evening News*, 29/7/00 *Time to go for cull in Forth?*	***Fishermen are calling for a new commission to be set up to control seal numbers in a move that could lead to culls of the mammals. Fishermen's leaders say seal numbers have quadrupled off the coast of Scotland in the last 20 years to 120,000 – with 600 in the Forth alone – and claim they are now having a significant effect on fish stocks. They believe a new Seal Commission should be set up which would have the power to recommend that culls take place to keep the numbers down.*** ***Callan Duck (SMRU)..also backed the federations's proposals – but as a way of revealing the truth about the seal issue. 'It could be a good thing to bring out the truth, rather than the stories which go round about seals eating all the fish,' he said, 'In fact too many fish are being taken out by the fishing industry. There are also 300,000 harbour porpoises which feed in the North Sea – five times the amount of seals – eating the same sort of food. But it is always seals which are seen as the bad guys. The reason there are relatively few fish is not because the seals are eating them but because the sea is being over-fished. People are often misinformed.'***

N. Sears, in the Daily Mail, 27/11/00	***Outrage at demand for 150,000 seals to be killed A leading fisherman provoked fury yesterday by calling for 50,000 grey seals to be slaughtered to solve a crisis over cod stocks. David Shiel, chairman of the Anglo-Scottish Fishermen's Association, said the animal 'pests' were the main culprits for the drastic decline in North Sea fish, and culling them was vital. The Ministry of Agriculture, Fisheries and Food said a cull could not be ruled out, although there would have to be studies first....Mr Shiel, 53, from Seahouses in Northumberland, claimed there were 'a lot more' than 100,000 seals, and said half of them should be wiped out in one onslaught. There would then be annual culls to keep the numbers down. 'They are pests. You can see them now in the North Sea in places where you've never seen them before. They aren't sticking to a quota like men, they're just helping themselves and not a thing is being done about it. Fishing communities are dying.....it's all very well for do-gooders to say it's wrong, but we're talking here about saving people's livelihoods.*** ***George Sutherland, of the Scottish Fishermen's Federation, said: '....We are quite firmly of the belief that seals are the root of the problem, and there is plenty of evidence to show that seals eat more fish than we are allowed to catch...if we look at Canada, where there has been a ban on catching cod for the past eight years, the seal population has doubled but the cod stocks have not recovered.'*** ***John Watkins*** (from Conservation Research in Cambridgeshire) ***said: 'The biggest threat to fish is other fish, next are seabirds, then it's man and then, way down the list, come seals and whales.'***
Iain Maciver in the *Daily Mail*, 28/11/00 *Minister backs cull*	***WHY THE CULL IS NECESSARY – by Hamish Morrison, chief executive of the Scottish Fishermen's Association. The problem with seals is that they eat the same cod that our fishermen target, but they also eat the same food as the cod. This has meant that in the last three years only a small amount of cod have grown to full term.***
Angus Macdonald, in Aberdeen *Press & Journal*, 1/2/01 *Plea to cut seal total*	***Fishermen in the Western Isles.....have also questioned the criteria for designating conservation sites and claim that the Government's policy of proposing seal sanctuaries around the islands does not make sense and should be abandoned because of the destruction they cause.***

T. Black in Aberdeen *Press & Journal*, 18/6/01 *Controversy over seal culls*	***Canada's annual seal cull has just concluded with worldwide condemnation of the yearly slaughter. But, on this side of the Atlantic, a campaign is underway to have the practice imported…*** Fergus Ewing (SNP), MSP for Inverness East, Nairn and Lochaber has backed calls from fishermen for a cull: ***'….I am not advocating seals should be subjected to clubbing. However, I believe other countries like Canada are not shying away from this problem and have been willing to look at the facts.'*** ***David Herriott, chief Executive of the Anglo Scottish Fish Producers Organization, is fully in favour of a UK-wide cull.*** ***David Shiel, chairman of the Anglo Scottish Fishermen's Association……deflected the claims levelled at the fishing industry: 'I don't think overfishing by the fishing industry is the problem. The scientists are only going to tell the Government what they want to know – I wouldn't trust a scientist, they can swallow millions of Government money, but they won't do anything for the fishermen.'***
J. Allardyce in *Scotland on Sunday*, 15/7/01 *The cull of the wild: dying for our fish supper?*	***Alasdair Morrison, the Highlands and Islands Minister….speaking …as MSP for the Western Isles…warned that desperate times may require desperate measures. He said that in his own constituency the presence of at least 60,000 seals around the Monach Isles…was clearly affecting all fish stocks, including wild salmon…he said it was time for a 'mature discussion about the impact of the ever-burgeoning seal population.*** ***George Lyon, the Argyll & Bute MSP and Lib Dem enterprise spokesman, is also sympathetic to calls for a cull….the issue of seal numbers is a major one to many of the rural communities I represent and we do need a sensible debate on whether there needs to be a cull to control them.'***
Anon, in Daily Mail, 16/7/01 Minister in call for new cull of seals	***Western Isles Labour MSP Alasdair Morrison, who is Minister for Tourism, said they should be shot to conserve fish stocks. He believes the explosion in the seal population is partly to blame for the critical shortage of cod, haddock and wild salmon in Scottish waters. Mr Morrison said: 'Every year we cull red deer. We are facing a stark choice as far as fishing stocks are concerned and I am very relaxed about the idea of culling seals too.' He said the mass slaughter of seals, outlawed in Scotland in 1978, was necessary to protect fishermen. The fishing industry welcomed the proposal. It claims the Scottish grey seal population, which has quadrupled to 120,000 in 30 years, now consumes more fish than trawlermen are allowed to catch.***

K. Schofield, in Aberdeen *Press & Journal*, 18/7/01 *Tory MEP in favour of mass seal cull off Scotland's coastline*	***Struan Stevenson said he was in favour of a mass cull of thousands of seals in a bid to preserve fish stocks off Scotland's coast…Following discussions on the problem with marine wildlife experts in Brussels, Mr Stevenson is to urge the European Commission to give the go-ahead for seals in Scotland to be culled. Mr Stevenson said: 'We now have a situation where the seals are eating more white fish than our fishermen are allowed to catch. They are eating about 250,000 tonnes of fish a year and that's more than our fishermen are allowed to land.***
A.Macdonald, in Aberdeen *Press & Journal*, 11/9/01 *Seal cull is a shot in the dark, scientist warns*	***…Earlier this year, Duncan MacInnes, secretary of the Western Isles Fishermen's Association, called for a Seal Commission – similar to the Deer Commission, which limits deer numbers – to be established. He said that the number of seals had grown enormously around the Western Isles. Mr MacInnes added: 'At Heisgeir in North Uist, for example, there are 30,000 seals. They eat 75,000 tonnes of fish a year, worth more than £50 million. If that income came to the islands' economy instead, there would be a huge benefit. The EC produces rules on quotas and it takes no account of the amount of fish eaten by seals…..the calls for a cull were supported by Roddy McColl, secretary of the Fishermen's Association. He said: 'If we are to look at marine ecosystem management, we shouldn't focus only on fishing effort. Clearly we must tackle predation by grey seal especially around Scotland. I have been arguing for this since the 1970s, when seals were protected and their numbers have exploded since then. They eat far more than the fleet can land. …Calls for measures such as contraceptives were made in the 1980s, but that won't work. It requires a management plan and if that means shooting seals then we have to do it. Anything else is a weak-willed attempt at being politically correct.'***
Ian Boyd quoted in Aberdeen *Press & Journal*, 11/9/01. (article by A. Macdonald) *Seal cull is a shot in the dark, scientist warns*	**..Prof Boyd said: 'A seal commission is not comparable to the Deer Commission, because deer are technically owned by the landowner, seals belong to no one and they travel over huge distances, so that kind of control is not an option.'**

Table Ib - Newspaper reports (legal issues)

Source	Comment
D. Lambie, in the *Daily Mail*, 24/2/99	***Jim Cormack, investigations support officer with the SSPCA, said there was a growing need for proper legislation to control seal culls. He added: 'I will be asking if the scope for shooting seals is too much, because there seems to be no proper control. If a seal is in the vicinity of fishing tackle or nets than it can be shot at any time of the year, and there is nothing to say how many can be killed. My job is to look after the welfare of the seals and it is not good for their welfare if fishermen are bobbing up and down on the water in a boat trying to shoot them.***
T. Barron, in *St John's Evening Telegram*, 7/3/99	***....Britain shares another claim to fame with the province (Newfoundland) – violence towards seals. Animal welfare inspectors are hoping to charge a number of fishermen in the next few weeks as a result of illegal 'drive-by shootings' of seals basking on coastal rocks. Under the British Conservation Act of 1970, fishermen can shoot a seal if they have a valid firearms certificate and if the seal is in the vicinity of fishing nets. However, the legal definition of 'vicinity' has never been established.***
Scottish office, quoted in the Express, 19/3/99; article by L. Kibby *Fish-eating 'monsters' are just too cute to cull*	The Scottish Office are trying to stay out of the debate, saying there is no evidence to suggest a wholesale cull would help the fishing industry. But they point out there is nothing to stop anyone going out and killing a seal, except in the closed breeding season.
Scottish Executive, quoted in The Sunday Post, 16/7/00 *Seal killings on the increase*	***A spokesman for the Scottish Executive said that the licences (under the 1970 Act) should be taken in context. 'Last year 55 seals were killed out of a population of over 160,000 in Scotland,' he explained. 'We take advice from the Sea Mammal Research Centre at St. Andrews. They are not allowed to kill breeding seals. We give a very small number of licences, and a very small number of seals are killed.'***
Scottish Executive, quoted in the Aberdeen *Press & Journal*, 23/10/00. *Returns*	***The Scottish Executive...also confirmed more seals had been shot this year to preserve stocks...'There will be an increase in the number of seals shot . Seals are more of a problem this year, the situation looks as if it is getting worse,' said the spokesman. 'Applicants have to convince us that there is good reason to kill a seal.'***

Table II - Fishing Industry's perception of sea fisheries with seals

Author and Date	Perception of Problem	Source
Northridge, 1988 (A), also Bonner, 1982.	***Oppion, in Halieutica…….No nets, even if there are very many at hand, would stay the raging seal, but with its violence and sharp claws it will easily break them and rush away and prove a succour to the pent up fishes but a grief to the hearts of fishermen.*** (Editor's note: this presumably referred to the Mediterranean monk seal)***.***	
Northridge, 1988 (B)	***Damage by seals in static gear fisheries is clearly the major area of concern amongst fishermen….. the cost of a typical gill net may be less than £100 and as such the net is regarded as expendable. … In some places seals are said to remove bait or fish from longlines, and even lobster pots….***and***…to remove or bite fish through the cod-end of trawls on occasion. Common seals in the Wash have …been reported to chew marker buoys……..by far the greatest number of reports of damage comes from gill and trammel net fisheries. .fishermen claim that seals will invariably rip nets in order to steal or mutilate fish, and neat fish sized holes in nets, as well as rips in the netting around a mutilated fish will be assumed to be seal damage…. Heap et al. point out that 'when catches are good the financial loss from a certain level of predation may be substantial but fishing may still be economically viable. However, when catches are poor, although the losses may be smaller, they make the difference between fishing being viable and uneconomic.'***	
Rae, 1962	Most damage to passive fishing gear in coastal waters; less damage to drift-netting in offshore waters. Estimated annual total of 80,000 tons fish consumed annually by seals, equivalent to 0.17–0.2 of total British commercial fishery.	Population estimate by Seals Research Unit (SRU) of 20,000 grey seals and 18,000
Summers, 1978	***…The fact that overfishing, restrictive fisheries legislation and foreign trawlers have a greater impact than the seals on fish stocks, or that sea birds and cetaceans also eat fish, does not make the uncontrolled expansion of grey seal stocks acceptable to the British fishing industry.***	Data on grey seal stocks collected by SRU since the 1960s showing a 6–7% annual increase in British grey

Parrish & Shearer, 1977	***The fish consumed by the seals constitute a loss to the exploited stocks which would otherwise be available to the fisheries.*** Estimated annual total of 195,000 tons fish consumed annually by seals, representing potential loss to fishery of 65,000 tons, or 5–10% of total UK catch, with market value of GBP15–20m.	Population estimate (SRU) of 69,000 grey seals and 15,000 harbour seals) consuming 15 & 11lb per day respectively.
Stansfeld, 1984 (A)	***Scotland's fishermen are being asked to support half the world's grey seal population……***	Sea mammal Research Unit (SMRU) 1984 report indicating world grey seal population of 150,000 —84,000 of which in UK
Stansfeld, 1984 (B)	***The NERC report calculates that in 1981 the British grey seal population consumed approximately 140,000 tonnes of fish….if we take the average landing value of the species they name and apply their percentages, it becomes immediately apparent that the 1982 grey seal population ate some GBP37 million worth of fish.***	SMRU (1984)
Stansfeld 1989 (C)	***A small province in India might value a population of five thousand tigers, but ninety thousand would create mayhem. The grey seal is much the same size, with a similar food requirement, but unfortunately it does not come ashore and eat suburban man. Its depredations go unnoticed.***	
Stansfeld, 1989 (D)	***Unfortunately the media have illustrated many endearing aspects of the grey seal. They have not featured at all the many vicious and unattractive sides to its life.***	
Stansfeld, 1989 (E)	***The people who wield that*** (political) ***power are unlikely ever to see a seal except on their television screens. Their world is bounded by concrete and mown grass and they have no conception of the havoc being wrought by the grey seal on Scotland's***	
McColl, 1993	***…..at a time when there are severe restrictive controls on fishing activities aimed at the conservation of fish stocks and when the fishing industry has been experiencing increasing hardship there is a compelling case for imposing restrictive control also on the grey seal population given that grey seals like fishermen prey together at the top of the food chain.***	

Scottish Fishermen's Federation, 1993	***In most areas around the Scottish coast fishermen*** (of the inshore small-boat set gill net and line fisheries) ***are now reporting high incidences of seal damage to their gear and catches on a regular basis; in some localities its magnitude has been such as to force them to abandon or heavily curtail their fishing activities.***	
McColl, 1993	***....It is clear that important commercially important species notably the gadoid species including sand eels and salmonids form a major part (of the grey seal diet) probably not less than 80%. An average annual consumption of about 2.4 tonnes per seal is unlikely to be an under-estimate in the average weight of food items killed per seal. The total annual quantity is therefore around 240,000–250,000 tonnes of which not less than 200,000 tonnes comprise commercially exploited fish species with the commercially important gadoid species constituting not less than 50% of the total i.e. 125,000 tonnes.....***	Based on SMRU population estimate of 90,000 seals in Scottish waters at that time
Crossley, 1994	The target species in this fishery are lobster, brown crab (these have been fished for many years) and more recently velvet and shore crabs (since 1985) and dog whelk (since 1992). A small amount of bait or catch theft, usually attributed to otters or congereels has always occurred in the longstanding lobster fishery. In this fishery 'soured' salted bait was used and entry to the creels was by 'hard eyes'. The new fishery uses fresh bait and 'soft eye' entrances. 39 of the 41 interviewees reported finding creels empty of fresh bait (mostly saithe and pollack) starting 3–5 years previously, i.e. ca. 1989. 14 fishermen volunteered that the problem had started suddenly. 4/10 reported >50% creels robbed, 4/10 reported 10–50% robbed, and 2% reported <10% robbed. About half of fishermen working in waters >40m said they were affected. Modifications to the soft eyes initially solved the problem, but predators (presumably seals) then learned to open the creels by undoing the catches holding the creel doors shut, etc. Damage occurred thoughout Orkney except in the very north, and was most severe around western S. Ronaldsay, eastern Hoy and northern mainland. Fishermen seeing the seals diving on creels thought they were mainly smallish animals (therefore probably not adult greys), but reliable identification was not made. Observations such as one fisherman reporting creel doors being opened in one area for the first time in January 1994, suggested the problem may be caused by a few 'rogue' animals. This problem led to a call for a seal cull by Orkney fishermen in 1993.	Questionnaire to creel fishermen in Orkney

Crummey, 1996 (A)	***The average food requirement of a grey seal is estimated to be 9.75kg per day. Therefore 140,000 grey seals would consume half a million tons of fish a year, a figure considerably greater than the Total Allowable Catches of all whitefish species within the areas where they feed.***	
Crummey, 1996 (B)	***....grey seals poach directly from inshore fishermen's nets.....The affected inshore fisheries include salmon driftnetting, gillnetting for cod, hake, monkfish, turbot and pollock and inshore whitefish trawling, trammel netting and fish traps.***	
Crummey, 1996 (C)	***Many conservation measures are now in place to deal with general overfishing....However, a large and growing seal population could negate these conservation efforts by preventing stock recoveries. This phenomenon has already been implicated in the recovery failure of the northern cod stocks following a moratorium on fishing for this species within Canadian waters several years ago.***	
Crummey, 1996 (D)	***Left alone, the continued growth in grey seal populations could result in further depletion of inshore stocks and fisheries, putting more inshore traditional fishermen out of business.***	
Crummey, 1996 (E)	***Eventually, as has occurred previously with harp seals in the Barents Sea and fur seals in South Africa, the population growth will cease and perhaps reverse as a result of food exhaustion leading to starvation. To allow such a situation to arise would not be in the interests of conservation or indeed the welfare of the seals themselves.***	
Irish Seal Sanctuary, 1997	Of 32 responses, all said seals were a problem. 66% cited loss of catch, 84% cited damage to catch and 22% cited damage to gear. When asked 'How do your respond to seals at present, 9% replied that they ignored the seals, 66% replied that they evade or scare the seals and 19% that they shoot the seals. When asked 'What solution would you recommend, 9% replied 'management', 66% culling, 19% compensation and 13% 'other'. To the question 'What alternatives are there to seal culling?', 3% replied decommissioning, 41% payments for co-operation in research, 13% replied tourism and 50% replied harvesting of seals. When asked "Would you forego a seal cull in favour of fair compensation payments, 81% replied yes, 19% no. When asked if they would support proposals to exclude fishing from Dublin Bay, all replied no. When asked 'For a premium price for fish, would you adopt a more eco-friendly system of fishing?', 9% replied that they would adopt seal protection, 22% would use long-lining, and 34% would adopt unspecified measures. When asked to identify other threats to their fishing, 72% replied pollution, 66% Sellafield, 31% markets, 16% public opinion, 56% lack of Government support, and 3% 'other'.	Questionnaire to fishermen in SE Ireland

Meisenheimer (IMMA), 1998	Discussing reason for slow recovery of NW cod stocks since fishing moratorium in 1992, fishing industry representatives, Ministry and media argue that it is somehow obvious that seals must be having an effect, ***i.e. seals eat fish, including some cod, therefore they must be having a negative effect on cod stocks.***	Review & discussion of Problem with cod in NE Canada.
Glain, 1998 (A)	34.6% of respondents were 'very concerned' about interactions between grey seals and fishermen (these were mostly boats between 5–12m rather than larger or smaller boats); 46.2% were 'a bit concerned' and 19.2% were 'not concerned'. 83% considered that grey seals had an influence on their activity. 78.7% using tangle nets complained about the influence of seals; 57.9% complained about damage to gill-net fishery, but only one fisherman complained about grey seals and handlining for mackerel. Other fishing methods (pots, longlines and trawls) were not affected by grey seals. 81% did not consider that grey seals damaged their gear while raiding their nets (saying their nets tended to get damaged anyway in the course of fishing). Losses through direct predation amounted to 6% annual profit, 4.5% through tangle nets and 1.3% through gill nets. 75% thought interactions had increased over time, 56% of these estimating an increase in last 5 years, probably because of an increase in seal numbers (43.6%) or that they have learned how to get an easy meal, or become craftier (28.2%). 23.1% of cases suggested a lack of free-ranging food supply for seals and the same number suggested a negative influence of the Cornwall seal sanctuary releases. 63.5% think action should be taken to limit seal influence, while 34.6% think the opposite. Of those wanting action, 54.4% thought that either rogue seals should be killed or that a selective cull (limited in areas or numbers) should be carried out or that an unrestricted cull should be carried out (suggested by 72.2% of those who were 'very concerned'). 15.2% suggested non-lethal methods (contraceptives or pingers on nets). 18.2% did not suggest any solution. 77.8% of the 'very concerned' fishermen reported having to change their fishing methods because of the increase of interactions.	52 questionnaires conducted in 13 harbours around Cornwall. The 52 respondents were mainly boat owners and their responses were also on behalf of their crew, and therefore altogether representing122 fishermen; this is at least 30.3% of all full-time netters in Cornwall.
Glain, 1998 (B)	The above survey of 52 fishing boat owners in Cornwall was carried out by the 'snowballing technique' (Oppenheim, 1992), in which fishermen are asked for details of other netters in the same or different harbours. It was found that ***a few strong personalities who complain heavily about seals appear to influence some of their fellow fishermen, even if the latter do not actually encounter many problems themselves. This would explain why fishermen from certain harbours (Newlyn, Helford, St. Ives) are more concerned than people from other harbours independently of where they fish.*** They were also worried about future uncertainties. ***For example, they may become affected by seals were they to change their fishing methods in the future, towards more tangle-netting for monkfish.***	

Glain, 1998;citing Berry, 1996	Overall the fishing industry ***is in dramatic decline and under pressure (Berry, 1995). The influence of seals is one more factor affecting fishermen, maybe one too many.....structural changes within the fishing industry, towards fewer, larger boats, mean that small, daily boats are disproportionately threatened (Berry, 1996).***	
Kiely, Lidgard, McKibben, Connolly & Baines, 2000	The results from 48 questionnaires returned by active fishermen indicated that: 94% commonly observed seals while fishing, 34% said they experienced damage amounting to >30% of their catch, 89% felt that the problem of seal predation had increased in the last decade & 88% favoured culling of seals. Several respondents said that illegal culling had historically and even recently taken place in their areas.	Results from 700+ questionnaires posted to fishermen in SE Ireland in the spring of 1997.

Table III. Salmon fishing industry's perception of interactions with seals

Rae, 1962	Seals have a harmful effect on salmon fisheries, (1) fish mutilated or killed or eaten, (2) nets torn, (3) interruption of fishing time, (4) diversion of fish from nets.
Northridge, 1988	Fishermen report damage by seals to Scottish stake and bag net fisheries for salmon…***Seals will on occasion get inside these salmon traps and, besides eating the fish, may also tear the nets to get out.*** This damage is no longer a major problem since the introduction of synthetic twines in the 1960s (citing Parrish & Shearer, 1977)
Stansfeld, 1984 (A)	***NERC*** method of diet analysis (by otolith counts and measurements) ***is going to show gross bias against the proportion of the larger commercial fish in the seal's diet…Everyone who lives by the sea knows that when seals eat the larger fish, they strip the flesh from the back bone and discard this with the head, skin and tail.***
Stansfeld, 1984 (B)	***The decline in the spring run of salmon and the increase of grilse and late summer runs of salmon have had an enormous effect upon the whole industry….If the (SMRU, 1984) report had been able to say whether or not the changing migration patterns had been caused by the increasing grey seal population, it would have been a useful contribution….***
Stansfeld, 1989 (A)	***The grey seal over the years has been one of the major factors causing the decline in the percentage return of Scottish salmon to their home rivers.***
Stansfeld, 1989 (B)	***As the net and coble fishermen depart our estuaries, their place is being taken by grey seals….Seals pay no fishery assessment and the whole structure of Scottish salmon fishery management is liable to crumble……Scotland's salmon may become a matter of historical anecdote.***
Arnold, 1992	Referring to a survey of 34 salmon farm operators in Shetland, ***….Most operators expressed the view that would rather live with the local wildlife than kill it. They seemed tolerant of seals and other predators, considering them mainly an irritant except for the odd individual attacks which varied in frequency and severity……Seal colonies are valued by some as a natural part of their habitat, and the majority of farmers showed an appreciation of the relatively undisturbed environment in Shetland. Salmon farmers are also aware that blatant incidents of seal shooting can harm their market.***
Scottish Fishermen's Federation, 1993	In the salmon fixed net fishery, fish that have suffered varying degrees of mutilation by seals…now form a common, day-to-day feature of the catches taken, and result in considerable losses in their marketability and value.

Anon, 1999 (NMFS report to Congress)	The report consists of recommendations to the US government that would permit killing of California sea lions and Pacific harbor seals in certain rivers on the US west coast where these animals are perceived to be a threat to the recovery of depleted salmon stocks. Prior to the 1994 Amendments to the 1972 Marine Mammal Protection Act (MMPA), ***lethal measures by commercial fishers were authorized in cases where pinnipeds were damaging gear and catch and could not be deterred by non-lethal means***. The recommendations recommend only lethal taking of individual seals or sea lions at specific sites, and specifically do not recommend any large-scale removal or population culling programmes. A number of comments were quoted at the end of the report to the effect that negative impacts of seals and sea lions has not actually been determined, and that research should therefore preceded any lethal taking, The NMFS response was that in order to be sure of protecting endangered and vulnerable salmon populations, lethal removal should not be delayed until the outcome of actual research.

Table IV. Seal scientists' views on seal culling

Author & date	Proposal or conclusion	Rationale or comment
Rae, 1962	Seal stocks should be substantially reduced and thereafter maintained at a level which will not interfere unduly with fisheries. Seal stocks should be harvested in a rational manner.	Seals are considered to be harmful to fisheries interests and their numbers in the UK had increased by the early 1960s to an estimated 20,000 grey seals and 18,000 harbour seals.
Recommendations of the Consultative Committee on grey seals and fisheries, 1963	**Further studies should continue on the distribution, population structure and general biology of seals, and in particular on changes in the population which may be related to the measures on control recommended below....** Replacement of traditional netting materials with new artificial fibres should be speeded up… ***A policy of control of numbers, and, where feasible, of harvesting the crop of seals, should be applied to the two (grey seal) colonies of the Orkneys and Farnes. In both cases the killing of seals on the breeding grounds should be arranged so as to reduce the breeding potential by about one quarter (to 75% of the present breeding potential) and the operation should be spread over five years.***	***It is well established that that the local effect of large numbers of seals is deleterious to fisheries on account of the damage to fishing gear and to fish-catch, direct predation and as vectors of worm parasites....In certain areas...seals are of real significance in the economics of the industry*** (both salmon and whitefish)***...The Committee has assessed the damage occasioned by seals and has considered methods by which it can be reduced.***
Harwood, 1978	***Introduce a management policy to maintain the grey seal population at a new lower level.***	***Undisturbed British stocks of the grey seal...have increased annually by 6-7%...present population consumes more than 100,000 tonnes of commercially exploitable fish annually (Parrish & Shearer, 1977).***
Summers & Harwood, 1979 (A)Also Harwood, 1978 (above).	Future management of Outer Hebrides/North Rona population (half of UK total)… **is of paramount importance from fisheries viewpoint**	Direct predation on catchable fish stocks (Parrish & Shearer, 1977) ***....is a function of seal numbers.***
Summers & Harwood, 1979 (B)	Annual pup quota of 4,000; 950 cows shot until mid-1960s level attained, then 4,000 pups and 150-200 cows in each subsequent year.	Management brief to reduce UK grey seal population to 35,000 (mid-1960s level) ***and maintain it in stable equilibrium at this level.***
Summers & Harwood, 1979 (C)	Monitor any untoward effects of culls and adjust procedures accordingly; make final adult culls proportional to pup production the preceding year.	This form of control introduces a ***powerful form of density-dependent mortality*** and is more stable to environmental changes, and therefore a better management tool, than an ***equilibrium established by a fixed quota of pups.***

Summers & Harwood, 1979 (D)	Simulation ***assumed that females would be killed in the middle of the breeding season and that only fully moulted pups would be killed on a commercial scale.*** Simulation takes into account that ***adult culls cause considerable disturbance to breeding beaches.***	***..adult cull would result in 15% of all cows not coming ashore to breed.. a proportion of cows surviving a cull would desert their pups. Unweaned pups of shot cows would be killed....***
Lister-Kaye, 1979 (A)	THE SUPPORTERS OF THE CONTROL PLAN: NERC Sea Mammal Research Unit (SMRU), NERC Seals Advisory Committee, The Department of Agriculture and Fisheries for Scotland (DAFS), the Fishermen's Federations of Britain and Scotland, The Nature Conservancy Council, the sealing industry and (a borderline support case) the Scottish Society for the Prevention of Cruelty to Animals (SPCA). THE OPPOSERS OF THE CONTROL PLAN: The Greenpeace Foundation, the World Wildlife Fund (WWF), The International Union for Conservation of nature and Natural Resources (IUCN), The Society for the promotion of Nature Conservation, the Scottish Wildlife Trust, The Fauna Preservation Society, the Orkney Field Club and the general public in Britain.	
Lister-Kaye, (B)	The author's personal view was that the opposition to the control plan was ill-considered and that ***..Greenpeace and their supporters did not know what they were doing. What the opposition action...really did was to reveal some reputable organizations, straight away to the scientific world, and perhaps later to the world at large, as inadequately prepared (and therefore unqualified to oppose)....if the outcome of the opposition is later seen to be damaging to the conservation movement as a whole, they must be held largely responsible.***	
Lister-Kaye, (C)	Parts of the Greenpeace UK Policy statement of October 1978 are as follows: ***the incidence of damage (to salmon nets) has not increased in proportion to the expanding grey seal population...a switch to synthetic fibres has led to a decrease in damage...The most significant damage to the salmon fishery is caused by drift netting operations....proponents of the management scheme claim that the seal population in UK waters consume 130,000 tons of fish a year, of which 50% they claim is a loss in the potential annual fishery catch. This estimate is based on a number of assumptions which are not based on any established scientific fact. Neither the quantities of specific fish species consumed by grey seals, nor the feeding habits of grey seals have been adequately assessed. ....Greenpeace views the seal kill as an attempt to shift the blame for declining fish stocks from human overfishing to the seals. Man has been, and continues to be, the cause in decline of fish stocks in UK waters.....***	
Lister-Kaye, (D)	IUCN sent a cable on 16.10.78 to the Scottish Office, as follows: ***RECOGNIZING that the wildlife management practices of the Government of the United Kingdom have enabled the British population of Grey seals so to increase that it now comprises half of the world population of this species;*** ***RECOGNIZING FURTHER that this is one of the world's rarer seals, and one that has been depleted in many parts of its range outside the UK;AWARE that inshore fisheries in Scotland have declined in recent years, and that seal numbers have been blamed for adversely affecting commercial fisheries;*** ***CONVINCED that the decline in inshore fisheries is in part due to commercial overfishing;*** ***CONCERNED that the UK Government is planning to reduce Grey seal numbers in Scotland by 50 per cent over the next six years, a cull that it proposes to start during October 1978;The General Assembly of IUCN, at its 14th Session, Ashkhabad, USSR, 26 September-5 October 1978;*** ***URGES the Government of the United Kingdom to suspend any cull of Grey seals in Orkney, North Rona, and the Western Isles until adequate data on the impact of Grey seals on fish stocks and the role of Grey seals in their ecosystems are available;*** ***RECOMMENDS that stronger conservation measures be introduced to prevent further overfishing of the inshore fish stocks in British waters; and*** ***REQUESTS that a copy of the management plan which prescribes the present cull may be supplied to IUCN for evaluation.***	

Bonner, 1989	Culling programme for grey seals in Scotland 1977-82 was to be done by killing a total of 1,800 cows and 131,750 pups in Orkney, North Rona and the Outer Hebrides combined.	Estimated fish consumption by grey and harbour seals in Scottish waters of around 195,000 tonnes, calculated to be 5-10% total commercial catch with market value of GBP15-20m.
Harwood, 1987	***..general conclusions*** (from modelling studies) ***are that the reduction in one predator will lead to an increase in all its competitors (not just the fishery), and that an attempt to catch all of the 'surplus' prey released by the reduction in one predator can lead to overexploitation.....it seems likely that ...a reduction in seal numbers.....will usually result in an increase*** (in available fish).	***However, the list of extenuating factors is so long that it also seems very likely that that the resulting increase will be substantially less than predicted by a simple surplus production calculation. In addition, recruitment to many fish stocks is highly variable and any increase in stock size that results from management action is likely to be masked by this natural variability.***
Wickens, Shelton, David, Field, Oosthuizen, Roux & Starfield, 1992	A simulation model was formulated for the S. African fur seal (***Arctocephalus pusillus pusillus***) 'to evaluate the appropriate management action' when culling either to reduce population growth or to decrease fish consumption.	To reduce population growth, cow removal is most effective, but the population sex ratio becomes severely altered and this may be undesirable ecologically. Reduction of fish consumption is best achieved either by removing cows, with the same caveat regarding sex ratio, or by removing bulls (who eat more) and including disturbance effects. However, the acceptability of a reduction achieved by humans disrupting seals is questionable, and the continued removal of bulls may eventually lead to further decreases in pregnancy rate.
SCOS, 2000	In response to question: ***How many seals would need to be killed to stabilise the grey seal population?*** - Calculation of the numbers of pups or older animals needing to be killed to stabilise the British grey seal population at its 1998 level (approx. 123,000 seals) would be 18,000-25,000 pups (after weaning, to minimise colony disturbance) per year, or 6,000 females one-year and older (at breeding colonies).	Experience from culls in the 1970s indicated that they resulted in massive disturbance and desertion of the culled colonies by large numbers of seals for several years, and also in establishment of new breeding colonies. ***Such responses make it very difficult to predict and monitor the long-term effects of a cull.***
SCOS, 2000	In response to question: ***What is the impact of changes in seal numbers on predation of fish?...***To stabilise the North Sea grey seal population at its 1998 level would require killing 9,000-13,000 pups annually, which would result in 41,500 tonnes fewer fish being consumed annually by seals in 2003.	Any projected changes in fish consumption resulting from a cull will simply reflect percentage changes in the number of seals unless a number of important interactions are taken into account. This calculated amount of 41,500 tonnes of fish is small compared to fisheries catches, and would be even smaller if catches taken by other natural predators also taken into account. Also, ***The considerable uncertainty in any estimate of fish 'freed up' for fisheries would likely be within the range of uncertainty of fish stock assessments, forecasts, or reported catches.***

Anon, in Aberdeen *Press & Journal*, 17/9/01 *Camera plan may prevent seal cull*	***...In fact in the whole of the Outer Hebrides the grey seal population has not increased since 1984 - and the number of grey seal pups born in the Monachs have stabilised at 9,000 a year since 1992 (SNH figures).***	
SCOS, 2000 (Annex I)	The increase in grey seal pup production has slowed in recent years. The decline was particularly marked from 1998-99, when declines of 6% in the Outer Hebrides and Orkney, 10% in the Inner Hebrides, 9% in the Isle of May and 36% at the Farne Islands were recorded.	
Lavigne, 1987 (A)	The grey seal in eastern Canada: to cull or not to cull?This article was in respect of a pending decision by the Government of Canada whether to cull grey seals during January and February 1988. The Government was taking advice from a Royal Commission on seals and sealing. The Commission concluded, ***on the basis of 'biological and economic considerations,' that 'substantial advantages would be gained by a cull of grey seals'....'because grey seals are increasing rapidly, a decision on the cull needs to be made as soon as practicable.'***	In its calculations cited in the report, The Commission made several errors, including the size of the average grey seal and its daily food consumption, overestimating the latter by at least 2.5 times. If one accepts the Commission's argument for the cull (based on the adage that fewer seals mean more fish and more profit for the fishery), the ***'average annual cost per seal' drops by a factor of at least 10. The presumed economic benefits of culling... evaporate in the process.***
Lavigne, 1987 (B)	The Commission's estimate of the Canadian grey seal population as 70,000, used in all its calculations, is arrived at by multiplying the annual no. of births on Sable island (6,000) by 2 and then multiplying that number again by 6.	If this estimate is true, ***then there are thousands of grey seals breeding in unknown locations. Since grey seals are usually quite gregarious during the breeding season, they should be quite easy to find.....***
Anon, 1991 (Benguela Ecology programme Workshop)	***The question of monitoring the results of a seal cull (of fur seals, Arctocephalus pusillus) was raised: how could the success or otherwise of such an action be determined. With only a single 'experiment', it is of course impossible to observe what would happen had the experiment not been conducted; indications can only be provided by modelling studies.***	
UNEP, 1992 (A)	***In many cases...predictive modelling will be the only feasible way of evaluating whether a marine mammal cull might achieve its intended result.***	***The example simulations also showed that even in cases where there were clear differences in mean yield between the cull and no-cull scenarios, these could be less than the variance in fish catches that occurred with or without a cull. ....in the real world, the potential benefits of a marine mammal cull in fishery yield could be similar to or less than the normal fluctuations observed in fishery yield.***
UNEP, 1992 (B) citing Yodzis, 1998	In experimental models one finds a high incidence of counter-intuitive results (such as removal of a predator resulting in a decrease in abundance of one or more of its prey), due to a prevalence of effects propagated through indirect pathways. As well, there is a high incidence of indeterminate results, in which the effect of a removal of one species on the abundance of another species is so sensitive to parameter values that it could go either way.	

UNEP, 1992 (C)	The workshop suggested a basis for a protocol for the formulation of culling proposals. Any proposal should include a clear statement of the seal species and fishery/fisheries involved, the target fish species exploited by the fishery and the geographical area where the interaction is believed to occur. The objective of the cull should be stated with a clear specification of the expected benefits. Biological information required in the proposal would include the following: 1. annual energy budget, diet composition including prey sizes, and energy density of each prey species of the seal, 2. distribution in time and space of the seal, 3. seal population size, age and sex structure, and 4. sufficient information on other possible ecological interactions need to evaluate the implications of simplifications involved in calculating the benefits predicted from the proposed cull. In addition, details of the proposed programme of culling (e.g. location; numbers, age and sex; years; means of killing, monitoring; scientific sampling) and overall policy of management of the fishery in question would be required. This information is believed to be the minimum required for a scientific evaluation of a culling proposal.	
Yodzis, 2001	***Even with the slight increase in system complexity from the 'surplus yield' reasoning of Parrish & Shearer, 1977), the intuitive idea of surplus yield calculation fails....On a short timescale there might be an increase in fisheries yield,*** but complications due to the complex food web interactions might become apparent ***only on a longer timescale, possibly even leading to a ....decrease in fishery yield.***	The 'surplus-yield' reasoning, e.g. Parrish & Shearer, 1977, is inadequate for assessing the response of fisheries to a cull of top predators. Furthermore, to test the effects of any cull, data would have to be collected for at least 10 years to ensure that effects had enough time to propagate along all food chain pathways. To measure a probability distribution to take the large amount of random variation in these systems, an experimental culling programme would take a millennium…

Table V - outcome of seal culls carried out

Author & date	Description & reason for cull	Outcome of cull
Bonner, 1989 (A)	…proposal was for a fisheries-related grey seal cull (apparently to benefit salmon netting) on the Farne Islands. 10 pups were killed in 1958 and 996 seals (?ages) were killed between 1963 and 1965.	After much adverse publicity in 1965, the National Trust disallowed further seal killing on the Farnes. No result or effect on fisheries of the executed cull recorded.
Harwood & Lavigne (A) 1981; citing Bonner & Hickling, 1974 and Hickling et al., 1976.	Cull of grey seals carried out on Farne Islands, NE England, to reduce erosion on two islands (Brownsman and Staple) used for puffin breeding, and also to reduce the high levels (>20%) of pup mortality on crowded breeding sites. ***603 adult females were shot in 1972, as well as a number of bulls and pups, and a further 486 females were shot in 1975.***	***These culls did not have the desired effect. In fact levels of pup mortality were actually higher in 1973 than in 1971 and a large number of seals still insisted on breeding on Staple in 1973, 1974 and 1976… with consequent damage to the soil cap.***
Harwood & Lavigne, 1981 (B); citing Hickling et al., 1978; Hickling & Hawkey, 1979.	New tactics were tried in 1977 & 1978 of constantly disturbing the seals and shooting any seal attempting to breed on Staple's soil cap.	***The disturbance associated with these culls can cause a redistribution of breeding seals in subsequent breeding seasons, e.g. pups are now born on many islands in the Farnes which had not been used in the past; the decline in pupping since the major culls of 1972 and 1975*** is greater than expected on the basis of numbers of females killed. …***The disturbance has had a profound, and not wholly understood, effect on the seal population.***
Bonner, 1989 (A)	Part of the Farnes colony has migrated to the Isle of May…90km away…. 373 pups were found there in December 1980…extremely healthy and well fed, in contrast to conditions at the original breeding islands in the Farnes.	***The migration to ..the Isle of May…and other islands in the Farnes ….may have increased its resilience to minor catastrophes***(though some of the skerries now used are inundated in severe storms, killing pups).
Bonner, 1989 (B)	The disturbance tactic has continued with any females that try to come ashore being scared off by the wardens.	***As far as the environmental issues at the Farne islands are concerned, the management scheme may be judged to be a success.***
Harwood & Lavigne, 1981 (D)	None of the management methods has had much effect on pup mortality.	This is primarily because grey seals insist on breeding at high densities on the more favoured islands. Higher mortality rates have been recorded at North Rona in Scotland and at Ramsey in Wales. The authors raise the question of ***…moral problems of when attempts should be made to interfere with 'natural' mortality levels…***

Summers & Harwood, 1978	Indirect effects of grey seal culls. An attempt is made to quantify these effects, which are considered to be major (e.g. 50% females deterred from giving birth). However, it is unclear whether these indirect effects are considered to be a bonus to the culling programme or a problem affecting the seals' welfare and conservation status.	1.Culls can reduce pup survival and adult fecundity as a result of desertion, production of pups in unsuitable places (e.g. outer skerries of Farnes) , and poor fertilisation. 2. Some of the females deterred from pupping may find new and equally suitable sites for pupping, thus founding new breeding assemblies (e.g. Isle of May).
Harwood & Lavigne, 1981 (C);Bonner, 1989 (C)	A cull was carried out on the grey seal colony on the Monach Isles, Gasker, Coppay and Shillay in the Outer Hebrides (NW Scotland) in 1977. The aim was to kill 900 cows and their pups and a further 4,600 moulted pups. However, due to bad weather only 394 pups and 286 cows were killed.	***Pup production fell by 40%... in 1978 and did not increase again in 1979.*** Apart from this, no result or effect on fisheries of cull recorded.
Bonner, 1989 (D)	Pup culling continued in Scotland after 1977, (despite the celebrated Greenpeace Rainbow Warrior protest in Orkney in October 1978 and subsequent public outcry) taking a total of 4477 pups in Orkney between 1978-81, and a further 285 pups in the Outer Hebrides in 1978-80.	No result or effect on fisheries of cull recorded.Note that only pups were killed, despite the theory advanced by Harwood (1978) and Summers & Harwood (1979) that a cull should not be of pups alone, but of a carefully calculated mix of females and pups.
Smith, 1994	The Canadian DFO issued a quota to aquaculturists in Charlotte County, NB, which allows them to shoot up to 200 harbour or grey seals that are 'actually taking, or attempting to take fish from within the sea cages'.	Very little known about grey or harbour seal populations in Bay of Fundy, and no reliable information on extent of seal damage to fish cages. ***The gathering of such information... would seem to be a logical step... before authorizing the pursuit of mitigative measures...***
H. Sand & H. Westerberg, 1997	Trial cull in Swedish Baltic to test the hypothesis that a limited cull of grey seals sighted close to salmon traps would decrease the rate of seal damage to fish and gear. Trial involved killing up to 10 individuals sighted within 100m of salmon nets in each of three areas and comparing the levels of damage at salmon nets with three control areas.	Trained marksmen succeeded in killing a total of only 16 seals. Only seven of these were recovered; six were males and one was a subadult male. The results demonstrated no significant difference in levels of damage between experimental and control areas following the cull and therefore did not support the 'specialist' theory (i.e. that damage in a particular area is caused by a few individuals). The study concluded that ***<u>limited</u> hunting at stationary fishing implements is no effective method to reduce the damage to coastal fishing.***

Table VI - Development of scientific viewpoint from the early 1980s

Author, date and subject	Review findings	Conclusions
Holt & Lavigne, 1982 (A)	***The IUCN/IFAW workshops found no clear evidence that marine mammal populations recovering under protection or under a conservative hunting regime would not stabilise themselves naturally before they had drastically affected fish stocks. And in no case could they say whether reducing such a population would result in better fish catches in the long run. The reasons for this are not difficult to understand, but they do require rejection of the naïve idea that every commercially valuable fish eaten by a seal or a dolphin represents a fish lost to humans.***	
Holt & Lavigne, 1982 (B)	***...If the changes in commercial fishes are only in part due to fishing, with a component of natural change, then there are likely to have been such changes in the non-commercial fishes also. For all these reasons it may be grossly misleading to calculate current and future changes in seal populations from trends that do not allow for pertinent environmental trends.***	
Holt & Lavigne, 1982 (C)	***Predation by humans and by a particular marine mammal species are not the only causes of death of the prey; they may not even be the main causes. Thus any supposedly surplus food liberated by reducing a marine mammal population is still vulnerable to capture by other predators (including the reduced numbers of the mammal) as well as by humans. And other non-predatory causes of mortality, whatever they may be, continue to operate. At best, therefore, fishermen will only secure a fraction of the supposed surplus, and probably quite a small fraction. Equally, other factors could lead to a reduced availability to fishermen of some valued species. We have no idea of the medium and long-term consequences of culling a predatory population. Even if the ecological consequences were predictable, there are problems with calculation of economic benefits, but it is hardly necessary to go into these to make our point. There is no scientific justification for making scapegoats of seals and dolphins, and specifically of harp seals, following the failure of fisheries management.***	
Holt & Lavigne, 1982 (D)	***In this situation we wish to make a plea to scientists engaged in such work to formulate their advice to managers with great care, to be vigilant for misrepresentation of that advice, and not to let such misrepresentation pass unchallenged.***	
Harwood, 1987 (A) Competition between seals & fisheries	***The problem*** (of perceived threat from seals) ***is exacerbated by recent world-wide changes in fishing practice which have led to more fishing in inshore waters, where the activities of seals are more evident than offshore....***	
Harwood, 1987 (B)	***In principle it is necessary to know how much of each size class of each commercially important fish species is consumed by the seal population, and how this consumption is distributed in time and space.***	
Harwood, 1987 (C)	***The long-term benefits of a reduction in seal predation depend primarily on the nature of the density-dependent processes which control the abundance of the fish stock, and whether the fish stock is being fished above or below the level for optimum yield. However, these long-term benefits may not be achieved for many years after the beginning of seal control operations.***	

Harwood, 1987 (D)	***The short-term benefits of reducing seal predation depend..on the proportion of natural mortality on the fish stock caused by seals and how heavily the stock is fished....However, there are two important caveats....First the estimate of fish consumption by seals is likely to have wide confidence limits; and secondly, this calculation is based on the assumption that the seals take exactly the same size classes of fish in exactly the same locality as the fishery.***	
Harwood & Croxhall, 1988 (A)	***Competition between seals and commercial fisheries The views expressed by the different protagonists often appear to be influenced more by their basic prejudices than by any objective evaluation of the situation. This is not surprising because, in most cases, the scientific evidence necessary for such an evaluation is unavailable.***	
Harwood & Croxhall, 1988 (B)	***...a number of***(grey seal) ***populations are obviously increasing at rates which are alarming, at least to fishermen.....But .a large and increasing seal population is not necessarily a threat to commercial fisheries, nor is an expanding fishery necessarily a threat to local seal populations....However, if a thorough analysis does indicate that there is competition between a seal population and a commercial fishery it does not necessarily follow that the fishery will benefit from a major reduction in seal numbers. The benefits will depend on the response of the fishery and other fish consumers (e.g. other fish, birds, cetaceans etc.) to the increased availability of fish which would follow such a move, and on the response of the market...***	
Harwood, 1992	***The importance of predation by marine mammals can be evaluated crudely by considering the marine mammal as a rival fishery whose operation is constrained by physiology and energetic requirements, rather than by catch limits and gear restrictions...***....In order to define competition in this context, ***it is necessary to demonstrate that one, or both, of the putative competitors*** (marine mammals and the fishing industry) ***will suffer in some manner as a result of an increase in removals by the other competitor for the limited resource. In practice, conclusive evidence is hard to find and cases rest on inference. ...If all the data*** (size of the marine mammal 'fleet', total catch, target species, gear selectivity and 'discards', distribution of effort and stocks exploited) ***can be collected, it is possible to evaluate the 'fishing' activity of marine mammals in a particular area at any one time and to compare it with the activities of the relevant commercial fisheries. To date this has not been done anywhere in the world...***...Calculation of a change in fish population dynamics resulting ***from a small change in predator abundance....is only realistic if it is evaluated in a multispecies framework. No widely accepted framework exists at present.***	
Hislop, 1992 The North Sea fishery: A case study	Annual consumption (tonnes) of fish in North Sea: **Fish:** 3,000,000 **Seabirds:** 340,000 **Seals:** 90,000-155,000 **H. porpoise:** >60,000 **Other cetaceans:** ? **Commercial landings:** 2,500,000	Seals in the North Sea consume <6% of all fish taken by all predators, including the commercial fishery. They take less than seabirds and probably less than cetacean species combined. Greatest predators are other fish (50%) and the commercial fishery (41%).

Lavigne, 1995 Ecological interactions between marine mammals, commercial fisheries and their prey: unravelling the tangled web.	When the prey species of a marine mammal and a commercial fishery overlap, it is usually assumed that the two are in competition and, once again, that a reduction in the marine mammal population will result in larger catches for the fishermen.	***Entirely neglected in such simple-minded arguments is the fact that dietary overlap alone is not a measure of ecological competition……consistently, there is not one single example where it has been demonstrated that marine mammals are competing (in an ecological sense) with commercial fisheries.***
DeMaster & Sisson, 1992, cited by Kiely et al, 2000Review of advantages and disadvantages of 'pinniped management' to replenish fish stocks	***These authors described four accepted ecological relationships that work against the success of culling pinnipeds to enhance fisheries:*** ***1. Prey species almost always have more than one predator;*** ***2. Seals and other pinnipeds are rarely dependent on just one species of prey;*** ***3. The recruitment rate of most fish stocks is highly variable in nature;*** ***4. Predatory fish consume more fish than do other predators.***	
Meisenheimer, 1998 (A) What is the problem with Cod? Cause of collapse of NW Atlantic stocks off coast of Labrador and Newfoundland	General consensus was that collapse of stocks was the result of overfishing by all, but Canadian TAC (set at unsustainable levels) & by-catch were largely responsible for driving cod to commercial extinction.	No data to support hypotheses that collapse of stocks caused by changing environmental variables such as water temperature or natural predation (usually by harp seals).
Meisenheimer, 1998 (B) Why have NW Atlantic cod stocks not yet recovered?	Stock recovery is slow because fish only mature at 5-8 yrs, and older females produce more viable offspring. At present spawning stock is still dominated by young females, which are the offspring of fish remaining at the beginning of the moratorium in 1992.	No scientific evidence that ***harp seals have had any substantial effect on the abundance of northern cod since the collapse.***
Ian Boyd quoted in Aberdeen Press & Journal, 11/9/01. (article by A. Macdonald) Seal cull is a shot in the dark, scientist warns	***I understand fishermen's concerns and seals do take a certain amount of the catch. Local solutions might be more appropriate, such as seal exclusion zones, or better techniques of keeping them away from fishing nets. Culling is a blunt instrument with unpredictable results…..How to administer seal management is a valid question which is being examined by the Scottish Executive. But by taking seals out of the sea through a cull doesn't mean that more fish will be available to the fishermen, because seals might take non-commercial species, or non-commercial age-classes, or even species that compete with, or prey on, species caught by fishermen.'***	

Table VII. Studies of biological interactions between seals and fisheries since the early 1980s

Author and date	Study findings	Discussion and conclusions
Bailey & Ainley, 1982	Seasonal changes in California sea lion feeding correspond to the availability of Pacific hake, which was 90% by number of the diet between April & August. From September to March the hake are spawning offshore and to the south and are less available to sea lions. Preferred size was 2-3 year old hake. Decline in hake predation in 1977-78 coincided with a decline in juvenile hake . During the inter, rockfish (92% by number replaced hake as the principal prey	***California sea lion population estimated at 80,000-125,000 animals....calculations indicate that the California sea lion is the dominant pinniped predator on pacific hake, consuming an estimated 185,000 tons per year (range 100,000-250,000 tons), while 3 otariid species combine to eat 201,000 tons per year. The average annual harvest of hake by the foreign trawl fishery is 175,000 tons. Whereas the California sea lion eats mostly juvenile hake, the northern fur seal and sea lions, due to their more northerly distribution, may eat larger fish and be more competitive with the fishery***
Beverton, 1985	Beverton devised a series of models to illustrate the possible interactions between marine mammals and fisheries. 1. The seal and the fishery both exploit a stock of a single prey species. 2. The prey species are likely to have other predators, such as seabirds or cetaceans. 3. Fish eat other fish, and these fish predators may be eaten by the seals as well as being fished commercially, 4. The fish predator may be preyed on by seals but not fished commercially, 5. The seals (or other marine mammal) feed exclusively on the predator while the fishery concentrates exclusively on the prey 6. The fishery takes the predatory fish and the predator and the fish both eat the same prey.	1. This situation is a theoretical starting point, but could rarely occur. 2. This is the first step in complexity towards a more realistic situation. 3. e.g. In the Gulf of St Lawrence cod feed on capelin and both are eaten by harp seals and fished commercially. 4. e.g. Sea-lions in a Pacific west coast river feeding on bothsalmon and lamprey, the lamprey being a significant predator of salmon, but itself of no commercial value. 5. Antarctic krill are exploited commercially and consumed by an intermediate predator - squid, which is itself eaten by the top predator, sperm whales. 6. No examples given.In all these cases the effect of the seals or other marine mammal on the fishery will be different ranging in theory from adverse to beneficial.

Butterworth & Harwood, 1991 (A) (Benguela Ecology programme Workshop); Wickens, Japp, Shelton, Kriel, Goosen, Rose, Augustyn, Bross, Penney & Krohn, 1992	Estimates of the consumption of commercially important fish in South African waters (Wickens et al., 1992) indicate that: **1. Anchovy:** the largest predator is predatory fish, mainly hake, followed by commercial fisheries (less than half that amount), followed by fur seals (less than half again). **2. Hake:** By far the greatest predator, accounting for about 70%) is larger hake, followed by other ground fish, then fisheries and then other predators, of which fur seals are amongst the least important.	The 1991 workshop concluded that although simple predator-prey models suggest possible benefits to fisheries from reducing seal numbers, these results were not robust and a minor increase in the complexity of the model led to a wide range of possible conclusions. Examination of data (e.g. Butterworth & Harwood, Annex J) indicate that seals are probably not the most important predator for any S. African stock. Even where seals appear to be important, there are a number of other species whose consumption is of a similar order of magnitude. In no case would it be realistic to construct a model of interactions between the seals and a fish stock which excluded all other predators. The workshop concluded that a biological impact by seals on commercial fisheries has yet to be demonstrated.
Butterworth & Harwood, 1991 (B)(Benguela Ecology Programme Workshop)	Instead of a simple 'surplus-yield' model, 'minimal realistic models' were suggested. However, such models ***can address the question of the effects of seals on fisheries, but not vice versa. This is because the seal dynamics (specifically the density-dependent response) is a direct input to that model, rather than related to to consumption of prey by seals. An expanded model would be needed to address the question of how fisheries affect seals, as this model would need to include all the species that contribute substantially to the seal diet, together with a an explicit submodel of how the seal chooses between these species in relation to their different abundances.***	
Punt & Butterworth, 1995	The following are conclusions from a 'minimal realistic model' (Butterworth & Harwood, 1991). 1. The benefits of seal culls for the bottom-trawl fishery for Cape hake *Merluccius paradoxus* are likely to be small, and could even be detrimental for reasons related to predation on *M. paradoxus* by the shallow-water *M. capensis*. However, the extent of actual predation by fur seals on *M. paradoxus* is not well known, although they prey more heavily on *M. capensis*. A seal cull might benefit the fishery if (a) seals preyed heavily on *M. paradoxus*, or (b) if the fishery targeted *M. capensis* to a greater extent than at present.	
Thompson, Tollit, Greenstreet, Mackay & Corpe, 1996	The study found significant between-year variation in diet composition and in the seals' body condition. The seals' predation on a particular prey species may result from changes in abundance either of that species or of other potential prey species.	The predatory impact of a seal population on a particular prey species may differ markedly from year to year. Therefore information on inter-annual variability of the seal population's energy requirements, diet composition and prey stock abundance and structure are all required in order to make any accurate predictions concerning the impact of seals on particular prey stocks.

Bundy, 2001 ***Editor's note:****'Bottom-up' control assumes that predator populations are controlled by the number of prey. Conversely, 'top-down' control assumes that prey populations are controlled by the number of predators.*	A modelling study, using Ecosim, of the interplay of fishing and predation in Newfoundland-Labrador. Five fishing mortality scenarios used and both bottom-up and top-down energy control assumptions modelled. Results showed ***that a 5% increase in the harp seal population has a negative effect on the recovery rate of cod under conditions of intermediate and top-down control, but not under bottom-up control. In the long term, however, the 100-year simulations predicted that cod biomass would eventually be re-established whether harp seals increased or not.***	Under top-down control, the model correctly predicted biomass changes for 10 groups (including harp seal increase and Atlantic cod) and was wrong for six groups (including Arctic cod). Also, reduction in spawning potential, due to removal by fisheries of the older age groups, would not only cause the collapse of the stocks, but would also seriously retard, if not prevent, recovery (Longhurst, 1998). This was not included in the Ecosim model, although it was given by Meisenheimer (1998) as the prime reason for the lack of recovery of Atlantic cod.
Furness, 2002	Sandeel recruitment in the North Sea shows inverse density-dependence, suggesting that sandeel abundance is controlled by 'bottom-up' processes rather than by predation. Study conclusions that predatory fish taken more sandeel than any other consumers are robust and that stocks of the main predatory fish have declined in the North Sea are beyond dispute. The net effect is of an increased availability of sandeels to seabirds, seals and the fishery, with increased fishing harvest or natural predation by birds or seals simply tending to increase sandeel recruitment. Increased sandeel abundance since the 1970s may have been a factor in the increasing breeding success and population size of both seabirds and grey seals in the North Sea.	
Yodzis, 2001 (A) Other authors Making same point include Bonner, 1989;	SURPLUS YIELD CALCULATION: ***if we remove top predators from the system, the prey they would have consumed become available to the fishery*** (e.g. Stansfeld, 1984; 1989; Summers & Harwood, 1979)	***This reasoning might not reflect the true outcome of a cull...*** because the model ***depicts only a small portion of any real system....Even with the slight increase in system complexity, the intuitive idea of surplus yield calculation fails...*** On a ***short timescale we might observe the effect from the shorter pathway(an increase in fisheries yield, with the contribution from the longer pathway making itself felt only on a longer timescale, possibly even leading to a ....decrease in fishery yield.*** This model ***is inadequate for assessing the response of fisheries to a cull of top predators.***
Yodzis, 2001 (B); Punt & Butterworth, 1995.	MINIMUM REALISTIC MODEL , e.g. the Punt & Butterworth model for the Benguela system	This model applied to the Benguela system ***found that culling fur seals is predicted to have a neutral to detrimental effect on the hake fishery, depending on parameter values.***

Yodzis, 2001 (C); also 1998; 2000.	LOCAL MODEL: multi-species modelling for a relatively local ecosystem ***..derives population dynamics from bioenergetics. ...Predictions are probability distributions.***	Applying this model to the Benguela food web ***the qualitative result, that a cull is more likely to be detrimental than beneficial to the total fishery, is robust with respect to*** varying ***underlying assumptions.***
Yodzis, 2001 (D); also Christensen & Pauly, 1992.Ecosim (http://www.ecopath.org) Christensen, 1998.	GLOBAL MODEL: multi-species modelling for large systems ***also uses bioenergetic approach and is available as a computer package called Ecosim.***	***Some successes,*** but complex ***multi-species modelling still in its infancy.***
Bjørge, Bekkby, Bakkestuen & Framstad, 2001	A modelling study of harbour seal -fisheries interactions in a coastal archipelago area off the Norway coast, from a landscape analysis perpective in which GIS was combined with other methods. Specific aims were to: **1.** simulate the energy requirements of a resident population of harbour seals, **2.** identify the most frequently occurring fish species in the seal diet and estimate the total food consumption, **3.** relate the consumption to habitat type, **4.** describe spatial distribution of fishing operations and relate these to habitat type and **5.** relate the distribution of predation by seals to the deployment of fisheries likely to interact with seals.	Seals and fisheries exploited the same habitat types, in particular the deeper parts of the model area. The total removal of fish cod, haddock, pollack, whiting, poor cod) by seals during the 73 days simulation period was approximately 32, 20 and 40 tonnes from areas also fished by bottom-set gill nets, Danish seine and shrimp trawl respectively. About 35% of seal population foraged in kelp forest areas, where there was no direct seal-fisheries interaction. The authors that the seal predation most likely had detrimental effect on the availability of commercial fish for bottom-set gillnet and Danish Seine fisheries….at water depths of 100-200m, but suggested the predation on the gadid fish might benefit the shrimp fishery. Otherwise the authors did not take complex ecological relationships, including fish predation on other fish, into account; nor did they consider the size of fish taken by seals and the fishery.

Table VIIb. Annual fish consumption by fisheries and natural predators in different ecosystems

Ecosystem	**Annual fish loss (tonnes/sq.km)**			
	Birds	**Mammals**	**Fish**	**Fisheries**
Benguela current	0.3	2.6	56.5	1.6
Georges Bank	2	5.4	42.5	6.1
Balsfjord	0.0	0.0	14.1	1.5
East Bering Sea	0.2	1.5	11.0	1.4
North Sea	0.6	0.1	7.0	4.4
Barents Sea	0.0	3.0	5.1	1.8

Table VIII. The feeding habits of seals - (a) their diet

Author & date	Findings of study	Conclusions
Lavigne, 1995 (A)	Analysis of stomach or faecal contents may yield data on prevalence (% stomachs or faecal samples sampled containing a given prey species), numbers (e.g. % otoliths of each species found), wet mass (% prey weight estimated from otolith size) or energy (% energy estimated from calculated weight and size of prey eaten).	Data in terms of prevalence and numbers of prey may be most relevant to assessing possible impact of seals on prey stocks, whereas data in terms of prey mass and energy may be most relevant to a study focussing on seal biology, feeding ecology and energy requirements. However, the relative 'importance' of a given prey species in the diet will vary markedly according to the type of analysis used.
Lavigne, 1995 (B)	In context of a perceived seal-fisheries conflict, it is always noted that more information of the seals' feeding habits is needed. ***However, even when feeding habits are relatively well known, critics still claim that there are too few samples or that those which do exist are badly dated and not relevant to the current situation (which invariably corresponds with a decline in one or more fish stocks).*** The example of NW Atlantic harp seals and the cod fishery is a case in point.	***Responding to such criticism, it must be acknowledged that studies of feeding habits of a particular marine mammal will always refer to an earlier time..***and to only part of the species range and season. ***So, if such criticisms were valid, it would be pointless, perhaps, to initiate further studies of feeding habits.....I am not convinced, however, that such criticisms are very constructive. In the future, however, more care should be given to the problems of sampling wild populations, and the results must be reported using appropriate and consistent standards...Field collections....should also be supplemented by some carefully designed experiments...***
Lavigne, 1995 (C); also IUCN, 1981.	***....in order to evaluate interactions between marine mammals and fisheries, data on the size distribution of common prey species taken both by the marine mammal and by the fishery were also required.***	
Fedak & Hiby, 1985; Prime & Hammond, 1985 (A)	The volume of prey in a seal's diet may depend on the type of food consumed, which determines the calorific value of the prey. Fedak & Hiby (1985) estimated that a seal requires 5,530 Kcal/day of energy. If UK grey seals are eating the fish species indicated by the faecal analysis of this study, each seal requires on average 5 kg of fish per day. The required amount of energy (5,530 Kcal) would be provided by about 4 kg of sandeels or about 8 kg of cod, which is about 2.5-5% of the average body weight of a grey seal (Prime & Hammond, 1985).	
Nordoy, Martensson, Lager, Folkow & Blix, 1995, cited by Kiely et al., 2000	These authors estimated that the food intake of captive harp seals varied seasonally from a maximum of 5-6% of body mass/day in August-September (immediately after the breeding and moulting seasons) to a low of 1-2% of body mass per day in April-June, i.e. just before the breeding season.	
Hammond, Hall & Prime, 1994, cited by Kiely et al, 2000.	This study found that spawning fish of various species were dominant in grey seal diets, suggesting that grey seals take advantage of energy-rich prey when these are available.	

Lavigne, 1995 (D)	***The view that marine mammals have higher metabolic rates than other mammals, together with the suggestion that they are "inefficient converters of fish flesh" (Sergeant, 1973), leads logically (but incorrectly) to the conclusion that marine mammals have "voracious" appetites (e.g. Power and Gregoire 1978)....and are"gluttons"(Slijper, 1979).***	***For their size, "maintenance" rates of energy ingestion (NRC, 1981) by adult marine mammals are not significantly different from those of terrestrial mammals and, consistently, feeding rates of growing marine mammals are similar to those of growing terrestrial mammals (Innes et al., 1987)...as better time-activity budgets (for seals) become available, it seems likely that estimates of energy requirements will be further reduced. Many seals spend much of their time sleeping and energy consumption at such times is usually below basal levels (Worthy, 1987; Boily, 1991). Also, moulting seals may have reduced metabolic rates (Ashwell-Erikson et al., 1986).***
UNEP, 1992	***Most*** (seal-fisheries interaction) ***models assume that predators consume different prey species in proportion to their abundance. But there is evidence that some predators will ignore less favoured prey until their preferred prey are extremely scarce.***	***This could be a consequence of the need to learn new pursuit tactics for a new prey. More data on foraging habits would be extremely valuable.***
Prime & Hammond, 1985 (B)	Over all the North Sea sites sampled in 1984-85, sandeels were the most important component of the diet by weight (61%), followed by cod (19%), saithe (6%), unidentified flatfish (3%), haddock (3%), whiting (2%) and flounder (2%). Total annual consumption was estimated at about 57K tonnes. The size of prey was estimated by weight rather than by length and some prey species varied in average size over the different sites. Overall, however, recalculations (by SCW) suggest cod prey was approximately 400-500mm, saithe 450-500mm, haddock 200-350mm, whiting 250mm and flounder 250-420mm).	***Assuming the overlap*** ('between the populations of fish predated by seals and those taken by the fishery') ***is total - each fish consumed by grey seals is lost from a commercial fish stock, ...for most of the commercially caught species ...the mortality induced by grey seals is insignificant. The exceptions are sandeels, flounder and dab in ICES division IVa and saithe, ling and flounder in divisions IVb and c. The commercial catches in division IVa of flounder and dab are small while those in divisions b and c of ling, flounder and saithe are fairly small. Only for sandeels in division IVa does seal consumption compare significantly with a large commercial catch.***
Harwood & Croxhall, 1988 (A)	***The extent of competition between grey seals and commercial fisheries in the North Sea was evaluated by comparing the quantities of different fish species consumed by the seals, estimated by fecal analysis, with the commercial catch of the same species in the same area over with the seals are likely to have foraged (Hammond & Harwood, 1985).....In general the mortality caused by seals is one or two orders of magnitude less than that caused by the fishery. However, by multiplying the quantity of each species consumed by seals by its average market value*** the study calculated that grey seals consumed £5,946K worth of cod and £798 worth of Dover sole annually in the North Sea in 1984/85.	***The consumption (by seals) of highly valued fish (such as Dover soles) may appear to be of considerable commercial importance, especially locally.***

Hammond & Prime, 1990	The diet of grey seals in the UK from five sites (the Hebrides, Orkney, Isle of May, Farne Islands and Donna Nook) was studied from otoliths retrieved from faecal samples. Sandeels and large gadoids accounted for 78-97% of the diet by weight in all areas except for Donna Nook , where they made up only 50%. The dominant gadid in all areas was cod, except in the Hebrides, where a high percentage of ling was found. Whiting was also a consistent contributor. Flatfish were the major dietary component at Donna Nook, and were also important in the Hebrides and Orkney, but less so in the Isle of May and Farne Islands. No evidence of predation on salmon was found.	
Prime & Hammond, 1990	This study was of diet of grey seals from Donna Nook only. Large sandeels (*Hyperoplus lancolatus*) were eaten in most months, but especially June-September. Because this is an offshore species, this suggests that Donna Nook grey seals regularly feed away from the haul-out site. Data on cod movements indicate that cod in their 2nd winter are about 35 cm, after which time they move offshore. The seals ate all sizes of cod up to 75 cm, but took larger cod all year round, suggesting again regular feeding away from Donna Nook. Assuming a passage of otoliths through the gut of up to 30 hours and an average swimming speed of 4.5 km/h, these seals could have been feeding as far away as 130km, possibly the SW edge of the Dogger Bank and the Norfolk Banks where sandeels are abundant. Most Dover sole taken were less than 35 cm. Shrimp remains were found in the samples mainly between January and May (peaking in April), which corresponds to the time of year when pups, born mostly in December, are starting to feed. Very small cod (up to 15 cm) were also taken mainly in the first half of the year.	
SCOS, 2000	***Grey seal diet was studied in the central North Sea in 1997 and 1998 as part of the EC-funded project ELIFONTS (Effects of Large-scale Industrial Fisheries on Non-Target Species). Results from this work showed a diet composition similar to the results from 1985 but with some variation from year to year. In particular, consumption of sandeels was significantly lower in 1998 than in 1997.***	
Harwood & Walton (in DEFRA, 2002, Annex E)	***The results of the most recent analyses by the relevant ICES working group (ICES, 1997) indicate that grey seals are important, and possibly the most important, natural predators on cod, although ICES calculated that they consumed less than 10% of the amount taken by the commercial fishery in 1995. Although seal numbers have increased since 1995 (the size of British grey seal population at start of 1999 pupping season estimated to be 122,800 animals) and cod TACs have declined, the estimated consumption of North Sea cod by grey seals in 2000 was still only 25% of the commercial catch*** (assuming, possibly incorrectly, that the proportion of cod in the diet of grey seals has not changed since 1985, when the last study was conducted).	
Bowen & Harrison, 1994	This study investigated diet composition of grey seals from faecal samples at an offshore site, Sable Island (where 90% of grey seal births in the NW Atlantic occur), which is 160 km east of mainland Nova Scotia.	Sandeel *Ammodytes dubius* accounted for the largest part (69.2%) of the diet by weight, followed by cod Gadus morhua (15.5%) and flatfish (10.7%). Fish <40cm were the main target of predation, similarly to the results of other studies of grey seals. The authors concluded that ***length-specific abundance may be a more sensitive measure of prey availability to seals than total abundance***. The diet from Sable Island differed from that of grey seals on the Nova Scotia mainland, where herring and mackerel replaced sandeel and flatfish as important foods (Bowen, Lawson & Beck, 1993).

Kiely, Lidgard, McKibben, Connolly & Baines, 2000	In this study of grey seal diet, both faecal samples from haul-out sites in the SW Irish Sea and eastern Celtic Sea and stomach samples from 17 by-caught seals were analysed. The diet was found to consist primarily of demersal fish species, principally gadids (especially poor cod and whiting) and flatfish (especially plaice.Mean lengths of commercially important fish from otoliths found in seal faeces (stomach) were (to nearest cm):Cod - 24(32)cm, Haddock, 21(39)cm, Plaice, 25(19)cm. Whiting 20(25)cm, and Sole 21(19)cm.	***It is evident that the most valuable fish stocks in the Irish Sea are not the principal prey species for grey seals. Such results agree with BIM (1997) in western Ireland, which found that whitefish and non-commercial species formed the most significant part of the grey seal diet when prey components were compared in terms of ingested weight and frequency of occurrence.***
Harwood, 1987	***Some aspects of the size-class problem are fairly easily resolved. If the seals consume fish that are on average smaller than those taken by the fishery, they will have a proportionately greater effect than if they took fish of exactly the same size. If they take larger fish, then they will have a lesser effect.***	***These sorts of calculations ignore the possible effects of predation and fishing on the density-dependent processes within the fish stock...***
Harwood & Croxhall, 1988 (B)	Notothenia rossi ***forms 5% of the diet by weight of juvenile fur seals in the summer*** (Doidge & Croxhall, 1985)***.....In addition, fur seals take mainly juvenile N. rossi whereas the fishery has concentrated on adults.***	***This*** (taking of juvenile fish by seals and adult fish by the fishery) ***may reduce competition. Indeed it can be argued that, because older N. rossi are cannibalistic on younger age-classes, the fishery may have benefited the fur seal population, in the same way that changes in the age-structure of stocks of pollock*** Theragra chalcogramma ***in the Bering Sea may have improved the food supply for the northern fur seal Callhorinus ursinus*** (Swartzman & Haar, 1985).
Des Clers & Prime, 1996 (A)	Maximum length of fish eaten by harbour seals in Firth of Clyde (1993) was 36cm. Larger fish were herring and mackerel, caught mainly in August, while gadids, forming the bulk of the diet in May and October, consisted of numerous small fish of the year, weighing less than 30g. Only a few cod were found and these were generally smaller than those caught in trawls with 70mm mesh.	The size of gadid fish, including cod, taken by seals was much less than the minimum legal landing size for cod of 35mm.
Tollit et al., 1996, 1997, 1998), Brown & Pierce, 1997, 1998), Hall et al, 1998, Wilson et al, 2002.	Studies of harbour seal diet in the UK (Moray Firth, Shetland, the Wash and Irish Sea respectively), all using fish otoliths recovered from faecal samples, indicate a wide variety of prey including gadids, flatfish, herring and sandeels.	Prevalence of different prey types, particularly herring, varies according to the seal population, season and year.

Tollit, Greenstreet & Thompson, 1997 (A)	Five fish species, sandeel, herring, sprat, whiting and cod were the key prey of harbour seals in the Moray Firth. However, at any one time period, only one to three of these species dominated (>80%) the diet….In all three time periods, the most abundant fish species in the sea was the dominant or one of the dominant species in the diet of the seals. The results ..indicate that the diet tended to be dominated by either pelagic or demersal species. But, clearly, the prey choices …were not dependent upon the absolute abundances of these species.	These results are most easily explained if one accepts that harbour seals in the Moray Firth adopt one of two foraging strategies in …winter. When clupeid availability is relatively high, seals adopt a 'pelagic foraging strategy.' When clupeid availability is low, seals follow a 'demersal foraging strategy'….these strategies may involve different foraging behaviours.If this hypothesis is correct, the predatory impact of seals on cod and whiting in the inner Moray Firth is dependent not on variation in the abundance of these gadoid species but on the abundance of herring and sprats. This has clear consequences if the impact of seals on their prey stocks is to be accurately predicted.
Tollit, Greenstreet & Thompson, 1997 (B)	Compared with the average size of prey caught in experimental trawls in the seals' foraging area, the seals tended to select slightly larger whiting, considerably larger cod, but sometimes smaller herring. The seals showed a strong preference for herring around 14-16cm. Most whiting and sandeel were 12-16 cm, while cod were larger at 20-30 cm.	Possibly higher swim burst speeds and longer handling times may make larger herring less optimal prey, although other populations of harbour seals are known to eat large herring (e.g. Olesiuk, 1990). Preferential selection of juvenile walleye Pollock over adults by northern fur seals has been reported (Sinclair et al., 1994).
Wilson, Pierce, Higgins & Armstrong, 2002	A study of the diet of harbour seals from Dundrum Bay, NE Ireland in the summer and autumn found that the seals were preying almost totally on small demersal fish, particularly gadids and flatfish. The frequency of occurrence of each size class of fish corresponded approximately with those caught by trawl in nearby coastal sampling stations. Most whiting, plaice and flounder were 100-200 mm, haddock/pollock/saithe were mainly 200-400 mm and *Trisopterus sp* (poor cod) were 0-200 mm.	Seals appeared to be preying opportunistically on the most prevalent species and size-classes of fish in the inshore coastal waters; these were mostly juvenile fish.
Wallace & Lawson, 1997	An updated review of contents of over 12,500 harp seal stomachs confirmed the earlier conclusion that Atlantic cod is a very minor component of harp seal diet, being found in only 6% of stomachs with some contents and contributing only 2.8% of total mass in the waters off Labrador and Newfoundland (NAFO divisions 2J3KL). Harp seals appear to feed most intensively in the northern part of their range (between Baffin island and Greenland), where they feed primarily on Arctic and polar cod, capelin and pelagic crustaceans. During the autumn migration to Labrador and the Gulf of St Lawrence they feed primarily on capelin and small gadids. Breeding females feed mainly on capelin before and after the pupping season. During the northern migration after the breeding season, weaned pups feed mainly on capelin and crustaceans while older seals fed on herring, capelin, shrimp and various codfishes. Most codfish eaten are smaller than the commercial size. Harps seals incidentally caught in offshore cod trawls had been feeding exclusively on cod, but the size of cod were similar to, or smaller than, those discarded during fishing operations and were of no commercial value. Pemberton et al. (1994) reported that most harp seals collected round cod trawls were scavenging discarded fish and less than 0.002% of the catch was actually foraged from the nets.	

Table IX. The feeding habits of seals - (b) their foraging behaviour

Author and date	Findings of study
Thompson, 1993 Harbour seal movements	Some seal species (such as grey, harp and hooded seals) have very separate areas for feeding and breeding. However, harbour seals do not have such discrete areas. All telemetry studies so far have shown that harbour seals do not appear to forage >50 km from their haul-out sites. In cases where seals have travelled >50 km, they have also switched to alternative haul-out sites closer to foraging areas. Foraging locations in the Moray Firth (with fairly uniform seabed) have clustered around relatively scarce submarine features such as rocky reefs and offshore banks. ***Where inshore habitats are more diverse, a wider range of foraging locations might be expected.*** ***During the summer, breeding females from the Moray Firth showed a marked restriction in their range size during the early part of lactation... although longer feeding trips do resume later in lactation... successful (breeding) males may also restrict their foraging activity in order to maximize the time spent in display areas.*** Summer location of Moray Firth harbour seals mostly occurred 20-40 km from the haul-out areas (Thompson & Miller, 1990). In contrast, seals in the winter of 1988/89 reduced their foraging range to 5-10 km when large numbers of herring and sprat moved inshore to over-winter (Thompson, Pierce et al., 1991). The following winter few herring and sprat were recorded in the area and seals were located further offshore. Trips to sea often last several days, interspersed with a day or two at the haul-out area. Although seals may forage around haul-out sites, most foraging probably occurs during longer trips of >12 hours. One adult male foraged just 8 km from the haul-out site, but remained at sea for several days at a time. Seals may spend more time at sea at night, probably due to nocturnal changes in prey movements. However, seals in Moray Firth feeding on wintering clupeids fed more often during the day, when prey were in tight schools near the seabed (Thompson, Pierce et al., 1991). Juvenile harbour seals in Monterey Bay, California, made overnight trips along the continental shelf, returning to haul-out sites each day. Seasonal movements between haul-out sites have been reported from many areas. Some such movements are local (10-20 km), while others are long distance (>200 km). Immatures may travel further than adults (Herder, 1986). Observations of 35 marked females on Sable Island shpwed that 73% between-year movements were <2 km. Such local movements between haul-out sites probably relate to characteristics of haul-out site. In several estuaries along Pacific coast of N. America there are seasonal increases in abundance at haul-out sites during major runs of prey species, sometimes moving as much as 200 km (eg Brown & Mate, 1983). However, some evidence that in UK harbour seals do not make such extensive movements in relation to local variation in prey abundance. The Kuril seal in N. Japan shows a sex difference - males apparently remaining near the breeding area year-round, while females are more widely distributed in winter (and are more likely to be by-caught in salmon net fishery).
Harkönen, 1987	Developed a hypothetical model - differences in population size & haul-out patterns of harbour seals in European waters could be explained by availability of suitable foraging habitats around haul-out sites. Model based on 3 assumptions: 1. Harbour seals are bottom feeders, 2. Profitability of taking different prey species is dependent on water depth, 3. Sizes of feeding grounds available to seals are dependent on local bathymetric conditions. Data from faecal samples suggested that harbour seals fed mainly on soft seabeds, shallower than 30m, where vegetation was sparse or lacking.

Bjørge, D.Thompson, Hammond, Fedak, Bryant, Aarefjord, Roen, & Olsen, 1995 Habitat use and diving behaviour by harbour seals	The movements and diving behaviour of 13 radio-tagged harbour seals was studied in the Foan nature reserve, Norway. Travelling to and from the the foraging grounds, the seals moved in typical V-shaped dives in a constant direction (transit dives). These dives did not always reach the sea-bed. When seals ceased directed travel, U-shaped dives were recorded. These dives usually reached the sea-bed and the swimming direction frequently changed during and between dives (foraging dives). Feeding was confirmed by an ultrasonic temperature indicator placed in the stomach. In areas with complex topography, transit and foraging dives were sometimes mingled. Average dive duration was 3.3 min, with no significant difference between transit and foraging dives. Maximum dive time was 14.3 min. For both types of dive swimming speed was 1.1-1.6 m/s (= 3.96-5.76 km/h). Seals foraged on the sea-bed between 15-200 m and on different substrates. At < 35 m the rocks were covered by kelp forest (*Laminaria*), sheltering concentrations of fish thought to be young saithe *Pollachius virens*. From the deeper part of the kelp zone to 120m the substrate changed from rocks and stones to stones, gravel, shells, sand and mud, where shoals and single fish were probably young saithe; one seal foraged in this habitat. Where sea floor sloped gently from 100-500m, one seal foraged on dense schools of fish thought to be herring. The diel cycle noted at haul-out sites may indicate a preference for foraging at night and a tendency to skip one haul-out bout at low tide during the night. The authors suggested that night feeding may be favoured by seals feeding on fish, such as argentine, which are close to the deep sea-bed during the day but make vertical migrations at night. Foraging during the day may be advantageous if seals are feeding on species (such as herring) which are more easily caught when they are concentrated on the sea bed and this limits the range of escape routes. During the pupping season male seals were found to remain in the water close to haul-out sites, emitting 'display' calls during underwater dives. At this time seals were solitary when foraging and most foraging took place within a few km of the haul-out sites, individual seals returning to the same foraging grounds for several trips - possibly indicating individual specialisation on prey species/habitats to minimize intraspecific competition during this period.
Bekkby & Bjørge, 2001	Mean dive duration of harbour seal pups in Froan, Norway, aged 56-80 days, was 3.09 min, similar to adults, but higher than that observed in adults (from Sable island in E. Canada; Boness et al., 1994 - mean 1.60 min) and by juveniles in the Moray Firth (Corpe, 1996 - mean 1.67 min). Geographical differences in foraging dive times are thought to be explained by differences in water depth.
Bjørge, Bekkby & Bryant, 2002 Home range and habitat selection by harbour seal pups	13 harbour seal pups were radio-tracked, both pre- and post-weaning, in 1997-98. All pups remained within 30km of their natal site. The pre-weaning pups stayed in inshore areas. The median home range of post-weaning pups (6, tracked in 1998) was10.4 km2 and the median core area was 1.2 km2. The home range was larger during calm weather (10.1 km2) than in strong wind (7.6 km2). One of the 6 pups remained in inshore kelp forest areas; the other five pups had their main activity in the outer part of the archipelago, but also used inshore kelp areas. The habitats selected most frequently by post-weaning pups were deep basin areas > 100 m, kelp forest areas including land and areas of 25-100m depth including land. Least selected were shallow sheltered areas without kelp and deep (>100m) plains. Deep[waters outside the archipelago were rarely used by the pups and the deep inshore trench and areas accessible by crossing the trench were never used. In studies of other species, home range size has been found to be smaller in areas of good food quality than in poorer areas. The relatively small home range sizes of the Froan pups are thought to relect sufficient local food resources. The choice of deep basins for feeding may be because these often accumulate particular organic material from dead kelp plants, which accommodate a rich fauna that may be an important food resource for harbour seals, Norway pout was found to be common in the diet of this seal population and is also commonly found in the deep sea basins. The inshore kelp areas contain several fish species and is suitable for feeding and resting.

Suriyan & Harvey, 1998 Diving and foraging by harbour seals in Washington State, NE Pacific	11 harbour seal were radio-tracked. Seals had greatest dive duration (4.0-6.22 min) when actively foraging. Maximum dive time was 15.4 min. Mean water depth was 110m. Seals often foraged *near* ***shoals and shoal edges where tide rips frequently occurred.*** Strong tide rips form at locations due to subtidal reefs and currents from water moving in and out of the southern Strait of Georgia. Tracked seals often moved to and from areas of tide rips, where water was <200m . In these tide rips seals were seen feeding on herring and salmon (salmon may move in main currents and orient along axes of tidal currents). Other marine mammals also use tide rips for feeding.	
Bailey & Ainley, 1982	In the case of California sea lions preying principally on juvenile hake in spring and summer and on rockfish in the winter, a model was devised to simulate the effects of predator switching behaviour, abundance of hake and abundance of alternative prey on the functional response of sea lion feeding in the spring and summer. Switching behaviour best simulated the observed data, i.e. when hake are abundant sea lions feed heavily on hake for both cases, but when hake are not abundant switching results in less hake in the diet compared to the non-switching case	**Conclusions** ***....Although feeding in any one location may be opportunistic, switching behavior could result from feeding on animals that occupy different habitats. Theoretically, if hake are in short supply, sea lion feeding on rockfish may displace them away from the habitat of available hake, which results in a predator switching response. These behavioural interactions are important to consider in multi-species modelling for use in species management. ....Carefully designed studies of predatory feeding behavior are needed to clarify these processes.***
Tollit, Black, Thompson, Mackay, Corpe, Wilson, Parijs, Grellier & Parlane, 1998.Harbour seal diet & dive-depths	Tested Harkonen's model (above) with harbour seals from two sub-populations in Moray Firth (Inverness and Dornoch Firth seals). The majority of seals foraged = 30 km from haul-out site, with strong modal distance of 10-20 km. All foraging areas were < 20 km from land. There was broad overlap between the foraging areas used by seals from the same site, but little overlap in the areas used by seals from the Inverness and Dornoch Firths. Individual seals returned consistently to the same areas, size of core foraging areas being only 10-21 km2 . 95% OS squares in areas used by seals were < 60 m and over soft sea-beds. Seals tended not to use shallow water of < 10 m; most used moderate water depths 10-50 m, with only one seal using depths greater than 70m. However, the authors suggest that this may be due to the lack of deep water foraging areas within close range of the Moray Firth haul-out sites, since harbour seals in Norway and California are known to dive deeper than this while foraging. A large proportion of foraging dives were estimated to be to the sea-bed, but seals also made occasional mid-water dives between benthic dives. Mixed diving has also been observed in northern elephant seals (Le Boeuf et al., 1993) and may be linked with encounters with pelagic prey. Seals from the Inverness Firth were more likely to be found over pockets of gravely sand at 10-30 m, and during this period were found to feed mainly (67% by weight) on sandeels, which are found in this habitat. Sandeels contributed less (45%) to the diet of the Dornoch seals, who rarely used the gravely sand patches available to them. Seals from both areas also dived in areas of muddy sand, sand and, in the Dornoch Firth, slightly gravelly sand. Other frequently taken prey in the Dornoch Firth were were flatfish (19.36% by weight) and octopus (28.71%). The variety of different foraging habitats used by individual sealsmay be an indication of individual specialization for particular prey or foraging techniques. Alternatively, the tendency to use one particular area repeatedly may be related to previous successful experience.	

Thompson, Mackay, Tollit, Enderby & Hammond, 1998 Influence of body size and sex on harbour seal foraging trips	A study of 37 radio-tagged harbour seals of different sexes and various body size in the Moray Firth in early summer found that - In all cases seals appeared to travel rapidly to foraging areas and remained at similar distances from haul-out sites throughout the middle 80% of the trip. Males made significantly longer foraging trips (averaging 61 hrs, considering trips > 12 hours) than females (30 hrs) and the foraging ranges (distances travelled from haul-out site) were also greater for males (average 25 km) than females (average 15 km). There was a positive relationship between both time spent at sea (i.e. not hauled out) and foraging trip duration (i.e. the larger the seal, the more time it spent in the water and on foraging trips. In contrast, harbour seals in the NE Pacific typically made trips lasting one day or less and in one study site >90% seals travelled 10 km or less. Possibly these differences are due to geographical variation in prey availability or to probability of predation from orcas or sharks while at sea.	***The data support theoretical predictions (Orians & Pearson, 1979; Stephens & Krebs, 1986) that variation in foraging trip duration will be related to the distance that individuals travel to feed.*** The authors suggested that size-related differences in foraging range may result from intra-specific competition for prey in inshore areas - seals therefore travelling as far from their central resting place as possible within energy and time limits. Since the relative abundance of different prey species may vary with distance from haul-out sites, it is possible that size- or sex-related variation in diet composition exists. These findings highlight ***the need to employ techniques that permit diet composition to be determined at the individual level ....when assessing interactions between coastal seals and their prey populations.***
Pierce, Hislop & Carter, 1997	***...common seals tend to feed very largely on small shoaling prey (herring, sprat, whiting, sandeels) which are relatively easy to catch. Thompson et al. (1991)....showed that common seals in the Moray Firth targeted shoals of sprat and small herring during the day when they were densely packed near the sea bed, rather than at night when the fish were spread throughout the water column.***	***...Thus adult and juvenile salmonids may only be attractive to seals when moving in relatively large concentrations along the coast and when confined in river estuaries.***
D. Thompson, Hammond, Nicholas & Fedak, 1991 Movements, diving and foraging behaviour of grey seals	Three subadult male grey seals caught in the Farne Islands were radio-tracked and followed by boat. Diving when seals were travelling between haul-out sites, on short-duration trips and when resting beside haul-out sites were recorded. In all contexts seals spent an average of about 84% of the time submerged. When travelling between the Farnes and Isle of May, one seal swam continuously for 20 h at a mean horizontal velocity of 1.25 m/s (=4.5 km/h) for 90 km. During this travel, however, he dived continually, close to the sea-bed. These dives were mainly ' V-shaped', i.e. the seal did not remain at the seabed. Of a total of 399 transit dives, only eight were longer than 8 mins, i.e. 'square-shaped' dives. Mean transit dive time was 206s. Maximum dive times of all types were approximately 10 min. The authors proposed that the purpose of the continual V-shaped dives is opportunistic foraging en route, and perhaps sampling the sea-bed for potential foraging sites. ***The rapid, direct swimming between distant haul-out sites suggests that the seal 'knew' these destinations and had presumably visited them previously***. The cues possibly used by the seal in navigation were discussed, but no conclusion was reached except possibly a short-term accurate sense of direction. During short-duration trips dive profiles were invariably of the uniform square-wave type, of mean dive time 243s. Depths obtained suggested that seals always dived to the bottom. Swimming speed was slow, mean horizontal velocity of 0.8 m/s (= 2.9 km/h). ***Square-wave diving began with the first dive and continued until the seal returned to shallow water adjacent to the haul-out site.*** However, The seals spent only about 14% of the time on these trips actually engaged in square-wave diviong. Seals were sometimes diving directly beneath dense assemblies of feeding seabirds. It was suggested that seals may be feeding on the deeper parts of the shoals being preyed upon by the shallow feeding birds, or on predatory fish which were themselves feeding on the smaller shoaling fish.	

McConnell, Chambers & Fedak, 1992 Foraging ecology of southern elephant seals	Elephant seals are capable of diving to 1500m and staying submerged for up to 77 min. This performance can be sustained for weeks at a time. This study tracked by satellite tags 3 adult female seals on S. Georgia after the breeding season. All 3 seals travelled SW to sites on the Antarctic continental shelf. Travelling swim speed was approximately 0.93 m/s (=3.3 km/h) for one seal during the first travelling phase. She swam in the upper km of the water column, with dive depths of max. 900m and max 40 min. These were interpreted as transit dives with some opportunistic feeding. In Phase 2 this seal followed the continental shelf margin for 805 km t a location near an underwater canyon 110 km west of Adelaide Isl, water depth of 300-400m, at average speed of 0.55 m/s (= 1.9 km/h) and dives often to the sea-bed, probably searching for a suitable foraging area and feeding. Dives while she was in phase 3, off Adelaide Isl, were shallower and less variable, seal swimming slowly to bottom, remaining there, sometimes swimming slowly, and then surfacing. These dives were interpreted as targeted benthic feeding. Benthic feeding was thought to be mainly on squid and octopus. Migration away from the breeding site of South Georgia may be because there are insufficient food resources locally to sustain an adult female seal in peak reproductive condition. The shelf and ice edges are areas of predictable high productivity, in contrast to the open ocean, where prey occurs in unpredictable patches. The authors suggest that the benefit of using distant foraging areas with a reliable food source associated with readily relocatable oceanographic features may outweight the costs of transport to these areas, and the long swim may be more productive than 'pelagic meandering'.
Harwood, 1992 (A)	1. The 1994 population of grey seals probably consumed nearly 90K tonnes of fish, about 50% of which was sandeels. However, this represents only a tiny fraction of the commercial catch of the species eaten and of the stock biomass. (Hammond, Hall & Rothery, 1994). 2. New methodologies allow estimation of the number of seals using particular areas, the amount by size class of fish they consume, where the seals forage and what parts of the environment they are exploiting. 3. Most seals are faithful to one haul-out site and there is relatively little exchange between haul-outs (Hiby, 1994). 4. The largest fraction of each seal's time is spent at or near haul-outs, e.g. on the Farnes 1500 seals are likely to be in the vicinity out of a population of about 5000. The duration of a seal's trip away is usually 1-3 days and median distance away only 35 km. Seals using the Farne Islands spent 78% of their time <50km away. The central areas of the North sea were relatively little used (McConnell & Fedak, 1994). 5. Particular places away from haul-outs are 'hot spots' in that many animals use them, e.g. all seals tracked spent 5% of their time at one place just SE of theFarnes. 6. Seals return to near haul-outs between feeding trips, although they may remain in the water. 7. Foraging sites (characterised by low travel speed and frequent changes of direction) are often shallow, sandy gravel banks typical of good sandeel habitat. 8. Once an individual establishes a particular foraging location and tactic, it seems to repeat this pattern for extended periods. 9. Taken together, these studies show that while seals may not be significant consumers of fish in the scale of the whole North Sea, they could be having important local effects and these could have economic significance for fishermen. 10. The kind of information broadly reviewed here will feed into fine-scale multi-species fisheries models which can look at the combined effect of interactions among all predators on fish and is also essential for modelling of management strategies.

McConnell, Fedak, Lovell & Hammond, 1999 Movements and foraging areas of grey seals in the North Sea	An essential component of modelling biological interactions between seals and fisheries is the temporal and spatial distribution of seal activity. Understanding the geographical relationships between grey seals at haul-out sites, when they may be censussed and their aquatic, feeding phase is essential in assessing the distribution and intensity of foraging. In this study 16 grey seals (14 from the Farne Islands and two from Abertay) were tracked using satellite technology 1. Movements were on two geographical scales: long and distant travel (up to 2100 km away) and local repeated trips from the haul-out sites to discrete offshore areas. 2. The longest 'travel trip' including visits to haul-out sites in Shetland, Faroes and the west of Ireland. During distant travel the mean daily speed was between 75-100 km/day. Such direct travel to, and arrival at, a distant haul-out site suggests both navigational ability and knowledge of that site. The geographical mixing resulting from long travel trips indicate that grey seal colonies at the Farnes, Orkney, Shetland and the Faroes are not ecologically isolated. Therefore local population control measures may have a reduced effect due to the interchange of seals from other regions….. The costs and benefits of long-distance travel for grey seals are not clear, but might include exploration of new foraging areas and opportunistic foraging en route. 3. The mean local (return) trip duration was 2.3 days with a mean distance of 39.8 km. Outward and return routes were often very similar. 4. The time spent within 10, 25 and 50 km of the Farnes was 40%, 62% and 77% respectively. Clusters of locations when seal movements were classed as SAS (slow movements at sea) were found - four very close to the Farnes and four more distant. Foraging at these clusters was inferred from tracks and dive profiles. All these clusters were over a sand and gravel mix or just gravel sediment type, i.e. suitable sandeel habitat. Less than 1% of SAS were over sand, even though this accounted for 41% of the area. 5. All but 2 of the study animals at the Farnes used localised foraging areas repeatedly; the predominance of sandeels in the diet at the Farnes during the pupping season persists over years, and sandeels have a requirement for gravely sediment, the location of which is stable. Therefore the patterns of movement and foraging observed in farnes seals may be stable over time, but this may not be the case for other colonies if their prey species have chaotic or transient distributions. 6. Overall, 43% time was spent near a haul-out (NH), 44.5% on FAS (fast movement at sea) and 12.5% SAS (i.e. foraging). Note that the NH times excluded the breeding season. The reason for spending so much time NH may be resting and social interaction when sufficient food has been taken. 7. Most dives at deeper offshore areas were to the sea-bed. Mean sea-bed depth near Farnes was 65 m, 87% area being 50-90 m. 8. The study showed that although grey seals are capable of extended and sitant travel, the impact of predation may be greater on inshore fisheries, particularly those close to seal haul-out sites, rather than on fisheries further offshore. 9. Many of the patterns recorded here were repeatedly observed. The persistence of such patterns provides confidence that data of this quality and quantity can be incorporated into the future development of spatially and temporally explicit models of seal-fish interactions upon which management decisions may be based.

Harwood, 1992 (B)	***The way in which marine mammals catch prey is poorly understood. However, recent advances in the telemetric study of marine mammals have indicated that many forage on the bottom and are relatively inactive when they are at depth (Thompson et al., 1991; Martin & Smith, 1992; See also McConnell et al., 1999). Thus, they are 'sit and wait' predators, rather than active pursuit feeders. However, some otarids may be pursuit feeders in midwater (Croxall et al., 1985).***
Harwood, 1992 (C)	***The assumption that the distribution of resting and breeding sites used by seals reflects their feeding distribution has been seriously undermined by recent telemetry studies of grey seals and southern elephant seals. Some individual grey seals do feed close to pupping and resting sites, but others may travel hundres of kilometres and then remain within a confined area before returning to the same resting site (Thompson et al., 1991). Female southern elephant seals from the large (350,000 individuals) colony on South Georgia in the Southern Ocean have been shown to travel more than 2,500 km from the colony in order to feed within an area of just 20 km radius (McConnell et al., 1992).***
Harwood, 1992 (D)	***Fishermen often report that marine mammals are 'wasteful' feeders and remove only the most nutritious parts of their prey, discarding the rest. This may be the case when the marine mammals are consuming fish which they have removed from fishing gear, when they are often faced with a large surplus of available prey. However, there is little evidence that they indulge in this practice with free-ranging prey (Harwood & Greenwood, 1985).***
Wickens, 1995; NE Pacific	***In 1979/1980 sea lions were observed to take herring from lampara and round haul nets in California. Steller's sea lions, Californi sea lions and Hawaiian monk seals take line-caught fish during various types of active-line fishing.....In Hawaii, monk seals are occasionally seen taking hooked fish from bottomfish fishing lines or near lobster fishing vessels (MMC, 1993). During 46 monitored fishing trips, 2 Hawaiian monk seals were seen to take hooked opelu from lines before they could be retrieved...and one monk seal was seen to tug at the night light used to attract lobster and in doing so chased away the lobster from the trap (Humphreys, 1981.....In California, California sea lions enter round haul nets before the bag reaches the boat and frighten fish out of the net.***
Wickens, 1995; NW Atlantic	***In the Gulf of St Lawrence, seals, probably harp seals, feed on smelts caught in set nets when ice is scarce ...grey seals enter traps set for mackerel and herring and mutilate large numbers of fish (Malouf, 1986, Colbourne & Terhune, 1991)....Along the Canadian coast, grey seals enter traps set for mackerel and herring and sometimes drive the fish out through the trap opening....They also open lobster traps, force their way into them and steal bait...(Mansfield & Beck, 1977; Malouf, 1986).***
Wickens, 1995; NE Atlantic	***In Britain, seals are reported to wait at the entrance to nets and divert fish from entering the net (Rae, 1960).*** (Otherwise no actual behaviour observed).
Wickens, 1995; S. Pacific/Atlantic	***Southern sea lions attack sharks and fish entangled in nets, generally biting the belly.... and taking the liver....Depredation occurs mainly in winter and spring and is done by individuals or groups of 3-6 animals per net...*** 3-4 individuals at a time also steal salmon from fish farms in Chile and try to remove squid from nets.
Wickens, 1995;Australasia	Hooker's sea lions are frequently observed taking squid from trawl nets ***during retrieval and generally take squid from the side panels of the net as it is hauled along the surface of the water and aboard (Donoghue, 1985).***
Arnold, 1992	***It is...no surprise that seals are attracted to salmon farms where large volumes of fish are concentrated into and around relatively small enclosures, presenting a potential take-away meal.... Farm operators agree that the most common mode of seal attack is from beneath the cage, although....from the net sides as well. The animals apparently charge at the floor of the cage from below. This drives the net against the cage where fish can be slashed, bitten grabbed or sucked through the net (see also Ross, 1988)***

Table X. The biological effects of commercial fisheries on seals

Author & date	Study findings	Conclusion or comment
Harwood & Lavigne, 1981	Consideration of implications of proposed development of clam fishery in SE sector of range of Pacific walrus. Surveys of population have suggested the species, possibly numbering 140,000 in 1975, may now be near to its pre-exploitation level, and the calculated consumption of molluscs may be close to the net annual production of the mollusc populations, and hence a suggestion that the walrus population may be close to the carrying capacity of its habitat. The problem may be expressed as ***...there are too many walrus for their own good if man exploits their food supply...***	***Even if the available evidence is treated with due scepticism there can be no doubt that such a fishery can only be detrimental to the interests of the walrus population.... obviously conflict between walrus and fisheries can be avoided by preventing the development of a fishery!***
Holt & Lavigne, 1982	***..So what could ' threaten' a numerous animal? One possibility is a substantial lowering of the overall abundance of their food. Predators need, for survival, a concentration of food items above a certain minimum level. If the concentration becomes less than that level the predator will decline no matter how many of them there were originally, and irrespective of hunting. Hunting will hasten the decline....Harp seals eat a small fish, the capelin (Mallotus villosus), cod (which eat capelin), other fishes, shrimp, euphausids and many other species. Human fishing on the food items of harp seals in the Northwest Atlantic increased in the 1970s. Catches of capelin and shrimp increased fivefold from 1972 to 1977. The biomass and the density of capelin fell so dramatically in the same period that drastic regulatory measures eventually had to be taken. Other species have been depleted to varying degrees by fishing. We do not know to what extent these depletions reduced the food for seals overall but we must presume they had some effect.***	
Lavigne, 1995(A)	The perception that seals are opportunistic predators, consuming the most abundant prey, ***leads to the belief that when a particular prey becomes less abundant, it will have little effect because the marine mammal predator will simply switch to another, more available prey.***	***This is not always the case.*** Two cases cited below of harp seals indicate the adverse effects on harp seal populations when capelin abundance declined due to intensive fisheries.
Lavigne, 1995 (B); also Stewart & Lavigne, 1984 and McClaren & Smith, 1985	***When capelin abundance declined in the NW Atlantic during the 1970s...the condition of harp seals also declined significantly ....***	This suggested ***that the seals did not simply switch to an alternative food source.***
Lavigne, 1995 (C); also Haug et al., 1991.	***When the Barents Sea capelin stock collapsed in the mid-1980s, tens of thousands of harp seals, some in poor condition...moved beyond their usual range and invaded the coastal waters of northern Norway.*** In 1987 there were a number of sightings of unusual seals, thought to be juvenile harp seals, in Shetland (B. Tulloch, pers. Comm.; S. Wilson, unpublished records). There were also sightings of a group of unusual seals, thought to be harp and/or hooded seals in the Tees estuary, NE England in late 1989	These animals ***were possibly*** or probably migrating ***in search of food.***

Furness, 2002 (A)	***Bogstad and Mehl (1997) and Gjøsæter (1997) reported that in the Barents Sea, increases in predation on capelin Mallotus villosus by a recovering cod stock caused collapses of the capelin stock, closure of the industrial fishery, and had devastating impacts on populations of seals and some seabirds.***	
Lavigne, 1995 (D)	South American sea lion (Rodrigues & Bastida, 1993)Steller sea lions off N. Pacific coast of Alaska (e.g. Anon, 1991)North Pacific fur seal (e.g. Trites, 1992)	These are all incidents where the activities of fishermen were thought by some to be contributing to the decline of certain marine mammal populations….
Lavigne, 1995 (E)	***We continue to neglect, for the most part, the possible effects of commercial fisheries on marine mammals.***	
Des Clers & Prime, 1996 (B)	The Clyde herring fishery has declined dramatically since 1930s, due to unrestricted catches until late 1970s and poor recruitment in 1980s. Local demersal fish stocks reached low levels in 1970s and have since been further depleted by by-catches of juvenile fish in the Clyde Nephrops fishery. Very few cod obtained in weekly research trawls in 1993. About 200 harbour seals but only about 35 grey seals were counted over 5 areas of the Clyde between April and October 1993.	Seal numbers in Clyde relatively few, especially of grey seal. Commercial herring and cod fishery, which directly exploited many of seals' prey, have been replaced by a Nephrops fishery. Therefore, fishermen complain little of competition from seals at present.Implication is that seals' prey abundance has been depleted by commercial fisheries, resulting in reduced seal seal numbers frequenting Clyde. Authors also point to disturbance of harbour seal haul-out sites.
Thompson, Tollit, Greenstreet, Mackay & Corpe, 1996	Harbour seals in the Moray Firth (NE Scotland) had a lower body condition index in 'bad' clupeid years (clupeids formed <11% by weight of the winter diet) than in 'good' years (clupeids >50% diet). Body lengths of yearlings were also greater after a 'good' clupeid year. Seals also had an increased foraging range during years of poor clupeid abundance.	Decreased clupeid abundance may impact negatively on juvenile seal growth, adult seal body condition, and cause the seals to increase their foraging range. The relationship between prey availability, seals' energy requirements and possible influence on average age of sexual maturity should be further explored. Also, ***accurate predictions concerning the impact of seals on particular prey stocks will require accurate predictions of the relative abundance of all potential prey.***
Thompson, Tollit, Corpe, Reid & Ross, 1997 (A)	Harbour seals in the Moray Firth (NE Scotland) in 'bad' clupeid years, when the seals switched to alternative prey, principally gadid fish & sandeels, showed indications of macrocytic anaemia.	Gadid fish are thought to contain an anti-metabolite, which inhibits the absorption of iron in susceptible predator species, causing the macrocytic anaemia.
Wilson, Pierce, Higgins & Armstrong, 2002	A study of the diet of harbour seals in Co. Down, NE Ireland, found that the diet appeared to be deficient in clupeids, while consisting increasingly of gadids over the 5-year study period.	There has been a decline in the size of the breeding population over the past 10 years, and juvenile seals are rarely seen to play in contrast to frequently observed play behaviour in the late 1960s. It is suggested that both these changes may be related to the clupeid-poor and gadid rich present-day diet of these seals.

SCOS, 2000 (Annex I)	A decline in the British grey seal pup production from 1998-99 of 6-10% in The Hebrides & Orkney, 9% at the Isle of May and 36% at the Farne Islands was recorded.	This decline appears to be too great and too widespread to be related to shortage of space at breeding colonies - environmental changes, possibly relating to the availability of prey were therefore also suggested as an underlying cause.
Furness, 2002 (B)	The industrial sandeel fishery in the North Sea started in the early 1950s, grey rapidly in the 1970s to reach 800K tonnes per year by 1977, after which the catch has remained fairly steady with no indication of decrease in sandeel stocks. Numbers of grey seals and most species of sandeel-dependent seabirds have, on an overall North Sea scale, increased during this period.	Multi-species modelling has shown that predatory fish consume many more sandeels than are taken by the industrial fishery, birds and seals combined. The decrease in sandeel consumption by predatory fish as a consequence of depletion by the fishery of mackerel and gadoids in particular has been far larger than the increase in sandeel catch, resulting in a net increase of sandeels available to birds, seals and the fishery. This may be one of the reasons for the breeding success and population growth of seabird and grey seal populations in the North Sea. If so, a future recovery of mackerel or gadoid stocks would be likely to severely compete with sandeel-dependent wildlife, as well as threatening the sustainability of the present industrial fishery (cf. capelin stocks and harp seals, Furness 2002 A)
Thompson, Tollit, Corpe, Reid & Ross, 1997 (B)	The decline in Steller sea lions and harbour seals in the Bering Sea is coincident with the decline in herring stocks in the late 1970s, as a result of intensive fishing. The ecosystem is now dominated by the gadid walleye pollack.	***Further experimental work is now required…. In the meantime, it is suggested that the long-term implications of dependence upon gadoids should also be investigated in those populations of marine top predators currently exhibiting unexplained declines.***
Gerber, Wooster, DeMaster & VanBlaricom, 1999 (A); also Merrick, 1995; NMFS 1992; Loughlin et al., 1992.	***The Western stock of Steller sea lions Eumetopias jubatus is estimated to have declined by 94% in the Eastern Aleutians, 72% in the central Aleutians, 82% in the western Gulf of Alaska (GOA), and 73% in the central Gulf between the late 1960s and 1989.***	***…the decline has been attributed to the unavailability of suitable prey for juveniles (Merrick, 1995). Fisheries, especially for walleye Pollock (Theragra chalcogramma) have been charged with reducing prey abundance as well as direct interference on the feeding grounds for juvenile sea lions. While there now seems to be general agreement that juvenile sea lions are suffering from nutritional stress…..there is still considerable uncertainty about the sources of that stress.***
Gerber, Wooster, DeMaster & VanBlaricom, 1999 (B); also Merrick, 1995;1997	The Steller sea lion decline is probably linked to the accumulative effects of a number of factors, including 'natural factors' such as predation, disease etc, pollution, and fisheries-related factors such as removal of prey by commercial fisheries, direct kills of sea lions by commercial and subsistence harvesting; intentional and incidental kills by fisheries and entanglement in marine debris (NMFS, 1992)…..	

Gerber, Wooster, DeMaster & VanBlaricom, 1999 (C); also Merrick, 1995;1997	Merrick (1997) speculated that the cause of the Steller sea lion decline ***may be interaction between oceanographic changes of the late 1970s and the effects of intense exploitation of marine mammal and fish species beginning in the 1950s……removals by the 1960s of most of the large whale biomass in the North Pacific may have adversely affected the composition of prey in the ecosystem for the Stelelr sea lion by leading to a large increase in the Pollock population and a corresponding decrease in the preferred forage fish prey (Merrick, 1995).***	
Gerber, Wooster, DeMaster & VanBlaricom, 1999 (D)	Under the mandate of the Endangered Species Act of 1973 (ESA), ***each decision within the fishery management subsystem now requires consideration of its potential impacts on the continued existence of the Steller sea lion…..the burden of proof has been put on the fishing industry in minimizing adverse impacts on Steller sea lion populations…***	
Yodzis, 2001 (A); also Loughlin & Merrick, 1989; Trites & Larkin, 1992	The Steller sea lion in the Bering Sea and Gulf of Alaska has declined dramatically since the 1950s; Pollock is the major prey item of these sea lions and there are large-scale correlations exist between the decline in sea lions and increases in the size of the pollock fishery.	The US NMFS stated ***that the Pollock fishery, as proposed for 1999-2002 , 'is likely to jeopardize the continued existence of the western population of Steller sea lions'.***
Johnson, 1999	The Hawaiian monk seal Monachus schauinslandi principally occurs on the uninhabitated islands of the Hawaiian chain. The colony on the French Frigate Shoals (FFS; 800 km NW of Oahu) has been declining, with poor juvenile survival and many underweight juveniles recorded. The US Marine Mammal Commission (MMC) report of 1998 reports that the decline at FFS appears not to be due to disturbance, but to limited prey availability.	Hawaiian monk seals feed on reef fish, octopus, crab, moray eel and lobster. The present lobster fishery by-catch in the NW Hawaiian islands is composed of reef fish (25%), crabs (23%), moray eels (11%) and non-target lobster species (4%), i.e. the present lobster fishery is most probably responsible for the decline in monk seal prey availability. In its report, the MMC points to its repeated recommendation that the NMFS close FFS to lobster fishing as a precautionary measure pending further scientific study - but to no avail. The fishery, meanwhile, (exploiting a total quota of 186K lobsters) has been shifting towards the western Hawaiian islands, including those supporting major breeding colonies.
Panou, Jacobs & Panos, 1993	***In Greece, fishermen traditionally persecute monk seals as competitors and enemies. The decline of fish due to overfishing (partly a consequence of increased tourism) probably attracts seals to fishing nets more now than in the past. The increasing damage to fish catch and nets may have intensified the fishermen's negative attitude towards the animals. ….The human contribution to overall monk seal mortality is likely to grow in the years to come because seals will concentrate more and more near fishing nets as coastal fish densities decline. Comments by older fishermen of Stavros support this view. These fishermen reported that 10-20 years ago the fish catch was about tenfold compared to the present, although fewer nets were used. At the same time the damage by seals was smaller although the animals were more abundant.***	
Yodzis, 2001 (B)	Several key international bodies (CAMLR Convention, CFP of the EU, UN/FAO and UNCLOS) ***all require that the possible effects of a fishery on its ecosystem should be taken into account.***	Given the access of humans ***both to powerful technology and to an abundance of alternative resources,…fisheries are more likely to affect predator populations than the other way round.***

Table XI. Interactions between seals and salmon fisheries

Author & date	Study findings	Study conclusions
Rae, 1962	Stomachs examined from 64 seals (41 greys seals and 23 harbour seals) shot between 1958–60, 34 of which trapped in salmon nets. 10 grey seals and 1 harbour seal found with salmon in stomachs.	Seals have a harmful effect on salmon fisheries.
Lockie, 1962 (A)	The weight of prey, found in the stomachs of 8 juvenile grey seals taken at salmon nets in the vicinity of the River Tweed in Berwickshire in July–August 1956–57, was estimated by weight as: gadids 110 oz., cephalopods, 296 oz and salmonids 80 oz (or 19.7% by total weight). A guesstimate of 67 young grey seals feeding along 30 miles of adjacent coastline was made.	From these estimations, a calculation of a total of 21,800 lb (9,875 kg) salmonids were estimated to have been eaten during the 1957 salmon fishing season (182 days) in the study area by the 67 young grey seals.
Lockie, 1962 (B) Discussion following papers at meeting	***E.A. SMITH: ....There is also competition within the fishing industry. The entrance to a river which it is claimed is robbed of salmon by seals, is frequently 'closed' by drift nets which are very successful at catching salmon before they enter the estuary.***	
Parrish & Shearer, 1977	Incidence of damage to bag and stake nets in Scottish east coast salmon fishery decreased markedly during 1960s and almost no damage reported by mid-1970s.	Decrease in damage attributed to synthetic twines in nets, which are less liable to be torn by seals.
Parrish & Shearer, 1977	Incidence of damaged salmon at Scottish east coast netting stations has not increased between 1964–76, although grey seal population in Scottish waters has increased markedly during this period.	Salmon damage at nets is not related to the size of the grey seal population, but is caused by individual 'rogue' seals.
Stansfeld, 1984	***Common sense indicates that the reason for this*** (no increase in damaged salmon in nets) ***is that in the late sixties and early seventies the migration pattern of salmon changed substantially in favour of large grilse runs. In the late seventies and early eighties migration patterns of salmon changed further from early running to late running fish.***	***It would have been interesting to see if the (SMRU 1984) Report had plotted these changing migration patterns against seal population levels and damage statistics to see if there was a significant correlation.***
Wickens, 1995	**NE Atlantic:** Various estimates for % damage to salmon in gill nets by grey seal in Scotland and NE England are 3–11%, 2%, 3%, 5%, 25%, 3-5%, 2.%; in Norway 15% (attr. to grey and harbour seals); In Ireland 25–45% salmon catch in Galway, 17% in Ballysodare and 7–10% in Sligo (attr. Mainly to harbour seals). **NW Atlantic:** Grey seals attacked 75% salmon farms in Bay of Fundy. **NE Pacific:** Harbour seals estimated to damage salmon in gill nets, variously 25% (Alaska), 7–12% (BC), 1–2%, 5%, 15%, 5–9% (Oregon). Steller sea lions estimated damage 6% salmon in gill nets in Alaska. Californian sea lion damaged 0.4%–>6% active line salmon fishing. **NW Pacific:** Damage to salmon catch in gill nets variously 5%, 2%, 2–3%, 1–2% on Japanese coast. **S. Pacific/Atlantic:** 0.5–2.2% salmon farm production damaged. **S. Indian/Pacific:** Adult male Australian fur seals (and occasionally leopard seals) tend to raid fish farms.	

Boyle, Pierce & Diack, 1990	Feeding trials with a captive adult male grey seal found that of 24 whole salmon fed to the seal, 19 of the heads were eaten and virtually all of the rest of the fish. Only one of the 38 possible otoliths and undistinctive vertebrae fragments were recovered from the pool floor when the pools was drained. Also, only one mackerel otolith was recovered from innumerable whole fish eaten.	The seal ate the salmon head in 79% of cases. Nevertheless, consumption of salmon by seals is probably very much under-represented by the number of otoliths and bones found in faeces. ***Editor's note:*** ***However, it should be noted that recovery of otoliths from faecal matter remaining in the pool after draining (and surviving flow through a grille with a 1cm2 mesh to a drain) is not comparable to recovery of otoliths from discrete faecal samples collected from haul-out sites in field studies***)
Pierce, Thompson, Miller, Diack, Miller & Boyle, 1990	In a study of seasonal variation in harbour seal diet in the Moray Firth, one salmonid otolith (a salmon) was recovered from a total of 407 faecal samples.	On account of its large size, this single salmon eaten was estimated to represent 11.8% of the diet of the seals in the month of July 1988 (but 0% of the diet in the other 11 months).
Boyle, 1990	In a study of harbour seal diet in Loch Linnhe during May–July 1990, a total of 9 salmonid otoliths were found out of a total of 2729 otoliths recovered from a total of 43 faecal samples (i.e. 0.33%). Of these, 5 were sea trout, 3 were salmon and one unidentified. The salmonids eaten were all 30–56 cm in length. The % weights of the salmonids in the diet were estimated as 2.69% for salmon, 6.05% for sea trout and a further 0.22% for the unknown fish.	The presence of salmon and sea trout in the diet of the Loch Linnhe harbour seals reflects the presence of these salmonids in the sea lochs at certain times of the year, including the study months. The results indicate that salmonid otoliths can survive passage through the gut of a wild seal and that harbour seals eating salmonids of this size do, at least sometimes, eat the head. This conclusion was also reached by Brown & Mate (1983), studying the feeding haboits of harbour seals in Oregon.
Olesiuk, Bigg, Ellis, Crockford & Wigen, 1990	In a study of harbour seal diet in the Strait of Georgia (BC) based on 2,841 faecal samples collected over a full year, salmonids were detected from otoliths and bones in 451 (i.e. 15.9%) samples. On a weight basis, salmonids were estimated to form approx. 4% of the diet. For seals in river estuaries the salmonid share was about 12% and for (the majority) of seals living outside estuaries the salmonid share was about 3%. Salmonid consumption was usually found to peak in the autumn, particularly November. Salmonids taken were mainly adult salmon that were taken as they returned to the river to spawn. Annual salmonid consumption was estimated at 394 tonnes, or 2.8% of recent annual escapement.	The study concluded that the harbour seal in BC is an opportunistic predator in that diets varied regionally and seasonally depending on the local availability of prey. This situation may be analogous to a 'mixed-species' fishery, in which abundant stocks can support high fishing effort and rates and ultimately lead to the over-utilization and demise of the rarer stocks…..the large concentrations of seals attracted to estuaries , presumably by other prey or by haul-out conditions, may exact a heavy toll on vulnerable resident fish such as trout or on smaller salmon stock. It is these situations that may be of greatest concern in holistic fisheries management…..By their nature, these localized conflicts are restticted to the areas and times that certain prey are especially vulnerable. Scat analysis is perhaps the best suited approach for obtaining a broad overview of the diet, and hence for identifying these conflicts…..the conflicts may (then) be investigated in greater detail, for example by direct observation.

Anon, 1999 (A), citing Hanson, 1993	This thesis was reported to document the results of 155 harbour seal scats collected over a one-year period at the mouth of the Russian River, California. A frequency of occurrence of salmonids of up to 20% during winter was reported, most of which was apparently on hatchery fish.	
Anon, 199 (B), citing uncredited 'research'	In the Columbia and Rogue Rivers systems on the western US coast, salmon were reported to occur in 43-60% of harbour seal scat samples during autumn when adult salmon are returning to spawn; in the spring, when smolts are leaving the rivers, the frequency of salmon occurrence ranged from 20-33%. At other seasons the frequency of occurrence of salmonids in harbour seal scats fell to zero.	
Pierce, Boyle & Diack, 1991	Compared frequencies of occurrence of prey species in 10 harbour and 49 grey seal digestive tracts in seals killed near and not near to salmon nets. Methods used otolith and bone ID and serological methods for salmonids. Frequencies of occurrence in net samples were higher than expected for salmonids. However, the frequency of salmonids in samples from nets was not high and these samples more frequently contained gadid and flatfish remains.	The presence of non-salmonid prey in the digestive tracts of seals shot in salmon nets indicates that those seals did not specialise on salmon. Compared to Rae's earlier studies salmonids were found to be relatively less important & gadids more important in seal diet.
Anthony, 1996	This review article describes the licensed seal kills in Scotland under the 1970 Conservation of Seals Act. These kills were because of damage to the salmon net fisheries, both in terms of salmon and to the nets themselves….For example, in 1974, the grey seal quota at Orkney was 1,000 pups and 1,000 at the Hebrides. The common seal kill was 200 pups at Orkney, 250 pups on the west coast and 300 on the east coast including the Moray Firth……The Scottish Salmon Grower's Association Code of Practice (1990) now encourages, but does not require, the use of non-lethal predator control measures.	
SCOS, 2000	To assess the impact of seal populations on salmon populations requires information on seal numbers, distribution, dynamics. Diet and foraging behaviour but also on the numbers, dynamics and the magnitude and causes of other sources of mortality for salmon.	
Greenstreet, Morgan, Barnett & Redhead, 1993	Numbers of shags and harbour seals were counted and subaqua surveys of plankton, fish & Mysids conducted during the salmon smolt run in River Lussa, SW Scotland, in May 1987–89. Counts of seals and shags, also quantity and variety of planktonic material and numbers of mysids, gadids, flatfish and gobies were highest during smolt run.	Timing of smolt run evolved to coincide with productivity bloom in estuary, providing an optimum marine feeding situation. Shags, seals, smolt and marine fish all attracted to this, resulting in shags & seals feeding on smolt and marine fish. But seals probably not attracted specifically by smolt run.
Thompson & Mackay, 1999	Inspected damaged salmon (19.5% of 1099 fish) returning to Conon River (NE Scotland) caught by rod (78) and trapped by the Fishery Board (136) hatchery. 33 fish (3%) were found with multiple parallel scratches. Estimates of spacing between parallel scratches made to determine possible cause. Comparing the patterns of scratches with number and spacing of teeth in seals, otters, dolphins, porpoises and claws in otters and seals, the authors found damage consistent with attack by a variety of predators.	Results highlighted multi-species nature of salmon-predator interactions. Damage typically attributed to seals suggested to be result of attacks by odontocete cetaceans.

Anon, 2000 (BIM)	This study was carried out in Kilalla Bay and North Mayo (NW Ireland) with on-board observers on fishing vessels in 1998-99. In the summer there were up to 90 harbour seals in Kilalla Bay in the summer and about 150 grey seals on the Inishkeas (80 km south of the North Mayo fishery). Drift-net-ting for salmon in these areas involves a single erect curtain of net which is allowed to float freely at the surface, held erect in the water column by a buoyant , floated headline and a sunken, leaded footrope. The nets are made of monofilament nylon. A single vessel may use a maximum net length of 1,400 m. The fishing vessel periodically patrols the net, to examine the gear, check for seals, retrieve caught salmon and scare free-swimming salmon into the net. Seals were sighted near the nets on 3 of the 16 days in Kilalla Bay and on 5 of the 9 days in North Mayo. The seal species could not always be identified, but were grey seals when identified. In Kilalla Bay 237 salmon were landed and observations suggested that a further 4 were taken by seals from or near the net (i.e. a loss of 1.7%). In North Mayo 138 salmon were landed, 2 were thought to have been lost due to seal predation (1.4%). A further 3 fish were damaged, two of which were unfit for sale (a further 1.4%).	The overall levels of loss to seal predation and damage (0.8% damaged and 1.7% taken from beside the nets) was less than the loss rates recorded in earlier studies (summarised in Wickens, 1995). One reason for this may be the present day practice of removing salmon from the net as soon as they are spotted rather than allowing fish numbers to build up before retrieving the whole net as previously practiced.
Carter, Pierce, Hislop, Houseman & Boyle, 2001	Observation of harbour seals in adjacent estuaries of Rivers Dee & Don in NE Scotland. Don used mainly as haul-out site while Dee used as foraging site. Seals in estuaries observed to eat salmon, trout, roundfish and flounder; otoliths from scats indicated marine fish also eaten.	Seal predation on large salmon in the estuaries was apparently an order of magnitude less important than mortality caused by angling in the river.
SCOS, 2000 (A)	Not cited	The available information suggests that salmonid mortality is likely to be caused by a few individuals rather than the population as a whole.
SCOS, 2000 (B)	The most important factor in determining the effectiveness of localised killing of grey and common seals around estuaries and river mouths to protect salmonids is whether the fish are being targeted by a relatively small number of individuals or by the local population as a whole. If salmonid mortality due to seals is the result of a few individuals, removing these animals may be an effective control measure for a time, at least until they are replaced by others. However, if all the animals in the local population prey on salmonids, localised killing will not be effective.	

Northridge, 1988	**It is still not clear if there is any relationship between absolute seal numbers** (referring to grey seals) **and damage levels at fishing sites. Indeed one fisherman's explanation that there was an influx of large black seals, possibly old bulls, during the salmon season, might confirm the theory that most damage is done by just a few 'rogue' individuals. If so, then any control measures would be most effectively directed at those animals.**	
Wilson & Knight, 2002	A 3-day visit to the Thurso river (N. Scotland) was made to assess the situation regarding the presence of a group of harbour seals hauling our near the river mouth, which was considered to be problematic to game fishing interests. Shortly before the visit, the fisheries manager had fenced off the grassy bank previously used by the seals as a haul-out site over high tide.	The harbour seal group (varying in size and composition between 3 adults on one day to 9 juveniles on another) was found to be entering the river mainly to haul out on the grassy banks over high tide. The seals spent time in the water only when the haul-out area was flooded by spring high tides. Predation on four black salmon (of no commercial value) and one trout was observed at a rate of 0.86 fish per hour while the seals were in the river. Consumption of the salmon was observed twice. On both occasions the entire fish was eaten, taking 7 min. for one fish and 20 minutes for the other, larger, fish.
H. Sand & H. Westerberg, 1997 (A)	Trial cull in Swedish Baltic to test the hypothesis that a limited cull of grey seals sighted close to salmon traps would decrease the rate of seal damage to fish and gear. Trial involved killing up to 10 individuals sighted within 100m of salmon nets in each of three areas and comparing the levels of damage at salmon nets with three control areas.	Trained marksmen succeeded in killing a total of only16 seals. The results demonstrated no significant difference in levels of damage between experimental and control areas following the cull and therefore did not support the 'specialist' theory (i.e. that damage in a particular area is caused by a few individuals). The study concluded that limited hunting at stationary fishing implements is no effective method to reduce the damage to coastal fishing.
H. Sand & H. Westerberg, 1997 (B)	Only seven of the 16 seals killed were recovered; six were males and one was a subadult male. This finding was not consistent with the sex ratio of seals drowned in these nets, which was 0.6 males.	One possible explanation is that adult males are less shy of humans and expose themselves more than females and juveniles. This might explain why the trial hunting did not result in any decrease of damage frequency, since it essentially concerned only 20% of the potential damagers in the area.
H. Sand & H. Westerberg, 1997 (C)	***The fact that killing a limited number of grey seals had no effect on damage frequency does not necessarily mean that all individuals in the grey seal population are potential destroyers. The damages can still be caused by a lesser number of the population, but this share would then certainly be larger than only 'a few individuals'.***	
Northridge, 1988	Some (salmon farm) operators were said to set anti-predator nets with plenty of slack to increase the likelihood of entangling seals and other predators. ….Seals are also shot by salmon farmers. Licences have been given to a number of farmers to shoot seals in the close season, and 6 grey seals …as well as one common seal…have been reported killed under licence from 1983–1985 (Anon, 1987).	Ross (1988) reported about 166 marine salmonid sites in Scotland in 1987. The Outer Hebrides and Shetland were the most heavily farmed areas and both have large numbers of seals. Ross estimated that the total number of seals shot by salmon farmers may be nearer to 1000 a year.

Arnold, 1992	***It is…no surprise that seals are attracted to salmon farms where large volumes of fish are concentrated into and around relatively small enclosures, presenting a potential take-away meal. Other wild fish include saithe (Pollachius virens) swim near the outside of the cages in their thousands. Attracted by the food pellets and the waste as well as the organisms (mainly algae, tunicates and molluscs) fouling the nets, these fish are exploited by predators…Farm operators agree that the most common mode of seal attack is from beneath the cage, although….from the net sides as well. The animals apparently charge at the floor of the cage from below. This drives the net against the cage where fish can be slashed, bitten grabbed or sucked through the net (see also Ross, 1988)…….The scale and nature of predation is highly variable between individual sites……attacks were commonly attributed to the occasional 'rogue' seal, often thought to be a young bull who might take small numbers of fish over a period of weeks, or indulge in an apparent feeding frenzy, killing, damaging or releasing large numbers of fish in one night……The frequency of seal problems did not necessarily bear any relationship to the numbers of seals reported to be nearby.***	
Bjørge, Bekkby, Bakkestuen & Framstad, 2001	About 2% of all tagged harbour seals in Norway were shot when they approached fish farms or salmon rivers (Bjørge et al., 2000). In a modelling study seals used areas close to fish farms for foraging, but there was no indication from the modelling that seals were actually attracted to the fish farms	According to the local fish farm keepers, there were no severe interactions between seals and fish farms in the particular area of this study.

Table XII. Operational; interactions between seals and fisheries - (a) the imapct of seals on fishing gear and catch

Author & date	Study findings	Discussion & conclusions
Northridge, 1988, citing Heap et al., 1987	Study (Heap et al., 1987) investigated the effect of grey seals on the inshore set net fishery for whitefish in NE England. Damaged fish accounted for 0–21% of weight of landings, with the maximum being recorded at Blyth in March. Mean rate of loss was of the order of 5%.	Damage most intense in more northerly reports of Blyth & Shields than in Scarborough or Bridlington, thought to reflect proximity of Farne Islands. However, Potter & Swain (1979) found seals were not specially abundant at Seahouses compared with other ports, despite its proximity to the Farne Islands.
Harwood, 1987 (A)	***Interference problems appear to be more prevalent around static gear, such as fixed nets, long lines and gill nets, than around actively-fished gear, such as trawls and seines... Levels of damage are best measured by direct observation on fishing vessels or around gear; interviews with fishermen on the dockside are likely to be less reliable.***	***In many cases it may be simpler and cheaper to attempt to drive the seals away from the gear with various scaring devices or to change fishing methods, than to attempt a reduction in seal numbers. However, to date scaring devices have not been particularly effective in reducing damage to nets, although they have reduced entanglement problems*** (which damage gear as well as drowning the seal).
Harwood, 1987 (B)	If all members of the seal population are equally likely to prey on fish in nets, then only a large-scale seal cull would have any conceivable effect on the problem. If seals near nets are killed, they will soon be replaced by others – the problem will remain while a large proportion of the local seal population could be killed inadvertently. If, however, it can be shown (perhaps by marking the seals) that only some individuals are involved, then killing these seals (if they can be identified), ***or the halting of fisheries operations in specific areas*** might alleviate the problem.	***Allowing fishermen to kill seals around their gear may make the fishermen feel better but it is unlikely to reduce damage significantly unless it really is caused by a small number of rogue individuals. ..***it may be more economical to compensate the fishermen for losses incurred, ***either by direct compensation or by ...giving them sole access to particular fishing grounds, than to fund*** expensive culling schemes.
Collins & Fitzgerald (BIM), 1993	30% of 1087 monkfish landed in Co. Cork from tangle nets fishery between April and August 1992, and 23.5% of 2149 April-Aug 1993, were damaged by the tail having been bitten off by a large predator. One of four by-caught grey seals had two monkfish tails in stomach. Estimated loss of revenue was (IRP)5031. Monkfish in gear set >5 miles offshore was significantly less than in gear set closer to land.	Grey seals are the most probable culprits of this damage to caught monkfish. Damage is economically significant for inshore fishery, but not for fishery >5 miles offshore.
Fedak, 1996 (A)	Once an individual grey seal establishes a particular foraging location and tactic, it seems to repeat this pattern for extended periods.	It is therefore very important that particular individuals are targeted rather than the population at large.

Fedak 1996 (B)	The distribution of activity of grey seals is very concentrated around major haul-outs. Foraging trips away are usually 1–3 days and median distance 35 km. Farne Island seals spent 78% of their time less than 50 km from the haul-outs. Individual animals often follow the same route and go to the same places repeatedly, and some places are often used by many animals at the haul-out.	It is important to consider the proximity to haulouts and frequently travelled areas when siting fixed fishing gear or marine farm installations since such spatial relationships will determine how quickly animals will discover such installations and how quickly 'problem' animals will be replaced if removed.
Crespo, 1992	The southern sea lion Otaria flavescens seems to be an opportunistic feeder with a tendency to feed on demersal fish and cephalopods, and is reported by fishermen to damage gill-nets. The opportunistic behaviour of the sea lions is also shown by males which feed in harbours and follow trawls to take fish from the nets. The southern fur seal *Arctocephalus australis* and the southern elephant seal *Mirounga leonina* seem not to interact directly with fisheries operating from the S. American coast, probably because they tend not to feed in inshore waters.	The sea lions all along the coasts of Brazil, Argentina and Patagonia appear to suffer widespread killing by fishermen using shooting or other means. 30% of animals found dead in in southern Brazil show scars or wounds made with fireguns, sticks, ropes or nets. In Argentina fishermen in the coastal gill-net fisheries claim compensation for net and catch damage.
Wickens, 1995	Of 60 populations of 45 pinniped species worldwide, 24 populations and 21 species were recorded as interacting with fishing operations through depredation, gear damage or disturbance, as follows (salmon fishing excluded here; included in table XI): **NE Atlantic**: 5/12 species involved: grey , harbour, harp, monk and Baltic ringed seals; quantitative data only for grey, harbour and harp seals; 2–26% cod in gill nets in Norway attr. to harp seals. **NW Atlantic**: 3/8 species involved – grey, harbour and harp seals. Little quantitative documentation. Harp seals damaged <0.002% trawl catch in Newfoundland. **NE Pacific**: 4/12 species involved – harbour and monk seals, Steller and Californian sea lions. Steller sea lions estimated damage 8% halibut in gill nets in Alaska. Japanese fishery report 20–30% sable fish in purse-seine net fisheries damaged in Bering Sea and 50% in Alaska. Californian sea lion damaged 1–10% fish of various species in gill nets. **NW Pacific**: 6/10 species involved – In order of frequency of occurrence of seals found dead in nets: harbour, largha, bearded, ringed, fur seal and Steller sea lion. **S. Pacific/Atlantic**: 1/6 species involved – S. American sea lion Otaria byronia. In Chile, 35% artisanal gill net fishery for sciaenids damaged. One individual adult seen to damage 60% of one catch. **S. Atlantic/Indian Ocean**: One species – S. African fur seal. <1% total fishery damage, including 2% netted St Joseph's sharks and 0.2% netted mullet. Also <1% of sole and 12% kingklip damaged in inshore trawl nets (total 0.3% fishery value); 12% demersal longlining catch (fishery ceased) and <1–8% handline-caught fish, including 3–6% snoek and 1.5% hottentot fishery. **S. Indian/Pacific Ocean**: 4/4 species involved – Australian sea lion (Neophoa cinerea); Hooker's Sea lion (Phocarctos hookeri); Australian and New Zealand fur seals. Little quantitative documentation. 774 incidents involving 1021 individual Hooker's sea lions taking squid from side panels in net of shelf trawls. Adult male Australian fur seals (and occasionally leopard seals) tend to raid fish farms.	

Kiely, Lidgard, McKibben, Connolly & Baines, 2000 (A)	In a study of seal damage to monkfish catches in the tangle net fishery in SE Ireland, data from one vessel owner for 1996–97 demonstrated that seal-related damage ***may be highly seasonal in nature with little variation between years …and that the period of greatest catch may coincide with relatively low levels of damage.***	
Kiely, Lidgard, McKibben, Connolly & Baines, 2000 (B)	***…in 1998, the total observed damage loss to tangle-net monkfish catches was an estimated 667 kgs, amounting to approximately ?1,533. This damage comprised an average loss of approximately 10% of the total catch by weight of the fishery. By simple extrapolation, this would amount to approximately ?50 per vessel per month.*** ***The greatest incidence of seal damage was 33.3% in a single haul. However, the average incidence of seal damage was 8% and 40% of trips did not experience any seal-inflicted damage to the catch….crab and skinner damage accounted for a significantly greater incidence of damage to net-caught monkfish (average incidence of 15%).***	The main result of this study, i.e. that about 10% of the overall monkfish catch was damaged by grey seals, contrasts greatly with the study by Collins et al (1993; above), which found 31% of the catch damaged. The authors suggest the difference might be due to the earlier study not being conducted on a shipboard observer basis, but rather relying on second-hand data from fishermen. However, the figure of 10% is more in keeping with the similar level of damage attributed to grey seals in western Ireland, of 7.7% for hake (direct recording) and cod (10% - indirect recording; BIM, 1997). The results of the present study ***suggest that damage to the monkfish fishery was not as great as perceived by the industry.***
Kiely, Lidgard, McKibben, Connolly & Baines, 2000 (C)	***An investigation of interactions between marine wildlife and net fisheries in Wales did not reveal any large-scale problems*** (Thomas, 1992 – reference not given)	This may be due to the fact that inshore fisheries around the coast of Wales are directed mainly at shellfish with pot-fisheries for lobster and crab most important. Although some tangle-netting for crayfish and demersal species (e.g. rays) takes place and seals are occasionally thought to remove bait from lobster creels, they are generally not perceived to be responsible for economically-significant impacts on Welsh fisheries.
Kiely, Lidgard, McKibben, Connolly & Baines, 2000 (D)	In spite of the evidence from the findings of their study of seal-fisheries interactions in the monkfish tangle-net fishery in SE Ireland, the majority of fishermen favour a cull of grey seals in SE Ireland to reduce the damage to caught monkfish (estimated at about IR?50 per boat per month, or 10% of the catch).	The authors point out that the grey seal breeding population in SE Ireland is relatively small (less than 1,000 animals), but the breeding population in Wales is much larger (about 6,000 seals), and grey seals move extensively within the Irish Sea, both in and out of Irish waters. Thus the actual population causing damage to particular fisheries is ill-defined. The authors also point out that current co-operation based methods are not going far enough to obtain accurate measures of the level of this interaction. The authors also cite the four accepted ecological relationships that work against the success of culling pinnipeds to enhance fisheries.
Panou, Jacobs & Panos, 1993.	Operational interactions were studied between 1986–88 in a population of 18–25 monk seals in the waters surrounding the islands of Kefalonia, Ithaca and Lefkada in the Ionian Sea. A total of 1864 fishing trips were monitored and on 136 (7.3%) damage was recorded. However there was considerable monthly variation (0–22%). If damage occurred, it was associated with seal sightings near fishing gear in about half of the cases. One test trammel net was placed in front of a cave inhabited by one adult male seal. Each night 10–15 fish were caught. In 2 of the 7 test nights the seal was in the cave, and on these two nights the net had 18 and 21 holes respectively, but was undamaged on the other nights. Inshore trammel nets had the highest frequency of damage, followed by offshore trammel nets and gill nets. Bottom long lines were damaged least. Seals fed on all types of fish in the nets, supporting the view of Marchessaux & Duguy (1977) that monk seals are opportunistic predators. Traditionally, fishermen in Greece shoot seals, seeing them as 'competitors and enemies'. This shooting are an important component of overall monk seal mortality and thus perhaps one of the main causes of the population's decline.	

Archipelagos, 1999.	Seal damage to nets was recorded in 21 of 1,043 fishing trips (2.0%; monthly variation between 0–15.6%), 20 cases of damage to trammel nets and 1 to long lines. Seal sightings at the gear were recorded in 16 cases (1.5%) and in about two thirds of all cases of damage (76.2%). One explanation for the relatively low mean value for seal damage compared with other studies may be the fact that during summer the nets are set mainly offshore….avoiding the setting places close to the coastline, the main foraging area of the monk seals.	
Eybatov, Asadi, Erokhin, Kuiken, Jepson, Deaville & Wilson, 2002	The Caspian seal Phoca caspica seems to be an opportunistic feeder with a tendency to specialise in small pelagic species, such as kilka. Of 127 dead Caspian seals on the coast of Iran during surveys in 2000, 62 were found, by post-mortem examination, to have died in fishing nets. Six of these were drowned in gill nets set for sturgeon, 14 were harpooned by fishermen in the kilka fishery and 42 were either shot or killed with a hammer by fishermen when they were trapped in encircling nets (pareh) set for kutum and mullet.	Of the 6 seals from the gill nets, two stomachs contained kilka (average 137 fish) and four contained gobies, Neogobius . Of the 14 seals from kilka nets, 13 contained kilka (average 101 fish) and one contained 9 mullet. Of 42 seals in encircling (pareh) nets, 36 stomachs contained grey mullet, Lisa auratus (average 10 fish, mostly 10-18 cm), 6 contained kilka, Clupeonella, spp.(average 97 fish of 8–15 cm) and 6 also contained kutum, Rutilus frisii kutum, and four also contained shad, Alosa kessleri (average 27 fish).

Table XIII. Operational interactions between seals and fisheries - (b) non-lethal mitigating measures for seal damage to nets and catch, and also caged fish

Author & date	Problem	Mitigation proposed	Carried out?	Successful?
Northridge, 1988 (B)	***In general changes in gear design or fishing method seem to be the most effective means of controlling seal damage. The effects of the introduction of the introduction of stronger, synthetic twines to the Scottish stake net fishery is one such example. In Alaska, fishermen found that the Steller sea lions' habit of chewing marker buoys, as common seals do in the Wash, could be countered by the use of a solid Styrofoam float (Mate, 1980).***			
Wickens, 1995	Operational interactions in general	***Acoustic scare systems have been tried but ....factors that need to be considered when designing acoustical methods, namely the temperature, salinity and depth of the water, background noise such as water turbulence, rain or man-made noises, bottom topography which affects sound propagation, water surface reflections, bottom reflections and the location of the subject relative to the sound source.***		***....while they may be initially successful their effectiveness does not appear to be long-term***
Wickens, 1995, citing Kuljis, 1985; Montgomery, 1986	General seal-fisheries operational interactions involving sea lions	Try to develop taste aversion to fish in nets by aversive condition-ing (by contaminating fish with lithium chloride), and used in conjunction with auditory signals ***to keep the negative stimulus and reduce habituation.***	Tests on captive sea lions (Kuljis, 1985) and field trials (Montgomery, 1986).	***....proved to be promising***
Wickens, 1995, citing Hansen, 1987	General seal-fisheries operational interactions involving harbour seals in Denmark	Use of various deterrents near fishing tackle, such as gas canons, fire effects, shooting and chasing seals.	Yes	No. ***Seals quickly became accustomed to the disturbance.***
Wickens, 1995, citing Sasakawa, 1989	Damage to bottom set nets by Steller sea lions in Hokkaido	Improving strength of nets to prevent sea lion > 75 yarns were safe from damage by sea lions and knotted webbing	Yes. Field trials to test baited bag nets of different twine strength	***Bags of more than 75 yarns were safe from damage by sea lions and knotted webbing is better in preventing the spread of broken areas.***
Wickens, 1995, citing Sasakawa, 1989	Damage to bottom set nets by Steller sea lions in Hokkaido	Use of automatic explosion simulator to keep sea lions away from nets	Yes – field trial	Yes , trial successful – during 13 hauls of the net, good catches were made without damage from sea lions.

Wickens, 1995	Interference with fishing operations in S. Africa by Cape fur seals	Use of acoustic deterrents, such as explosive firecrackers, electronic pulses and airguns, orca sounds and shots fired into the water.	Yes, field trials with fishermen	Firecrackers discontinued in early 1970s since they were thought to deter fish also; other acoustic methods had no lasting effect
Wickens, 1995, citing Wickens et al., 1992	Cape fur seals feeding on fish caught during demersal long-lining	Haul long-lines in more rapidly, making it more difficult for sea lions to take fish; also deploy inflatable boat to disrupt feeding behaviour of seals and keep them away from lines	Yes, tried by fishermen	No, ***seals adapted and dived further away and deeper to take fish from the lines.***
Wickens, 1995; citing Wickens 1993; 1994	Cape fur seals damaging propellers on some offshore trawlers while feeding on fish being discarded overboard.	Before fish are discarded overboard they are minced finely, making them inaccessible to seals.	Yes, trials with fishermen	?
Wickens, 1995; citing Wickens, 1993; 1994	Cape fur seals interfering with rock lobster hoopnetting fishery	Change to baiting technique found to reduce problems in one particular area	Suggested	?
Wickens, 1995, citing Pemberton et al., 1991; Pemberton & Shaughnessy, 1993	Fur seals attacking fish farms in Tasmania	Various non-lethal deterrents tried, including shooting, seal crackers, protection nets, emetics, pursuit by boats, light and acoustic scarers.		None is completely effective although the rate of attacks by seals may be reduced. Use of emetics may be promising if further researched.
Anon, 2000 (BIM)	Seals taking salmon from drift nets	Patrol nets frequently and remove fish soon after they are caught (by hooking the net with a gaffe & pulling in just enough net to remove the fish), rather than leave fish to accumulate in the net until such time as it is deemed practicable to retrieve the whole net	Yes, in the summer drift net fishery for salmon in NW Ireland (documented in a 1998-99 study).	Yes – damaged fish estimated at only 0.8% of catch and only 1.7% deemed lost to seal predation from or near nets. This figures are much less than in previous studies.

Lunneryd & Westerberg, 1997	Use of the 'seal-proof' Dyneema twine (in place of nylon twine) in trap nets for salmon and whitefish in Northern Baltic is only a partial solution. The number and size of net damages is reduced but no difference in damage to catch. Seals may enter via the fish entrance. Also with the stronger nets there is a higher risk of drowning to the seals	The authors therefore suggest a switch to such stronger twine, but in combination with a seal exclusion device at the trap entrance.	Carried out experimentally in study below (Westerberg & Stenström, 1997)	Yes, in experimental trials
Westerberg & Stenström, 1997	Damage by grey seals in the Baltic to trap nets for salmon and whitefish	Instead of an open entrance to the trap, a grating with a wedge-design with a 150 mm mesh was trialled. The grating allows fish to pass into the trap, but keeps seals out. (smaller mesh size was found to deter fish from entering the trap)	Experimental Trial carried out	Net efficiency of the trap was same as without the grate. On the rare occasions when a seal attacked the bag netting, the catch remained high where the grating was in place, as the grating made escape by the fish more difficult.
Arnold, 1992 (A)	Problem of predation by seals (also otters and seabirds) on salmon cages. Anti-predator nets are not only expensive to install and maintain, but are often ineffective against predator attacks and the slack nets frequently entangle and drown seals.	***There is a need to find a system which separates wildlife from stock effectively without causing entanglement, is adaptable to the extremes of existing conditions, requires less maintenance and is therefore more acceptable to salmon farmers than predator nets.***		
Arnold, 1992 (B)	Problem of entangling seals (and diving birds) in slack anti-predator nets surrounding fish farm cages	Use new cage NET TENSIONING SYSTEM instead of anti-predator nets	System is still being refined, but in 1992 used by at least ten salmon farming companies in Shetland	All but one of the operators using the new system estimated that it proved 95–100% effective in reducing predation. Seals are still seen near their cages, but the damage to stock has been negligible. Although there were no 'before and after' figures for predation, entanglement and direct kills, net tensioning has eliminated the perceived need to shoot seals at these farms and reduced entanglement.

Smith, 1994a	Seals (harbour and grey seals) taking fish from fish cages in Bay of Fundy, Canada	1. Relocate fish cages away from areas of local seal concentrations 2. Design fish cages to include an outer anti-predator net impenetrable by seals	no	
Smith, 1994b	Control of predation by seals and sea lions at fish cages.	3. use of acoustic deterrents (including the high decibel acoustic harassment device (AHD).	Yes	***These are expensive and are often not effective. They must only be used in conjunction with other technology, such as a system of predator exclusion nets***
Wickens, 1995, citing Oporto & Leal, 1990	Southern sea lions attacking salmon farms in Chile	Use of acoustic harassment devices	Approx. 12.5% salmon farms use or have used AHDs	No – sea lions become habituated to them. Frequencies used may be incorrect for Otaria, or individuals have different sound or intensity tolerances.
Ace-Hopkins, 2001; 2002	Seals attacking salmon cages or frightening fish in cages. Note, even if fish are physically protected by net tensioning system, they will still be stressed by seal presence, showing loss of appetite	Use an acoustic deterrent device (ADD) such as made by Ace-Aquatec – 'silent' seal scrammer, (ANSS). The theory ***is that a seal, which has panicked the fish, receives an audible conditioning signal followed shortly after by a loud irritating noise at a frequency of 6–7 kHz*** and intensity 194 dB re 1/Pa @ 1m. The seal quickly associates its behaviour (trying to attack the fish cage) with the conditioning signal.	Trials carried out in winter 2001-02 in Scotland.	Yes. Average efficiency during trials estimated to be 92%. Fish appetite also improved, indicating lower fish stress levels and therefore improved fish welfare. It is recommended that this type of device should be used in conjunction with a net tensioning system. For best effect the scrammer should be activated all the time as a preventative deterrent.

Table XIV. Changing human behaviour

Author & date	Changing human behaviour
Northridge, 1988 (A)	In the newly established tangle-net fishery for crawfish at Barra (Western isles in Scotland) large numbers of seals were by-caught in the nets…***..however, with experience, the fishermen learned that certain areas were worse than others and were able to restrict the places they fished to minimise incidental capture….current catches are unknown but assumed to be much lower.***
Panou, Jacobs & Panos, 1993	In relation to operational interactions between monk seals and Mediterranean fisheries – the authors believe the deliberate killing of seals should be stopped. The authors suggest that deliberate killing seems to be responsible for the animals' fear of man and their avoidance of much potential coastal habitat. They also suggest that fishermen should be compensated for seal damage. Protection zones, especially surrounding active caves, should be developed and public awareness of the problem should be increased.
Archipelagos, 1999	It was noted that seal damage to nets was lowest when, in summer, the nets were set offshore, thus avoiding the main foraging area of the monk seals. Such a strategy might be deliberately adopted to avoid operational interactions.
Anon, 2000 (BIM)	Predation by seals on set-net fisheries may be greatly reduced by checking the nets frequently and removing caught fish rather than allowing them to accumulate and attract seal predation. This has been found to be highly successful in the salmon drift net fishery in NW Ireland.
Smith, 1994	When establishing new aquaculture installations, ***emphasis should be placed on the prevention of predation rather than on its mitigation once it has begun……Since it is extremely*** important to ensure that new aquaculture installations are not established near concentrations of potential predators, ***an initial priority must be the collection of basic biological data on resident pinniped species. Good distributional and abundance data…are especially important.***
Lavigne, 1995 (A)	***The fact is, we do not know how to manage ecosystems and, in reality, we don't even try. What we do attempt to manage – and we haven't been very successful at this, either – is human activities. We grant licenses to fishermen; we limit their catches with quotas or total allowable catches (TACs); or we limit the time (seasons) they are allowed to fish. The real object of management is not really to regulate wild populations of fish (or other wildlife) but rather to ensure that catches from them are sustainable into the future.***
Lavigne, 1995 (B)	***We must also remember that perceived conflicts between marine mammals and fisheries tend to surface most often when commercial fish stocks are in a state of decline and when fishing interests seem threatened. Very often, the reasons for the decline in the fishery are clear – poor fishing practices and failures in fishery management. So, in addition to recommending more "science" as a solution to current fishery problems, we might also recommend some historical studies to examine the circumstances which frequently lead to the collapse of commercial fisheries: things like over-capitalization, over-optimistic quotas, excessive catches and failures in enforcement. These are things we can do something about, and which might not only ameliorate current fishery problems by prevent them from recurring.***

Glain, 1998	***The solution to tackle all these (operational interactions) problems is to adopt a participative approach. Involving local communities in conservation is strongly recommended by the UK action plan for biodiversity.....all stakeholders should participate in a forum or working group where concerns and needs of all would be taken into consideration. This may be the only way to achieve sustainable conservation of the grey seal (in Cornwall), as the status of this species is intricately connected to the fishermen's livelihoods.***
Young, 1998	Whale watching has developed into a world-wide multi-million-dollar industry, taking the economic place of commercial whaling in a past era… ***In 1994 around 5 million people went whale watching in as many as 65 countries, with total revenues reaching US$504 million……Between 1991 and 1994 the number of people participating has grown by an average 10.3% per year and total revenues have increased by 16.6% in the same period. Seal watching in the UK could also have a major potential. There are at least 117 seal watch establishments in the UK and Ireland. In 1996, the number of visitors watching seals in the UK and Ireland was estimated to be around 0.5 million and the total gross revenue of the industry was estimated at more than £36 million per annum. Employment created by the seal watch industry was extrapolated to be 193 full-time, 322 part-time/seasonal and 152 voluntary posts. Pupping and breeding sites were common destinations of these tours.***
Anna Douglas in The Mail on Sunday, 24/9/00 Return to the cull	***The rise in seal numbers has given birth to a relatively new and lucrative offshoot: seal spotting. Chris Parsons, of the Hebridean Whale and Dolphin Trust said: 'Tourists come here to see seals as well as dolphins and whales. We have found 65 per cent of tourists are against seal culls and 15% say if they took place it would affect their decision to come to Scotland.***
J. Allardyce, in Scotland on Sunday, 15/7/01	***The cull of the wild: dying for our fish supper? Cara Brydson (IFAW) …said…a drop in seal numbers….would also hurt the trade in seal watching trips, which generates £36m a year in the UK.***

Table XIX. Entanglement of seals in discarded fishing gear

Laist, 1995, (A)	19 of 33 pinniped species have entanglement records and two have ingestion records. ***The vast majority of reported entanglement cases involve small pieces of lost fishing gear; particularly trawl net, gillnet and monofilament line.***	***Lost fishing gear and gear scraps are the most hazardous types of marine debris pollution for marine life. Lost gillnets and traps can remain intact and catch marine life for well over a decade.***
Bonner & McCann, 1982	***Reports of otariid seals being found in the wild with ligatures round their necks have been increasing in recent years. Mostly these have referred to northern fur seals, Callhorinus ursinus, and Steller's sea lions, Eumetopias jubatus, in the Bering Sea and on adjacent coasts (Sanger, 1974; Engel and others, 1980), but examples have also been reported of collars on cape fur seals, Arctocepahlus pusillus, from southern Africa (Shaughnessy, 1980) and Antarctic fur seals, Arctocepahus gazella, from South Georgia (Payne, 1979; Bonner, 1982)…Most reports refer to rope circles, fastened with knots, often the knot known as a fishermen's bend (two half-hitches each made round the standing part of the opposite piece of rope). Characteristically the rope is made of synthetic fibre and is buoyant. It has been suggested (Payne, 1979) that these rope rings are discards from fishing boats and that a seal finding one floating on the surface of the water plays with it and pushes its head through the ring so that it settles round its neck. Probably the collar is usually loose enough for the seal to shake it off……If the collar fails to become dislodged, as the seal grows the ligature cuts into the tissues of the neck….One such rope circle was examined on a adult female Arctocephalus pusillus on south Georgia. The collar was formed of a loop of buoyant polypropylene rope, 8mm in diameter, the ends cut and heat-sealed and knotted together with a fishermen's bend.The collar had an internal diameter of 175mm.***	
Bonner, 1989 (B), citing Kenyon, 1980	The endangered Hawaiian monk seals (*Monachus schauinslandi*) are known to be prone to net entanglement, especially pups. In 1983, 11 of 26 pups were seen either entangled in netting (four pups, subsequently rescued by the observers) or playing among netting and debris in the water (Kenyon, 1980).	
Laist, 1995 (B)	***Entanglement rates*** (in pieces of netting) ***seen on short field visits to the Hawaiian monk seals' five major breeding sites range from 0 to 7.5% per year for individual colonies.***	***For some species entanglement-related mortality*** (in pieces of netting) ***is a key conservation issue.***
Johnson, 1999	The 1998 report of the US Marine Mammal Commission notes that during the 1998 field season 18 seals were found entangled in discarded fishing nets. Of these 5 were able to free themselves, 12 were disentangled by field crews and one was found dead.	A clean-up effort sponsored by NMFS in 1998 discovered 94 pieces of netting per sq. km. Fouling the reef surrounding the French Frigate Shoals, and 64 pieces per sq. km at Pearl and Hermes reefs. Following the partial clean-up, NMFS estimates that 38,000 pieces of netting remain at each of these reefs.
Laist, 1995 (C), citing Fowler, 1982	In the case of the northern fur seal *Callhorinus ursinus* on the Pribilov Islands, modelling studies suggest that 50,000 fur seals may have been killed annually by entanglement in pieces of trawl web and other debris during the 1970s.	It was suggested that this entanglement may have been the major cause of the population's decline in the late 1970s and early 1980s.
US National Marine Fisheries Service (NMFS) brochure, cited by Emery & Simmonds, 1995	Some 30,000 Northern Fur seals die yearly from entanglement in netting, a 50% decline in 30 years has been noted…..	
Gerber, Wooster, DeMaster & VanBlaricom, 1999	These authors list entanglement in marine debris as being one of several fisheries-related factors possibly contributing to the marked decline of Steller sea lions *Eumetopias jubatus.*	

Emery & Simmonds, 1995	A literature review suggested that generally less than 0.5% of any population of phocids or otariids are killed annually by entanglement, Hawaiian monk seal being exceptionally high. Entanglement of grey and harbour seals in the UK has been widely reported but not documented and published. Information obtained from five sources (Skomer Island, Orkney, Hebrides, Norfolk and Cornwall) all reported several seals over a four-year period 1991-95 (e.g. 11 seals from Skomer, including 4 adults, 2 subadults, 3 yearlings and 2 pups) that had been constricted or wounded by debris still attached. Most had rope, cord or netting around the neck, either embedded in blubber or causing raw flesh cuts. The authors point out that disposing of plastic at sea is theoretically illegal in British waters under the International Convention for the Prevention of Pollution from Ships (MARPOL), Annex V, but up to 1995 only one UK vessel had been prosecuted.
Kiely, Lidgard, McKibben, Connolly & Baines, 2000	***Grey seals are observed on occasions……carrying a 'necklace' of fishing net around the head (photograph of adult female grey seal with constrictive neck band thought to have resulted from entanglement in fishing gear).***
Public Service message from the Center for Marine Conservation (USA), cited by Emery & Simmonds (1995)	***To you, plastic debris may be merely an eyesore. But to an animal, it could be a deadly trap. Fish, birds and seals are known to strangle in six-pack rings and fishing lines……That's why the penalty for throwing garbage overboard is a lot more than a guilty conscience. It's now a class D felony, punishable by imprisonment for up to six years and a fine of up to $250,000.***

Table XV. Seals and worm infestations of whitefish

Author & date	Study or review findings	Conclusions
Des Clers & Wootten, 1990 (A)	Seals are the final host of the marine nematode Pseudoterranova decipiens, variously called the codworm or sealworm. After 2–3 weeks in a seal stomach, the adult worms lay and fertilise several hundred thousand eggs within the seal stomach; these reach sea water with the seal faeces and sink. The eggs hatch into larvae, which are eaten by an invertebrate host, probably a benthic crustacean. The larvae are then eaten by a bottom-feeding fish. The worm can infect any demersal fish, but cod is the most often infected species. The worm larvae migrate from the fish gut to the muscle, where they stay, coiled and encapsulated for several months until the fish is either caught by the fishery or eaten by a marine mammal. Any marine mammal may be infected, but only in grey seals Halichoerus grypus do significant numbers of larvae mature (but see Des Clers & Prime, 1996). At high levels of fish infection (e.g. with 2–10 worms per fish), the larval worms have to be removed before the fish can be sold.	
Rae, 1962	% of cod infested with larvae of the sealworm (codworm) Phocanema (Porrocaecum) decipiens varied from 0% in Southern North Sea (offshore) to 57% in the Inner Firth of Clyde. Infestation levels were generally higher in west of Scotland and Orkney and Shetland.	***The correlation between the areas of high worm infestation and those harbouring dense concentrations of seals is striking.***
Parrish & Shearer, 1977	Incidence of infestation of cod with *Phocanema* in Scottish waters ***has remained at approximately the same level as during the 1960s.***	Since the 1960s ***there has been a population explosion in grey seals.....latest estimates are... 69K for grey seals*** and around 15K for common seals.....but no comparable increase in Phocanema infestation of cod.
Lavigne, 1987	The (Canadian Royal) Commission also suggests that the cull will also reduce the number of worms in the fish caught	***...there is no simple relationship between the number of grey seals and the number of worms in fish. Capriciously changing the name of the codworm to sealworm and launching a major cull of grey seals on Sable Island will not eradicate this parasite.***
Des Clers & Wootten, 1990 (B)	The rapid growth of many grey seal colonies around the UK has caused concern that high levels of infection in cod will recur, following a period of decreased infection dating from the 1970s. In this study biological and mathematical models were developed and used to examine the basic reproductive rate of the parasite and see how this depends on the sizes of the interacting seal and cod populations. In this model system, 100 grey seals were assumed to prey upon a cod population of 100,000 fish. The following points are important: 1. Most fish are uninfected, with only a few carrying the bulk of the infection. 2. An increase in the number of fish will increase the number of fish eating infected crustaceans, and as a result, the number of infected fish. 3. An increase in the number of seals will increase the number of adult parasites reproducing, hence the number of free-living worm larvae, the number of parasites that reach the fish and the parasite transmission from fish to seal.	2. The large number of fish relative to the number of seals, and the low mortality of the worm while in the fish, combine to make the cod stock a reservoir, the size of which is critical to the total number of worms. 3. An increase in seals will mean that more infected fish will be eaten by the larger number of seals. However, the percentage of infected cod eaten by each seal is still fixed at a low level and in any case, the number of fish eaten is still very small compared to the number of fish removed by the fishery. 4. The model determined the relative influence of increasing the number of interacting fish and seal hosts independently on the worm reproductive rate and found that a doubling in the number of fish will have a much greater impact on the number of parasites present in the system than a doubling of the number of seals.

Des Clers & Wootten, 1990 (C)	The seasonal and spatial dimensions of an infection should also be incorporated in the biological model. The abundance of all hosts varies seasonally – seals congregate only in the pupping and moulting seasons, fish migrate seasonally and many benthic crustaceans show annual variations in abundance.	For example, the main cod nursery grounds in Iceland are to the NW of the island, next to the largest grey seal colonies. The longer cod are on the grounds, the heavier the infection. For cod going inshore only seasonally, as in the Moray Firth, the infection levels will be lower than in sedentary inshore stocks.
Des Clers & Wootten, 1990 (D)	The older the cod, the more infected it is likely to become. Seals probably eat fish younger than those caught in the fishery, but also probably catch more of the highly infected fish (due to their slower swimming speed).	The commercial fishery is the most important cause of change in the number of fish. If the fishery reduces the average age of the cod population, it will also reduce the total number of worms. The North Sea cod was (in 1990) the fastest growing of all the major N. Atlantic stocks and the youngest to be recruited in the fishery, and the age has been further reduced since the 1970s. This ***could explain why the North Sea cod is the only stock in which the codworm levels have decreased while the seal colonies have increased.***
Des Clers, 1990	Two versions of the model are suggested. In version F, parasites increase the mortality of the host in which they spend most of their life cycle. This is in the cod, and although the worms probably do not kill the cod directly, they may make it more susceptible to predation because of reduced capacity for bursts of swimming speed. However, this mortality is less than mortality due to fisheries. In version S, individual worm fecundity is decreased in seals with high adult worm burdens. An intrinsic (density dependent) control operates more efficiently in seals than in fish. Overall sensitivity is higher for version F of the model, in which parasite numbers increase more with fish and seal numbers than with version S.	***It is not possible at present to tell which one of these (F & S) mechanisms is most important, and it is also possible that both mechanisms control a sealworm population , at different times or places.....In the final host, an intrinsic decrease of the parasite fecundity has a clear stabilising effect, with parasites in fish increasing only slowly with the number of seals.*** This is probably the more important of the two naturally regulating mechanisms, but ***the mechanism needs to be identified to understand fully the indirect link between numbers of parasites and numbers of hosts. It is also crucial to identify the numbers of fish and seals effectively interacting in transmitting parasites.***
Des Clers & Prime, 1996	***Sealworm*** (Pseudoterranova decipiens) ***infection levels in cod (in the Clyde) in 1993 were apparently no different to levels observed almost 30 years earlier, but ...are still amongst the highest in the British Isles.***	Low infection in cod probably reflects predominance of young cod (fish accumulate worms from their food and therefore older fish have higher burdens). However, the sealworms in the Clyde fish are most probably mostly transmitted by harbour seals, given the few grey seals in the area. High fidelity to inshore sites by harbour seals may lead to higher sealworm burdens in inshore fish than for infections transmitted by grey seals.

Table XVI. By-catch and killing of seals in active fishing gear

Author & date	Study findings
Bjørge, Øien, Hartvedt & Bekkby, 2001 (A)	***Marine mammals are vulnerable to incidental mortality in gillnet fisheries worldwide... Focus has been on small cetaceans.....Mortality of seals from fishery interactions has received less emphasis, although mortality rates may be significant.***
Wickens, 1995 (A)	Of 60 populations including 46 species, records of incidental mortality in 42 populations and 33 species documented.
Wickens, 1995 (B)	**NE Pacific** **12/12 species involved**, but documentation mainly for Steller and Californian sea lions and harbour seals. **Steller sea lion**, estimated by-catch of 14,000 in gillnets (mainly salmon, also halibut & shark) between 1973–88 from Alaska to California. Also by-caught in trawls since 1954, estimated at 1000–2000 in early 1970s with >25 sea lions caught per 10,000 tonnes fish, and 87% marine mammal by-catch was Steller sea lion, but by-catch decreased by late 1980s. Also shot indiscriminately, e.g. 305 shot in Copper River salmon net fishery in spring of 1978. **Californian sea lion** overall 2000–3000 caught annually in Californian set net fishery. Smaller numbers (20–300 annually) killed in purse seine nets. Also shot and clubbed, e.g. 200–300 shot by salmon troll fishery in California in 1980. Harbour seal Total by-catch off Alaska estimated at 2,800 in 1979, in California between 130–2028 per year in gill & trammel nets net; fewer (0–20 per year) in trawls. Shot and clubbed by fishery, e.g. Copper River & Coghill salmon fisheries shot 303 in 1978. **Hawaiian monk seal** by-catch in different fisheries. Hooks from long lines embedded in mouth or skin; 5 at French Frigate shoals in Jan 1991 had head injuries consistent with hooks or clubbing. **Elephant seal** estimated >100 caught annually in swordfish/shark gill net fishery in California; also other gill net by-catch. Walrus 40 caught in groundfish gill nets in 1977/88; 5/6 annually in Alaskan offshore trawls. **Largha, ringed, bearded seals and northern fur seals** all caught in gill net fishery – no data and numbers may be relatively few; ringed and ribbon seal sometimes caught in trawls.
Bonner, 1989 (A), citing Henry, 1986	***Off the Californian coast...observations...on the activities of gill-and trammel-netters working in inshore waters....found that marine mammals were frequently caught in the nets, with an average of one marine mammal for every 534m of nets hauled. Harbour seals were the species most commonly caught, with one harbour seal for every 712m of nets hauled, though sea lions, sea otters, elephant seals and porpoises were also caught.***
Gerber, Wooster, DeMaster & VanBlaricom, 1999 (A)	Under the US Marine Mammal Protection Act of 1972 (MMPA), fishermen ***were required to obtain a permit to kill marine mammals incidental to legal fishery operations. Without such a permit, a fishery was legally liable... and could be fined up to $20,000 or jailed for up to 1 year for each illegal interaction.*** Prior to authorising such a permit, the NMFS had to make a determination ***that any population subject to incidental mortality was: (1) at its optimal sustainable population (OSP) level, and (2) the proposed level of take would not cause the impacted population to decline below the lower end of its OSP level.*** The MMPA definition of OSP for a given stock is the ***number of animals that will result in the maximum productivity of the population, consistent with the optimum carrying capacity of the habitat and the health of the ecosystem.***

Gerber, Wooster, DeMaster & VanBlaricom, 1999 (A)	In 1988, ***in Kokechnik Fishermen's Association v. Secretary of Commerce, the US Court of Appeals found that a federal permit allowing the Japanese high seas salmon fleet to take marine mammals during the course of its fishing operations in the US ...EEZ...was a violation of the MMPA.*** This permit allowed the incidental take of Dall's porpoise *Phocenoides dalli*), but failed to take account of the incidental by-catch of other marine mammals, including northern fur seals *Callhorinus ursinus*, whose populations were either considered to be depleted by the MMPA, or for which an ASP determination could not be made. This dilemma resulted in amendments to the MMPA. A new section 114 in 1988 authorised a 5-year interim exemption allowing by-catch in the absence of an OSP determination, with the proviso that the fisheries had to register with the federal government and report on by-catch mortality they had caused. In 1994 section 117 required the preparation of stock assessments for all marine mammal stocks in US waters and section 118 redefined the 'incidental take regime'. Under section 118, incidental take of species listed either as 'depleted' under the MMPA or 'threatened' or 'endangered' under the Endangered Species Act of 1973 (ESA) could now be authorised. However, the 'new regime, which became effective in 1995, also included goals of reducing incidental mortality to levels not likely to adversely affect any populations of marine mammals, and to reduce such mortality and serious injury to approaching zero by the year 2001.
Wickens, 1995 (E)	**NW Pacific** **8/10 species involved** **Steller sea lions** – several hundred annually drown in Soviet trawls in N. Pacific; also in Kamchatka region (no data). Small numbers drown in Japanese salmon drift nets. The population in this area was ca. 13,000 and decreasing in 1993. Shot in the Bering Sea to prevent damage to catch. **Northern fur seals** – mortality in Japanese drift net salmon fishery. Estimates for annual mortality range from very few (Northridge, 1991) to 3150–3750 (Fukuhara, 1974), to 7000 (Lander and Kajimura, 1982). The latter authors suggested that by-caught fur seals may have been used as food by the fishermen. Fur seals also caught in drift nets for squid; research nets with larger mesh catch more seals than commercial nets. Also caught in drift nets for salmon & pollock and in cod trawls in Kamchatka region. **Harbour seals** (Kuril seal) – this subspecies in northern Japan and the Kuril islands numbers <4,000. Numbers have declined markedly as a result of deliberate and incidental mortality during fishing. 1483 seals died in salmon set nets off the Kuril islands in 1970 and 557 in 1971 around the Habomai islands. In the early 1980s about 160 harbour seals drowned annually in salmon trap nets (many in one particular net); this is about half of the SE Hokkaido population and about 8% of the total population. Most were pups (27%) and subadults (69%). **Largha seals** – also die in trap set nets for salmon, especially the same trap in which many Kuril seals died (97 in 1982/83; most at that trap). There is one report of 10 pups dying in salmon trap nets on Daikoku island. Seals also die in crab trap nets. Largha seals are shot by salmon fishermen to prevent damage to catch in nets. Ringed, ribbon and bearded seals – relatively small numbers in both gill nets and salmon trap nets. **Baikal seal** – no data, but ***incidental catches of young seals are a possible threat to the population (Reijnders et al., 1993).***
Wickens, 1995 (F)	**S. Pacific/Atlantic** **4/6 species involved** **Southern sea lions** – caught in shark gill nets, but rarely in trawls. They are deliberately killed in all areas where fishing occurs. Also killed by king crab fishermen for bait in S. Chile and Argentina. Permits to kill may exceed local populations sizes, and no permit needed in Chile. Sea lions are shot, dynamited or killed with sticks or spears, and in Chile the military have culled all ages at certain rookeries. **S. American fur seals** – taken in gill nets and salmon farm anti-predator nets, but rarely in trawls. Taken in Chile & Argentina for king crab bait. **Galapagos fur seal** – have died in gill nets, but problem may have been resolved. **Juan Fernandez fur seal** – illegal catch for lobster bait. **Visiting leopard seals** – killed for use as bait in king crab fishery.

Crespo, 1992	Concerns about interactions between marine mammals and fisheries in the SW Atlantic (east coast of S. America) have focussed on the serious problems involving La Plata dolphin and other small cetaceans. However, the southern sea lion Otaria flavescens is also involved. The population is believed to be about 70,000 animals, compared with an estimated 300,000 at the end of the 1940s. The sea lion seems to be an opportunistic feeder with a trend to feed on demersal and bottom species. The sea lions are reported to interact principally with the widespread artisanal gill-net fishery. Sea lions found dead in the Rio Grande area show signs of mutilation. In Argentina sea lions are reported to damage coastal gill nets and also 'jigg' nets while trying to catch the trapped squid, and they are shot or otherwise killed by fishermen. Male sea lions tend to follow trawlers out to sea and be caught or otherwise killed in trawls when they try to take fish from nets, whereas females are more coastal than males and tend not to be caught in trawls. Also an unknown number of marine mammals, including sea lions and fur seals, are killed for bait in the crab fishery in Southern Argentina and Chile.
Wickens, 1995 (G)	**S. Atlantic/Indian Oceans** **Only one species – S. African (Cape) fur seal** – drown in gill nets, trawls and purse seines. 0.005–0.032 drown per trawl on S> coast and 0.057 on west coast, extrapolating to 1089 seals annually on west coast. Altogether, 438–1610 annually in offshore demersal trawls, 1034 in mid-water trawls 174 in purse seines and 14 in inshore drift nets. They are also shot by fishermen and may be killed on board fishing boats.
Wickens, 1995 (H)	**S. Indian/Pacific Oceans (Australia & New Zealand)** **4/4 species involved** – **Hooker's sea lions** (NZ) by-catch in squid trawls are a cause for concern for population (10,000–15,000). Annual kill is about 110, of which 72% were females, meaning that their pups may also die. Occasionally killed by fishermen and occasionally illegally killed for crab bait. **Australian fur seals** – die in fish traps, lobster pots and trawls. Juveniles especially vulnerable (24% of dead juveniles died in fishing gear). Significant numbers of juveniles are shot by fishermen and around fish farms. **New Zealand fur seals** – drown in set nets, lobster traps and especially in hoki midwater trawls (up to 800–900 per year). Sometimes shot when attacking hooked tuna. **Australian sea lions** (population of 10,000–12,000) – shot if caught damaging nets.
Wickens, 1995 (D)	**NE Atlantic** **7/12 species involved** **Harbour seal** – in Denmark between 1889–27, 37,000 seals shot or drowned in fishing tackle. Reported harbour seal bycatch in all forms of fishing gear, e.g. in wash some tens of harbour seals caught in mid-water trawls for sprats. In Netherlands a minimum of 4–10 youg harbour seals drown annually in mullet fykes & nets. Several hundred harbour seals may drown annually in salmon farm anti-predator nets in Scotland and numbers shot are in 2 or 3 figures. **Grey seal** – caught in various types of fishing net, 1–2% pups drown annually in fishing tackle. One fisherman took 36 grey seals in one season in Scottish tangle net fishery. In samples between 1967–69, 119 from salmon nets and 13 from whitefish & herring nets, and a further 109 had been shot. In Norway much of the 8% yearling mortality is due to by-catch, and approximately 20% yearlings in Baltic annually drowned in fishing gear. Number drowned in bag nets in east Baltic increased to 1987, when 70 reported deaths. Estimated by-catch mortality was 5% of estimated population in 1987. **Harp seal** – very large numbers of harp seals are drowned in gill nets, trawls and longlines in Scandinavia. 10,000–15,000 drowned annually in gill nets, mainly for cod, between 1978–84. In 1987 56,222 drowned harp seals were reported in 1987, but a total estimate that year was between 60,000–100,000, and >21,538 in 1988. Thereafter numbers have apparently decreased to the levels of the early 1980s. No specific pattern of age and sex caught. The reported figures may be conservative. These high numbers drowning in Norwegian coastal waters have contributed to a significant decline in the harp seal population that breeds in the White Sea. **Baltic ringed seals** – large numbers die each year as by-catch in the Baltic (but no data). Fishermen are permitted to shoot ringed seals around their nets, and kill perhaps a few hundred annually. **Mediterranean monk seals** - die in gill and trammel nets, trawls and longlines throughout the species range. Population estimated at 423–555. This is an important component of seal mortality, probably one of the main causes of the population decline and has been identified as one of the potential threats to the species. ….Deliberate killing of monk seals ….is probably one of the main causes of the population decline…..was largely responsible for the disappearance of the monk seals from Corsica……primarily a problem in the Eastern Mediterranean (Greek and Turkish waters), e.g. fishermen at Rhodes are reported to have shot 20 in 1985 in retaliation for damage to gear. **Saimaa seals** – high juvenile mortality in fishing nets, which is a main cause for sharp population decline. **Hooded seals** – drown off northern Norway in salmon driftnets and longlines.

Archipelagos, 1999	During a 2 year study 1997–99, no cases of accidental death in fishing gear were recorded, and such by-catch is a ***rather infrequent event and has been recorded in Zakynthos only a couple of times over the last decade.*** (However, seals are deliberately killed by fishermen).	
Harwood, 1987 (A)	Up to 10,000 harp seals (Phoca groenlandica) may be drowned each year in drift nets off northern Norway. However, this constitutes only a few percent of the population. ***Is it really worth taking management action to reduce these low levels? In some cases it may be. Many static-gear fisheries are barely profitable, an increase of only a few per cent in their catch would result in a much larger increase in the fishermen's incomes.***	
Harwood, 1987 (B)	Although incidental mortality (seal by-catch in static-gear) rates appear low, overall mortality rates for seals are also low, as is their potential rate of increase. So such mortality may have a significant effect on the population's status. In some cases, such as the Mediterranean monk seal (Monachus monachus), the species involved is so rare that the death of even a few individuals poses a serious threat to its survival.	
Northridge, 1988 (A)	**The amount of effort expended by the inshore set net fisheries** (in England) **is not known with any accuracy due to the large and proliferating numbers of part-timers who use such nets…** In England and Wales the proportion of total fish landings made by gill net fisheries rose from close to zero in 1973 to 4% and rising in 1982…***It is likely that there are several thousand such small boats which may on occasion set nets….perhaps some hundreds of kilometres of netting would be set at any one time…The inshore nets set by small boats are typically set out to only around 2 or 3 miles from the shore and generally a maximum of 6 miles…..The incidental capture of seals in nets appears to occur at least occasionally wherever they are present.***	
Kiely, Lidgard, McKibben, Connolly & Baines, 2000 (A)	***….a number of cases of grey seal entanglement in fishing gear were reported*** in a study of wildlife-net fisheries interactions in Wales (Thomas, 1992 – reference not given).	
Northridge, 1988 (B)	In 1980 two research cruises were made to the Western Isles (Scotland) for a trial tangle net fishery for crawfish (Palinurus sp.). These cruises caught 107 seals in two months. The fishery was started in 1983 by about 108 creel boats from Barra which started to put out tangle nets as well as creels. Whereas generally fishermen claim that catches of seals are very rare in gill nets, and that only young seals will be taken in gill nets, catches in the Barra fishery far exceed those reported anywhere else in Britain. Of 37 by-caught animals examined, the majority (19) were 3–12 months old, 15 were 1–5 years, one was 13 years and one 26 years old.	Three factors may explain why the by-catch in this fishery seems to be so much more serious than elsewhere***…according to the fishery officer in Stornoway, the nets being used are of relatively thick multifilament mesh, and are set very loosely, with a lot of slack. These two factors alone could be enough to ensure that an ensnared seal could not escape; another factor could be that there is no float line on these nets. Being set for crawfish which stay on the bottom, the nets are set flat on the sea-bed, and allowed to float up only to the extent that the natural buoyancy of the netting allows……The fact that the seals do not escape from these nets could be either because the nets themselves are more difficult to escape from, or because the they do not see the nets until it is too late. Both the dark background of the sea-bed and the absence of a float line could make nets less visible to seals at Barra. This is a clear demonstration of the fact that an interaction between a marine mammal and a fishery can often be greatly influenced by apparently minor differences in gear design or usage.***

Berrow, O'Neill & Brogan, 1998	Scientists on commercial trawlers fishing herring in Celtic Sea in 1994/95 season found four grey seal adults caught in nets, at rate of one per 217.5 tonnes fish, or 0.05 seals per tow.	**This by-catch rate extrapolates to around 60 seals caught in the (herring) fishery, which is not thought to have a significant impact on the Irish seal population.**
Kiely, Lidgard, McKibben, Connolly & Baines, 2000 (B)	In a study of seal-fisheries interactions in the tangle-net fishery for monkfish in the Eastern Celtic Sea in 1997-98, a total of 18 entangled grey seals were recovered from the hauled nets. The seals were mostly juveniles, all but two being between 100–140 cm in length and two 150–160 cm. The gear was all set at depths between 30–65 m. In 1999 a 2–4 month old pup was by-caught 0.5 miles off the east coast of Cork.	This number of by-caught seals was considered to be probably an under-estimate, since fishermen regularly stated that most (seal) carcasses fall out of the nets before they are hauled aboard…possibly the adult seals are too heavy to be held in the nets when they are hauled. Recent dedicated efforts by researchers (at UCC) to recover all seals by-caught locally have resulted in larger hauls per vessel than indicated in this study. ….The issue is of scientific concern in the case of gill and tangle-net fishing methods in general and…the issue warrants detailed study.
Anon, 1997 (BIM)	Examination of 51 grey seals caught in the Mayo gill net fishery for cod between 1994 & 1996 showed that 50 were immatures with no overall sex difference in by-catch frequency.	The authors thought that again this bias towards young seals may be because the heavier adults may not be retained in the nets.
Anon, 2000 (BIM) (A)	Reported (by fishermen) by-catch rates for young grey seals in their first year, tagged on the west of Ireland (Counties Donegal, Mayo and Galway) were as follows: 1997 - 7 (12.5%) of 56 tagged 1998 – 14 (11.3%) of 124 tagged 1999 – 1(1.6%) of 63 tagged All by-caught yearlings were caught in the tangle net fishery for cod.	The drop in reported by-catch of pups tagged in 1999 was thought to be due to bad weather severely curtailing the 2000 North Mayo spring tangle net fishery for cod.
Anon, 2000 (BIM) (B)	137 grey seals used in a study of nematode infestation were by-caught during the spring gill-net fishery near the Inishkeas in Co. Mayo in 1997, 1998 & 1999. Three of these seals were adult and the remainder were juvenile, <2 years old. The total number of seals caught in each season were 84 (1997), 45 (1998) and 8 (1999).	**Editor's note:** **The number of grey seal births in the Inishkeas was estimated at 154 in 1995 (Kiely & Myers, 1998), 234 in 1998 and 226 in 1999. These figures suggest a total population centred on the Inishkeas at 805-1035 animals.** **The % of the total population represented by these reported by-catch figures was therefore approximately 8% (1997), 5% (1998) and 1% (1999). The % of the population under 2 years old by-caught would have been approximately 19% (1997), 10% (1998) and 2% (1999).**

Northridge, 1988 (C), citing SMRU data	Of about 5,950 grey seals tagged (as pups) at the Farne Islands from the 1960s to the late 1980s, around 130 (about 2%) were reported to have died in fishing gear. The figures for grey seals tagged in Orkney were similar (about 1.3%). The distribution of weights from 29 seals examined indicated that most (13) were 25 kg, four were 15 kg (possibly unweaned or small post-weaning pups) and 12 were 35–45 kg (possibly post-weaning pups or yearlings) and one was 65 kg (juvenile).	These returns from tagged seals would extrapolate to 20 seals a year from the Farnes or 115 a year from Orkney (assuming population levels in 1988) drowned in fishing gear. Since not all drowned seals would be returned or reported, this figure is a minimum estimate. The types of gear involved were not recorded, but are most likely to have been inshore gill and trammel nets and midwater trawls.
Northridge, 1988 (D)	Fishermen at Megavissey (in Cornwall) have said that seals are quite frequently taken, at depths of as much as 40 fathoms, with slightly smaller boats which fish generally nearer the shore possibly taking more than the largest boats working further offshore. Vague estimates of several seals a year per boat were given by several fishermen at Megavissey, although these were all from people working two or three miles from shore.	From these vague estimates it is difficult to estimate the numbers of seals drowned this way in a year, but the total might be measured in tens at least….. It is perhaps disconcerting that the known population size of grey seals in the Southwest is thought to be only a few hundred (Ling 1983) with one estimate of only 40 pups produced per year (Prime, 1985). It is interesting that…the Southwest appears to be one of the least heavily populated areas by seals, and yet seal mortalities may be higher here than in most other areas (except Barra). This would suggest that the difference is due to the fishing gear and not numbers of seals.
Glain, 1998	52 questionnaire boat-owner respondents (about 30% total in Cornwall) reported a total of 82 by-caught grey seals each year. The 82 seals represent 20-23% of the population estimate of 350-400. At least 80% of the by-caught seals are juveniles. This is a large proportion of the 125 births and 115 weaned pups estimated per year. One respondent reported catching 3 drowned pups within one week of their release from the National Seal Sanctuary in Cornwall.	The Cornish population of grey seals must therefore currently be supplemented by a maximum of 30 surviving pups per year; this is considered to be inadequate to maintain the stability of the population, which is believed to be declining at about 8% per year.
Bjørge, Øien, Hartvedt & Bekkby, 2001 (B)	In a tagging & recovery study of harbour and grey seals pups in Norway between 1975 & 1998, at least 6% of both harbour and grey seal pups were killed by entanglement in fishing gear. Bottom-set nets were the single most important cause of by-catch (5% of all tagged pups), followed by traps set for cod. Two harbour seal pups drowned in remains of fishing gear ('ghost nets') left at sea. The pups were most vulnerable to by-catch during the first 3 months after birth (25% of the Hg and 14% Pv), but high incidental mortality prevailed until about 8 months in Hg and 10 months in Pv. Older seals seemed to be less vulnerable. The total recovery rate for harbour seals was almost twice the rate for grey seals. Some recoveries returned with no information of cause of death (6% grey seal recoveries, 34% harbour seal) may also be due to by-catch.	The vulnerability of yearling seals to entanglement in fishing gear may be partly due to naïve curiosity, but may also be due to ***less physical strength to work loose from fishing gear, limited diving skill and less control over physiological diving responses in young seals compared to adults.*** It is suggested that harbour seals may be especially vulnerable to entrapment in bottom-set nets because radio-tagging studies have shown that they swim at 1.2–1.6m/s when searching for prey during the bottom phase of the dive (Bj?rge et al., 1995). Grey seals may be less vulnerable because similar studies have shown that during foraging dives they tend to dive directly to the bottom and remain stationary there (Thompson et al., 1991). The overall by-catch mortality is not thought to threaten Norwegian populations of harbour or grey seals at present, ***although local depletions may occur.*** However, the levels of by-catch are sufficiently high ***to warrant further monitoring of by-catches in Norwegian coastal fisheries.***

Northridge, 1988 (E)	Anti-predator nets are common on many salmon farms in Scotland (Ross, 1988) and it is clear that seals sometimes drown in these nets. Ross estimated 24 seals drowned a year at 47 farms she visited.	Extrapolating, Ross estimated a total of 113 seals drowning per year in the 166 farms in Scotland at that time. ***Some site operators were said to set anti-predator nets with plenty of slack to increase the likelihood of entangling seals and other predators.***
Northridge, 1988 (F)	Seals occasionally drown in salmon bag and stake nets set around river estuaries in Scotland. More usually they can still surface inside the net to breathe, and if found in the trap when fishermen come to remove the salmon they are usually clubbed.	
Arnold, 1992, citing Ross, 1988	A survey of 47 Scottish salmon farms in 1988 revealed that 319 seals were reported killed in a year, 113 (approx. one third) were caused by entanglement, which in some cases appeared to be deliberate. The figure for Shetland is less, estimated at about 100 seals killed between 1991–92, about one fifth of which died as a result of entanglement.	Entanglement of seals (and diving birds) usually occurs in anti-predator nets surrounding the cages. Curtain or skirt nets are the type most likely to entangle seals because of their inherent slack nature. Envelope or box nets are generally kept more taut, but tend to become slack in rough weather, strong currents or high tides.
Lunneryd & Westerberg, 1997	This study was based on telephone interviews with fishermen in the northern Baltic during the winter of 1997. They were asked for the number of seals by-caught in their fishing gear between 1994–96 and the kind of fishing gear involved. Also, during 1996 fishermen known to be reliable in their reported were asked to keep a journal at 15 salmon or salmon-whitefish trap nets.	Most respondents stated either that the last seal by-catch was during the intense cod-fishing period in the late eighties, or that by-catch was more common then. Half had caught at least one seal between 1994-96. The sum of reported by-catches from the 15 traps in 1996 was 176, although the distribution was uneven. This figure extrapolates to between 300–400 a year in Swedish waters. It was found that use in the traps of the 'seal-proof' Dyneema twine means a higher risk of drowning seals caught in the trap. The authors therefore suggest a switch to such stronger twine, but in combination with a seal exclusion device at the trap entrance.
Eybatov, Asadi, Erokhin, Kuiken, Jepson, Deaville & Wilson, 2002	Of 127 dead Caspian seals on the coast of Iran during surveys in 2000, 62 were found, by post-mortem examination, to have died in fishing nets. Six (5% of the total dead seals) were drowned in gill nets set for sturgeon and 14 (11%) were harpooned by fishermen in the kilka fishery. The largest number, 42 (33%) were either shot or killed with a hammer by fishermen when they were trapped in encircling nets (pareh) set for kutum and mullet. These nets are two km long and are set in shallow water close to the shore, where they are anchored with lead weights. The cause of death of the remaining 65 seals was not determined.	
Wilson, Mo & Sipila, 2001; also Sipila & Hyvarinen, 1998	Fisheries by-catch is thought to be one of the main threats to the Saimaa seal (Phoca hispida saimensis). Newly weaned pups are extremely prone to being tangled in fishing nets.	

Table XVII. Suggestions for alleviating the by-catch problem

Author & date	Problem	Mitigation proposed	Carried out?	Successful?
Wickens, 1995, citing Pemberton et al., 1994	By-catch of harp and hooded seals in trawls for cod in NW Atlantic	Nets kept on deck and then shot to the bottom immediately on entering the water	Yes	Dramatic reduction in seal by-catch
Wickens, 1995, citing Pemberton et al., 1994	By-catch of harp and hooded seals in trawls for cod in NW Atlantic	***A chute from the working deck to the gunwhale was suggested as a method of allowing captured seals to leave the vessel quickly.***	?	?
Wickens, 1995, citing Montgomery, 1986	By-catch of harbour seals in NE Pacific	Studies should be done to identify factors (eg soak time of nets) that may be causing , or contributing to, the incidental take of harbour seals and to investigate alternative fishing gear and practices and the use of acoustic signals paired with shooting, loud sounds or other adverse stimuli and disturbance experiments.		
Laist, 1995	Problem of by-catch of seals (and other species) in discarded fishing gear	1. develop mechanisms so that discarded gear will be disabled 2. dedicated efforts to retrieve lost gear 3. develop technology to help locate lost gear and reduce the likelihood of losing gear at sea 4. further research on the nature and extent of the problem.	Some further research (eg Bjorge et al, 2001), but otherwise no progress recorded	
Wickens, 1995, citing Mattlin & Cawthorn, 1991; Woodley & Lavigne, 1993	Problem of by-catch of Hooker's sea lion and New Zealand fur seals in hoki trawls	It is recommended that trawlers deploy and retrieve their nets as quickly as possible, maintain the net below 150m, deploy a crew member to observe any seal entanglement to ensure timely assistance for the animals, and at night lights should be left on for a minimum period of time. Also include escape panels in nets and have closed areas for fishing.	Catch limits of 63 Hooker's sea lion deaths (32 females) was set for 1993–95, and operation of any vessel killing 3 sea lions would be reviewed. The industry would remove any vessel that killed 4 sea lions as a voluntary measure.	?

Table XVIII. Protected areas for seals

Gerber, Wooster, DeMaster & VanBlaricom, 1999	The western stock of the Steller sea lion *Eumetopias jubatus* was listed as threatened under the Endangered Species Act of 1973 (ESA) in 1990 and subsequently as endangered in 1997. ***Once a listing occurs, section 7 of the ESA requires that all US federal agencies assure that their actions do not jeopardise the continued existence of the species. In response to this requirement, Amendments 20 and 25 to the Gulf of Alaska and Bering Sea/Aleutian Island Fishery Management Plans incorporated buffer zones, restricted trawl zones and other protective measures into fishing areas considered to be critical habitat for Steller sea lions.***
Wilson, Mo & Sipila, 2001 (A); also Sipila & Hyvarinen, 1998	To limit fisheries by-catch of Saimaa seals, especially, pups, from 1982 fishing with nets was forbidden within 65 sq. km of the main seal breeding areas, and this area has now been extended to 300 sq. km. Also, there are now restricted fishing dates in areas of greatest pup occurrence. From 1999–2004 there is a prohibition on fish-baited hooks in the Saimaa seals' main areas and a ban on the use of strong-mesh gill nets. A ban on several types of salmon trap will be introduced in 2002.
Wilson, Mo & Sipila, 2001 (B)	To protect the endangered Mediterranean monk seal (*Monachus monachus)* from human disturbance, by-catch in fishing gear and other interactions with fishermen, three marine protected areas to date have been established. The Greek National Marine Park of the Northern Sporades extends over 2,200 sq. km and consists of a top priority Zone A, which includes a Core area extending 3 miles from the island in which no human activities are allowed, a scientific research area extending 400m from the shoreline and a Seasonal Prohibition Area in which boats within 100m of the coast are largely forbidden. Trawling and purse-seining have been forbidden within 1.5 miles of the coast and there are also other fishing restrictions. The Portuguese National Reserve of the Desertas Islands forbids gill nets within 100m of the shoreline, a Zone in which no human activity is allowed except a small local tuna fishery and a 'partial reserve' in which artisanal and recreational fishing only are permitted. The Turkish monk seal 'Foca Sea and Conservation Area' encompasses 18 sq. miles of sea in which fishing and recreational boating is prohibited, as is entering the monk seal caves.
Bjørge, Øien, Hartvedt & Bekkby, 2001	Froan nature reserve in Norway encompasses 720 sq. km of an archipelago of small islands, which is a major breeding site for both harbour and grey seals. Fishing activities are very limited within the reserve. During a tagging study of pups, it was found that none of the 37 harbour seal pups tagged within the reserve were later recovered, whereas 79 of 593 harbour seal pups tagged elsewhere were recovered dead, at least 38 entangled in fishing gear. The authors concluded that the protected area is probably large enough to significantly reduce the harbour seal by-catch mortality.
I. Iairikka, pers. comm.	In the Finnish sector of the Baltic Sea protected areas for grey seals were established in September 2001. These areas cover 192 km2, which is 0.37% of Finnish coastal waters. There are seven areas, each surrounding important pupping and haul-out rocks. The protected areas, within which no hunting is permitted, extend 1852 m from the rocks. No activities are allowed within the inner circle (926 m from the rock) without the permission of the Environment Ministry. In the outer circle boating and commercial fishing are permitted between June 16.6 and January 31 -31.1, but outside these times permission is required.

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