Chapter 25

Damage to Fishing Operations

Since the 1970s the fishing industry has been reporting ever increasing interactions with grey seals resulting in damaged gear and partially consumed fish in their nets (Canada, DFO, 1985).

Introduction

Complaints by fishermen about seals taking fish from their nets and damaging them are commonplace wherever fishermen and seals come into contact. Overall the amount of damage may not be great, but it is clear that losses are concentrated in certain areas, and that some types of gear are much more vulnerable than others. Thus the effect on some fishermen can be considerable. A review of this problem in eastern Canada is provided by Mansfield and Beck (1977). Entanglement in fishing gear can also cause the death of the seal. This additional source of unnatural mortality and its possible impact on seal populations is considered in Chapter 23.

The losses to fishermen fall into several categories:

- fish that are damaged, or removed completely from the catch;
- removal of catch and bait from lobster and fish traps;
- physical damage to the gear;
- loss of fish from the gear because of this damage;
- time lost from fishing to repair the damage;
- catch lost because gear is not being used;
- time spent patrolling to keep seals away from nets and aquaculture pounds; and
- modifications to gear or fishing practice needed to reduce seal damage.

None of these losses are easy to quantify, though some estimates are presented on gear damage. However, unlike most matters concerning seals, there is little argument about the occurrence of damage. Arguments arise in the matter of whether, in the words of the official Greenpeace policy document on seals, it is true "from the limited information available that seals pose an insignificant threat to fisheries equipment" (Greenpeace International, 1985), whether damage is important only locally to individuals, or whether it is also significant on a broader regional basis. Furthermore, if damage is significant, there is the question of whether reducing the overall numbers of seals is the most appropriate method of dealing with the problem.

The most active types of Canadian gear (trawls, purse-seines and others) do not seem vulnerable to seal damage. Cape fur seals in South Africa, however, interfere greatly with the fishery by purse-seines and, to a lesser degree, with the trawl fishery. Moreover, seals on both coasts of Canada take fish from all types of hook and line gear. Set-lines may be the most vulnerable type of such gear because they may keep the fish available to the seals for some time. But fish caught with trolling lines and sports gear are also occasionally removed or damaged by seals though usually no damage to the gear or other associated losses are involved. The most vulnerable types of gear are the fixed gears, such as gill nets or fish traps, which allow the seals to approach or enter the gear in order to get fish. When the seals do so, they may become entangled and damage the gear in attempts to escape. The resulting holes may allow all or most of the fish inside fish traps and culture cages to escape. For fish farms and for some types of fish traps in which most of the season's catch may be taken in a few days, these losses can be severe. In eastern Canada the fisheries most affected are gill nets for herring, mackerel, pollock, cod and salmon; fish traps for herring, mackerel and salmon; and lobster pots (Mansfield and Beck, 1977).

Table 25.1 shows the value of the fisheries catch taken in each province (excluding arctic Canada) by the main types of gear, grouped according to their vulnerability to seal damage. It indicates the importance of traps in all the Atlantic provinces. Gill nets are important in Newfoundland, but elsewhere account for a relatively minor 5%–10% of the total value of the catch. The following sections provide a more detailed, province-by-province examination of the extent of damage and loss. It draws on a report for the Royal Commission on damage by seals to fishing gear in Canadian waters (Northridge, 1986).

Table 25.1
Value of Fish Landed in 1983, According to Type of Gear (in $ million)

Type of Gear	Newfoundland	Quebec	N.S.	N.B.	P.E.I.	B.C.
Stationary Gear						
Set gill nets	32.4	0.8	6.3	3.2	2.8	-
Drift gill nets	-	-	1.3	0.8	0.1	-
Other gill nets	-	6.0	-	-	-	20.8
Salmon nets	-	0.8	0.3	0.5	-	18.0
Weirs	-	0.5	0.1	2.0	-	-
Fish traps	17.3	-	-	-	-	-
Traps/Pots	22.4	17.8	73.8	51.7	28.5	9.9
Sub-total	72.0	25.9	81.8	58.2	31.4	48.7
Mobile Gear[a]	69.5	18.2	148.8	16.7	6.5	109.7
Hook and Line	25.3	1.3	42.2	1.0	1.1	34.3
Other Gear[b]	-	-	3.6	2.2	3.8	6.2
Total	166.9	45.4	276.4	78.1	42.9	198.9

Source: Northridge (1986).

a. Trawls, purse-seines, Danish seines, etc.
b. Rakes, harpoons, etc.

Nova Scotia

The stationary gears of Nova Scotia produce, in terms of value, the highest catch of any province, largely because of the high proportion of valuable lobsters. The waters of this province also contain the main concentrations of grey seals, and harbour seals are also numerous. The problem of seal damage has therefore attracted considerable attention, and the most detailed studies have been made in this province.

Questionnaires circulated to, or personal interviews conducted with, 96 fishermen over the eastern part of Nova Scotia in 1975, between Ship

Harbour, Halifax County, and Scatari, Cape Breton Island, indicated that an individual fisherman may suffer losses of gear to the value of $1,000 in a single year. The estimate of average losses of gear was $300 per fisherman or a total of $450,000 for the 1,500 fishermen of the area. These estimates did not include the losses of netted fish to the seals and the interruption of fishing while the gear was being mended or replaced (Mansfield and Beck, 1977).

Grey seals are very effective in robbing the nets of salmon fishermen, especially in areas near their summer concentrations. Seals also enter the traps set for mackerel and herring, mutilate large numbers of fish and sometimes drive the fish through the trap opening back to the sea. Salmon-trap fishermen at Guysborough, N.S. estimated losses of 30%–45% of their catch to seals. In areas where suitable haul-out sites for grey seals are close, trap complexes cannot be used. Seals open lobster traps or force their way into them and steal the bait, allowing the lobsters to escape and preventing further catches until the trap is baited and set again (Mansfield and Beck, 1977). In New England, fishermen report that harbour seals eat lobsters taken from traps (Anthony, 1985).

Zwanenburg and Beck (1981) reported on a survey of grey seal damage conducted during 1978; again this survey covered the fishery from Halifax County to Scatari, Cape Breton. The 105 licensed fishermen using stationary gear who completed questionnaires for the entire fishing season, stated that the average damage caused to gear by seals amounted to $105 per fisherman; an estimated maximum cost to all of the 1,500 fishermen of the area was $157,000. This figure represented maximum cost because some of the fishermen not surveyed were using mobile gear. These values are lower than those quoted above by Mansfield and Beck (1977). This same study also showed considerable variation in costs along the coast: the mean damage to fishermen in the 11 statistical districts for which data were reported ranged from zero to $308.

The Eastern Fishermen's Federation (EFF) made a study of gear damages by grey and harbour seals in Nova Scotian waters in 1983 (Farmer and Billard, 1985). The study was confined to damage by seals to fixed gear and included the costs of repair and replacement, when necessary, of the damaged gear. It did not include fish injured or lost from the gear to seals, loss or replacement of bait taken by seals from lobster traps, and fish or lobsters lost because the gear was too badly damaged to fish. The area investigated covered most of the outer Atlantic coast of Nova Scotia from northern Cape Breton to the beginning of Minas Channel in the Bay of Fundy, but excluding the Halifax area – a larger area than that covered by the previous studies. Random selections of fishermen using fixed gear were made for areas where damage was expected and for control areas where it was likely that damage would be less, because of the greater distance of those areas from seal aggregations. A sample population of 297 fishermen responded to the survey from a parent population of 3,380 fixed-gear fishermen. By averaging the total losses for the sample population (Table 25.2), the average yearly loss per fisherman is estimated at $236. When adjusted to the parent population by a factor of 11.38 (3380/297), the total yearly losses to gill nets, fish and lobster traps caused by seal damage in the area of Nova Scotia investigated are estimated at $799,000. The report did not provide a detailed description of the forms of damage, but a submission from the Lobster District 4B Working Group (1985) related that as many as 75–100 bait bags were removed from lobster traps in the vicinity of harbour seal colonies in one day's fishing, and that some fishermen had lost up to 1,500 bait bags in a season. In addition, seals broke into many heads of traps. Only the damage to gear, and not the loss of bait, is recorded in Table 25.2.

Farmer and Billard (1985) conducted a further econometric study of the data to produce better estimates of the losses. This analysis produced the following values for repair and replacement costs of gear damaged by seals and the labour involved in repairs for the 297 respondents:

Mackerel–herring gill nets	$ 71,558.15
Groundfish gill nets	$ 5,518.60
Wooden lobster traps	$ 13,764.24
Total	$ 90,840.99

(An error in their value for the groundfish gill nets has been corrected.) The authors did not include the fish trap losses in the analysis ($2,916 from Table 25.2), because the numbers in the sample were too small. When it is added to the above, a total damage value of $93,757 is produced or $315.68 per fisherman, which when multiplied by the parent population of 3380 respondents produces total damages of $1,066,998. These figures and those from Table 25.2 are too high, however, as the sampling method of Farmer and Billard gave too much weight to the results from the area where seal damage was more common.

Mansfield and Beck (1977) discussed seal damage to fishing gear as though it was mainly a grey seal problem, and Zwanenburg and Beck (1981)

Table 25.2
Value of Seal Damage ($) to Fixed Gear for Sample (N = 297) along the East Coast of Nova Scotia in 1983

Gear	No. Units Used by Sample Population	Repair Costs Caused by Seal Damage		Replacement Costs of Lost Gear Caused by Seals	Total Costs
		Labour	Material		
Fish traps	8	1,645	1,271	-	2,916
Mackerel–herring gill nets	1,322	11,210	15,431	8,631	35,272
Groundfish gill nets	597	202	988	6,882	8,072[a]
Wooden lobster traps	36,449	5,519	1,987	16,439	23,945
Wire lobster traps	536	-	-	-	-
Longlines	1,771	-	-	-	-
Total		18,576	19,677	31,952	70,205

Source: Farmer and Billard (1985).

a. Error corrected in source.

called their 1978 survey a grey seal damage survey. Farmer and Billard's (1985) sample of fishermen did not report separately on damage by harbour and grey seals, but these authors found a far greater amount of seal damage to gear in the area from east of Halifax to Cape Breton Island. They attributed this to the post-whelp fan of grey seals which migrate especially into this eastern part of the outer Atlantic coast of Nova Scotia from their large colony on Sable Island. Grey seals were about six times as numerous as harbour seals on Sable Island in 1973 (Boulva and McLaren, 1979), and their present population in the Atlantic provinces is three to six times that of harbour seals. (See Chapter 21.) Grey seals are much larger, being at least twice as heavy as harbour seals, and they migrate widely. It is to be expected, therefore, that most of the seal damage, both in the area of Nova

Scotia adjacent to Sable Island, and in the Maritimes area generally, should be due to the grey seal.

The EFF survey is the most recent and the most extensive in both area and detail, and it provides the best base for an attempt to extrapolate to unsurveyed areas. It is not easy to go beyond these studies to obtain estimates of the total losses for Nova Scotia, or even of the losses resulting only from gear damage for Nova Scotia. An extrapolation based on the relative amounts of the various kinds of stationary gear for the outer coast of Nova Scotia in 1983 and the Gulf area of Nova Scotia in 1982 (for which the 1983 data were not available; data supplied by DFO Halifax) adds $140,000 to the $799,000 derived from Table 25.2, or a total gear damage loss due to seals for Nova Scotia of $939,000 in 1983. For the econometric analysis the additional proportional loss for the Gulf area would be $174,000, bringing the total for Nova Scotia to $1,241,000.

A number of factors affect these amounts. Not only was part of the outer coast of Nova Scotia not covered in the EFF survey, but 294 fishermen were also rejected from the population because they used their fishing licences on an incorporated basis and probably had larger than average operations. Furthermore, most of the Gulf area of Nova Scotia is in a region influenced by a breeding colony of grey seals approximately as large as that on Sable Island, and thus the extrapolation for that area might better be based on the part of the EFF survey area with greater seal damage rather than on the total outer coast area. These factors would all suggest that the total estimates for Nova Scotia are too low. On the other hand, the calculations of Farmer and Billard (1985) give too much weight to the results from areas of high seal damage, and this would suggest that their estimates are too high. At present it is impossible to resolve these unknown factors. It does appear, however, that the damages for Nova Scotia could be a million dollars or higher per year.

New Brunswick

The total value of New Brunswick's catch taken by stationary gear, amounting to $58 million, is less than the values for Nova Scotia and Newfoundland, but since there is less trawling for fish in New Brunswick than in the other two provinces, these types of gear account for a greater proportion, that is, some 75% of the total value. Traps, mostly for lobster and crab, are economically the most important of the stationary gear, but significant quantities of fish, amounting to some 50% of the weight of the total catch, are taken in weirs and gill nets (Northridge, 1986). Important differences, including the impact of seals, exist between the fisheries in the Gulf of St. Lawrence and the Bay of Fundy.

The New Brunswick Department of Fisheries (1985) stated that on the Gulf of St. Lawrence coast of New Brunswick, seals (presumably harp seals) cause damage in winters when the ice is scarce. At those times seals often come inshore and feed on smelts caught in set nets, causing loss of catch and damage to nets; typically, however, ice is more prevalent in winter, and these attacks do not occur. There is no information about the damage, if any, caused by seals at other seasons. In the Bay of Fundy, seals - either grey or harbour or both - are present all year-round and cause destruction of gear and catch. Gill-netted fish are eaten from the nets and seals are sometimes caught in the nets, causing serious damage. Seals eat fish from longlines, often leaving only the head attached to the hook. Lobster traps are badly damaged by seals seeking the bait that they contain. Seals attack fish in herring weirs, either by making holes in the twine or by passing through the door of the weir. The yearly cost of these various forms of direct damage caused by seals has not been estimated for New Brunswick, but in the Gulf, the major lobster fisheries and gill-net fisheries of that province are much farther from grey seal breeding colonies than are the fisheries of most of Nova Scotia. A subjective impression from the nature of the complaints from the two areas and their distances from the grey seal herds is that the damage per gear unit may be at a rate of about half that of Nova Scotia. Taking into account the relative values of landings from stationary gear in New Brunswick and Nova Scotia (Table 25.1) and allowing the rate of New Brunswick damage to be half that of Nova Scotia, the New Brunswick gear damage loss to seals would be about one-third that of Nova Scotia.

In previous years, when the salmon fisheries were more important than they are now, interference by seals was a major problem. In the estuaries of rivers such as the Miramichi in New Brunswick and in the southern part of the Gulf of St. Lawrence, seals, especially the grey seal summer concentration in the area, formerly interfered greatly with the gill-net fishery for salmon so that the nets had to be watched continually for seal interference and often taken up at night (Mansfield and Beck, 1977). Seals were also controlled by shooting those that went near the nets. The overall importance of seal interference with salmon and salmon nets has been greatly reduced by the decline in numbers of salmon and reduction or elimination of salmon fishing in many areas.

In the winter of 1983–1984, grey seals attacked aquaculture cages in the Bay of Fundy where Atlantic salmon and rainbow trout were being grown for market (N.B., Dept. of Fisheries, 1985). The seals made holes through the twine of the cages, passed into the cages, attacked many of the fish, and allowed many of the remainder to escape through the holes in the net. They attacked about 75% of the aquaculture net operations. Damage estimates are available for only one of the largest operators, who suggested that the overall loss may have approximated $500,000 in material, labour and lost stocks. A new wire cage design is being tested in the area, but the device is expensive and much more difficult to handle than twine. In addition heavier twine is being used to prevent the success of seal attacks. Salmon aquaculturists maintain a careful watch for grey seals, which are much larger and more powerful than harbour seals, with a view to shooting them. Beck and Stobo (1985) reported that heavier twine is now being used for the aquaculture cages, and that they were not aware of any seal damage incidents with aquaculture cages in the winter of 1984–1985.

Prince Edward Island

The fishing in Prince Edward Island, like that in New Brunswick, is dominated by stationary gear. Some 70% of the provincial catch, in terms of value, is taken by lobster pots, though significant quantities of fish, in terms of weight, are taken in gill nets. The fisheries are therefore potentially vulnerable to seal damage. In a brief to the Royal Commission, the Prince Edward Island Department of Fisheries (1985) stated that the grey and harbour seals have become a considerable nuisance to P.E.I. fishermen, and that gear loss from seals is a major economic consideration. The southeastern part of Prince Edward Island is close to a major breeding ground for grey seals. No detailed estimates of seal damage are available for the Island, though it may again be reasonable to assume, as a rough guide to the likely figure, that the rate of damage is somewhat similar to that experienced in Nova Scotia. On the basis of the location of Prince Edward Island in relation to numbers of grey seals and the value of the Prince Edward Island catch in stationary gear relative to the N.S. catch, the gear losses due to seals in Prince Edward Island may be about one-third those of Nova Scotia.

Quebec

Although trawling for fish and shrimp is relatively more important in Quebec than in New Brunswick or Prince Edward Island, stationary gear accounts for about half of the total Quebec catch in terms of weight and value. By weight, gill-netting for cod, flatfish, herring, mackerel and salmon accounts for more than half the 1983 total catch by stationary gear (Northridge, 1986).

No information on gear damage by seals is available from Quebec; but because the average density of grey and harbour seals is probably less than elsewhere in eastern Canada, the extent of damage may be small. The greatest density of seals occurs with the migration of the Gulf herd of harp seals. Little or no fishing is done when these seals are breeding, but as they migrate north along the north shore of the Gulf, there may be interactions, possibly similar to those noted in the most recent years in Newfoundland. In the summer there may also be some interactions with grey seals, especially close to the colony in the Magdalen Islands, and with harbour seals. Overall, given the relatively low total value of the catch by stationary gear, the total damage caused by seals in Quebec is probably much less than that caused in the Atlantic provinces.

Newfoundland

Slightly less than half of the value of the Newfoundland catch is from stationary gear and the proportion caught in pots is relatively small. Most of the catch comes from gill nets and fish traps.

One would expect to find that gill-net and cod-trap fisheries along the south coast of Newfoundland are affected by the moderately large summer concentration of grey seals on Miquelon Island, by other migrating grey seals from Sable Island, and by local colonies of harbour seals. On the contrary, the main complaints the Royal Commission has heard concerning gear damage or direct interference with fisheries by seals are in respect to juvenile harp seals on their spring migration northward from the breeding areas.

The Hon. W. Rompkey (1985), stated that, early in 1984, fishermen in his constituency of Grand Falls–White Bay–Labrador reported that an increased number of seals, mainly beaters several months old, were being caught in their nets. One White Bay fisherman caught 38 beaters and bedlamers in his gill nets in one day. Barker (1985) of Knight's Cove, Bonavista Bay, stated that in early May 1985, juvenile harp seals were seriously interfering with the gill-net fishery for lumpfish (harvested for lumpfish caviar). This fishery uses large-mesh nets, and its fishermen are finding increasing numbers of young harp seals in their nets. As many as nine have been caught; they had rolled up and drowned in one net, causing much damage to nets, and greatly reduced catches of lumpfish. Similar complaints about greatly increased numbers of young harp seals caught in gill nets were reported from the Newfoundland Gulf coast in late April and early May 1985 (Lien, 1985). These increased damages to gill-net fisheries by young harp seals are presumably related to an increased number of young seals accounted for by the reduced kill of whitecoats in 1984–1985. Large seals might break through a light net, whereas the small seals might be caught in it and drown. In the Newfoundland area, in early summer, most gear losses are caused by whales, especially by humpbacks feeding near the coast on capelin, and losses caused by seals may pass unnoticed unless the seals are caught in the nets.

It does not appear possible to estimate the costs of seal damage to Newfoundland fishing gear with any accuracy. The incidence of seal damage in Newfoundland appears to be less than that in Nova Scotia, and the total damage costs are probably not greater than those in New Brunswick and Prince Edward Island.

British Columbia

Traps are of relatively small importance along the Pacific coast, where the important stationary gears are gill nets for salmon and herring. Lines are also important, and because the individual fish (halibut or salmon) are often valuable, they are potentially more vulnerable to seal attack than those on the Atlantic coast. The situation is also different because of the presence of numbers of eared seals (fur seals and sea lions) and relatively fewer true seals (only harbour seals).

Fisher (1952) found that damage to gill nets from harbour seals in the Skeena estuary was negligible. The loss of salmon to seal attacks on salmon caught in gill nets was at its worst in the early part of the fishery for chinook salmon, when it could amount to 12% or more of the value of the catch.

The Prince Rupert Fishermen's Co-operative Association (1985) stated that harbour seals will swim along a salmon gill net, biting and pulling at the gilled salmon. Fish remaining in the net are often maimed and thus unsaleable. Steller sea lions will rip all fish from a net, making holes of considerable size. Fishermen who troll for salmon have problems with sea lions removing fish from their lines. This brief also blamed California sea lions for damage to the nets of herring fishermen in the Strait of Georgia and to salmon farms there and in Barkley Sound.

In a summary based on data collected by Mate (1980, in IUCN, 1982), losses of $54 for damaged fish and an estimated loss of $22 for damaged gear per salmon gill-netter in Hecate Strait, B.C. for May–September 1962 were attributed to the Steller sea lion. Examples of damage in adjacent areas caused by this sea lion to gear and to fish of species that are also caught by Canadians were recorded as follows: 20%–30% of the Japanese catches of black cod in the Bering Sea south of the Pribilofs suffered damage; log books for 58 vessels fishing Pacific halibut in the north Pacific in 1958–1960 showed 8.1% of the fish damaged or destroyed and losses for the whole fleet estimated at $500,000; salmon gill-net fishermen from Copper River, Alaska, in 1977 had 8.3% (30,688) of their fish damaged, which represented a loss of $517 per boat or $230,000 for the 445 boats in the fishery, and suffered gear damage in the amount of $162 per boat or $72,000 for the fleet.

The California sea lion has caused damages estimated as high as $122,000 annually to the catch of the salmon-troll fishery in California (Mate, 1980, in IUCN, 1982). In recent years this sea lion has become more plentiful and presumably behaves similarly in its migrations northward. In the Columbia River, salmon severely damaged by the harbour seal – which is probably also increasing in U.S. waters as a result of the United States *Marine Mammal Protection Act of 1972* – amounted to 15% of the catch in test fishing in 1976 and 30% in 1977; unsaleable salmon represented 5% of the catch in 1976, and 12% in 1977, though two years' data are not enough to establish a trend (Mate, 1980, in IUCN, 1982).

Because of the lack of any recent survey information like the Atlantic coast surveys already referred to, only crude estimates can be made of gear and related fish losses caused by seals and sea lions in the Canadian Pacific region. The greatest losses seem to be the result of removal of fish from gill nets and associated damage to the gear. The losses given above, in terms of average losses per gill-netter, seem to be rather lower in British Columbia ($76 in 1962), than in Alaska ($679 in 1977), even allowing for inflation. These differences seem reasonably consistent with the relative density of seals in the areas. Taking the B.C. figure and allowing for inflation to produce a loss per boat of about $300, the total losses to the whole B.C. salmon gill-net fleet of some 2,300 vessels could be of the order of $700,000 for 1985. However, seal and sea lion densities have been quite variable in space and time along the B.C. coast (including effects from Steller sea lions from Alaska on the northern B.C. coast, and a new influx of California sea lions on the southern B.C. coast) so that it is unwise to place much reliability on this estimate which is based on data gathered from a relatively small area of northern British Columbia in 1962.

Northeast Atlantic

There is also information available from the United Kingdom and Norway on the damage done to fisheries by Atlantic species of seals. Rae (1966) reported severe damage by seals to cod in the Scottish cod-net fishery, vessels from which had dumped at sea many boxes of badly mutilated cod. Some seal-caused damage to nets, the stripping of fish such as mackerel from hooks, and the removal of bait from lobster traps were also reported.

Rae and Shearer (1965) studied the damage done by seals, especially grey seals, to the Scottish salmon-net fishery. The amount of seal damage to the coastal nets ranged from less than 5% of the nets at some stations to more than 30% at others. Many mutilated salmon, including some of which only the heads remained, were observed in the nets or washed ashore, and many clawed or tooth-marked salmon were seen. In four weeks' observation of drift netting for salmon, it was determined that 24% of the salmon caught off the River Tweed in February 1963 were damaged by seals. Many salmon must also have been removed from the nets.

Parrish and Shearer (1977) reported that the incidence of seal damage to salmon bag and stake nets in Scottish waters decreased markedly during the 1960s, and by the mid-1970s very little net damage was reported. The decrease was attributed to the increasing use of the stronger synthetic twines in these nets. A few stations still showed some net damage. Damage to netted salmon showed no apparent trend at most Scottish stations between 1964 and 1976, in spite of a great increase in numbers of grey seals, but damage did increase at a few stations. Damage was highest in the spring run of larger salmon, possibly due in part to seals only taking bites from such salmon and leaving evidence in the nets that they had done so. Some of the smaller salmon, the grilse, which were mainly caught later in the year, may have be taken completely from the net by seals and the damage not observed. The average loss in value from damaged salmon was estimated at less than 1%, but this figure does not include fish, especially the smaller ones, which may be taken from the net or eaten completely and thus not noted as damaged fish. Stansfeld (1984) remarked, however, that in the late 1960s and early 1970s, the salmon run changed substantially in favour of larger grilse runs and fewer large salmon; he noted, too, that grilse were later than large salmon in returning to rivers. The lack of large salmon was presumably the result, in the main, of the west Greenland netting of the larger salmon returning in the second or later years of sea life; the grilse, on the other hand, are not affected by the Greenland fishery. The data of Parrish and Shearer (1977), mentioned above, combined results from salmon and grilse, rather than expressing the numbers separately. The percentages of seal-damaged salmon and grilse were much higher in the period up to 31 May, when salmon are relatively more plentiful, than they were in the predominantly grilse period from 1 June onward.

The International Council for the Exploration of the Sea (ICES) working group on interactions between grey seal populations and fish species (ICES, 1979) reported that the damage to the salmon catch has been monitored in Scotland since 1964, but that there has been no significant change in the level of grey seal damage to entrapped salmon, estimated at 3%–5%. In drift-net experiments, at least 2.3% of the catch of 1,305 salmon were seen to be taken from the nets by grey seals.

Potter and Swain (1979) studied the incidence of predation by grey seals on salmon caught in commercial nets on the northeast coast of England in 1977. They concluded that seals removed about 5% of the salmon caught in the nets and damaged an additional 1%–4%, causing a total loss to the salmon netsmen in the area studied of about £30,000 in 1977.

Annual damages to net gear, especially gill nets and trap nets in Norwegian waters were estimated for 27 fishermen as 2,900 Norwegian Kroner (Nkr.) per fisherman (Bjørge et al., 1981.) The reported percentages of damaged salmon (for 34 salmon fishermen) averaged 15% in areas with concentrations of grey or harbour seals. More than 10,000 harp seals were reported to have drowned in gill nets in northern Norway in each of the years from 1979 to 1981. The costs of gear damage caused by these harp seals were estimated at Nkr. 610,000 in 1979, and Nkr. 980,000 in 1980.

With the decline of several of the natural stocks of salmon, the significance of some of the types of seal damage described above may be decreasing. At the same time increasing attention is being paid to the culture of salmon, especially in Norway, but also in the United Kingdom. This type of operation is, in principle, vulnerable to damage by seals, and has been examined in a recent review by the U.K. National Environment Research Council (Thompson et al., 1984).

Questionnaires returned by 14 establishments with cages in the sea all reported some activity of both grey and harbour seals. Damage ranged from nil to frequent, or even daily, loss of fish, mostly caused by seals biting the fish through the net. There were two cases (over some years) of damage causing large-scale loss of fish. Seal damage appears to have been successfully kept in hand by deterrence (shooting), and by placing large mesh anti-predator nets outside the cages to entangle the seals or to prevent them from approaching.

Estimates of Total Loss

In the previous sections it was estimated that in the Atlantic provinces (excluding Quebec, where the damage seems small), seals cause damage to gear amounting to some $2 million annually. To this figure should be added the losses represented by fish escaping from damaged nets or being eaten or damaged by seals, the effects of lost fishing time, and the losses to aquaculture operations. Some information is available about fish losses from gear in the west coast fisheries, and how these values compare with gear damage. The information presented earlier for salmon gill nets produced ratios of 2.5:1 ($54:$22, B.C.) and 3.2:1 ($517:$162, Alaska) in terms of the value of lost fish to the cost of gear damage by sea lions. These ratios are not necessarily typical of all types of seal-fisheries interactions. In particular, they do not relate to the interactions with lobster pots. The impression given by submissions is that lobster fishermen are at least as concerned about removal of bait (and thus about loss of effectiveness of their gear) as they are about damage (e.g., N.B., Dept. of Fisheries, 1985; Lobster District 4B Working Group, 1985).

Losses to the individual fishermen through reduction in gear effectiveness or lost fishing time may not represent the net loss to the Canadian fishing industry as a whole. Lobsters and many fish stocks are heavily exploited. Therefore, if one fisherman fails to catch a lobster because a seal has removed the bait from his trap, that lobster may still be taken by the same or another fisherman in the same fishing season. Similarly, the effect of lost fishing time on the total Canadian catch will be small if the stock is heavily fished, with the result that the changes in fishing effort produce little change in total yield.

The total impact on Canadian catches, taking all factors into account, is greater, therefore, than the impact of gear damage but not as great as the individual fisherman might believe on the basis of his own experience of encounters with seals. The loss to the individual fisherman may nevertheless be considerable, if his operation is particularly vulnerable to seals. If seals are interfering with his gear, it is no consolation to the individual that someone else is catching the fish.

It is thus impossible to put a figure on the additional costs. For the present it seems best to confine attention to the costs of actual damage, which amount to about two million dollars annually in eastern Canada, but to bear in mind that these costs should really be larger, since the figure named above has not included fish not caught while the gear is not working, fish damaged in the nets by seals, fish taken from the nets by seals for food, or damage to aquaculture operations.

At the same time, it must be recognized that the data base from which the total cost figure was obtained is extremely poor. It is satisfactory for providing an indication of the probable extent of the problem, but much better information should be collected, probably along the lines of the survey already made in parts of Nova Scotia. This undertaking should not only provide a better estimate of the total impact of seals on fishery operations, but should also enable a much sharper identification of the particular areas and types of fishing gear that are more seriously affected. Such information, in turn, might help policy makers to form a better evaluation of various possible approaches to a reduction of the problem and to determine, especially, whether there are feasible approaches that do not involve extensive and large-scale culling of seals.

Approaches to Reducing Damage

Modification to the Gear

Lobster fishermen have modified their gear to minimize damage from seals. The modifications include putting boxes over the bait and using smaller rings which make it more difficult for the seal to get its head into the trap, though this method may preclude catching "jumbo" lobsters (Farmer and Billard, 1985). Salted bait is not attractive to seals, and its use may reduce seal damage. At the same time, it may also be less attractive to lobsters.

Stronger materials will reduce damage to nets. Parrish and Shearer (1977) reported that damage to salmon nets in the United Kingdom was considerably reduced after the change to synthetics. In eastern Canada, however, seals damage or destroy synthetic gill nets used for herring and mackerel. These nets are made of thinner twine than are salmon nets. In the chief species-directed fisheries, herring and mackerel are now caught in purse-seines and weirs, but lobster fishermen catching fish for bait find that it is much more convenient to use a few gill nets.

Deterrence

Since the most serious damage occurs at fixed points, that is, in large fish traps or fish-culture pens, it may be feasible to deter seals from approaching. Various methods have been used, and the ultimate deterrent in this form of warfare, shooting, is popular. Rifle fire is undoubtedly effective, and even when the seal is not hit, a rifle shot can increase the time before another (or the same) seal is seen in the vicinity (Thompson et al., 1984). This method does, however, require someone to be on watch, and therefore can add considerably to labour costs. It also raises the question, discussed below, of whether it is proper for fishermen to shoot seals. Moreover, seals become wary and learn how to approach a net and how to catch their fish without exposing themselves very much.

A less drastic approach to deterring seals is the use of various acoustic devices to frighten the seals. The most extensive work on such devices has been done in South Africa (Shaughnessy et al., 1981), where Cape fur seals take large quantities of fish from purse-seines, with up to 500 seals entering one net. Tests were made using recorded killer whale sounds and other acoustic devices, but these sounds, apart from some initial reactions, proved ineffective in scaring fur seals. Similar results were reported by Anderson and Hawkins (1978) in the United Kingdom. Tests were also made using explosive fire-crackers, including the commercially produced Seal Deterrents. Research trials and the results of questionnaires both showed that these devices were effective, though several might have to be used in succession to scare all the seals from a net. A ban on these materials was introduced in South Africa in 1976, because they had "no adequate effect on the seals and [their use] is extremely harmful to the shoals of pelagic fish" (Shaughnessy et al., 1981). However, as the authors reported, no evidence was produced for either of these somewhat surprising statements. Prior to the ban, some quarter of a million Seal Deterrents had been manufactured and sold between 1973 and 1975 which suggested that many fishermen did believe that they were effective. Shaughnessy et al. recommended the re-authorization of the use of Seal Deterrents.

A similar approach has been followed on the Canadian Pacific coast, where "seal bombs" have been used to frighten seals away from fishing gear. There are anecdotal reports that these can be fatal if accidentally or deliberately dropped very close to the seal, but there is no information on how widespread this practice is.

As with all use of explosives, there are obvious disadvantages to this method of seal control. At the high level of seal interference in South Africa, potential benefits can outweigh these disadvantages, but there is no indication, on presently available evidence, that such a method would be justified in Canada.

An alternative method is being examined by Dr. Mate of Oregon State University. This method aims to scare seals away from a fixed point such as the entrance to a salmon hatchery by producing an underwater sound the volume and frequency of which is highly unpleasant to the seal. There may therefore be less chance of the seal becoming used to the sound or, as appears to be the weakness of using recorded killer whale sounds, learning that, in fact, there is no killer whale and no reason to be afraid of the sounds. Preliminary trials in the United States and the United Kingdom are promising (Mate, 1985), but more studies are needed. An advantage is that seals apparently put their heads out of water to avoid the noise. This defeats any cautious submerged approach to a net, and makes the seals vulnerable to other countermeasures such as shooting.

Changes of Gear

Some types of gear used in Canada are relatively invulnerable to seals. Where a change can be made from a vulnerable to a less vulnerable type of gear, the change provides a simple and permanent solution. It appears from the statistical tabulations that lobster is the only species taken in a vulnerable gear that is not also, perhaps at different times and places, taken in less vulnerable types of gear. For other species, where seal damage does appear to be a problem, fishermen should be encouraged to change the type of gear wherever possible. This may involve providing grants to purchase new gear or to cover disruptions during the transition period.

Reduction in Seal Abundance

It would be reasonable to expect that, other things being equal, damage by seals would be proportional to the number of seals present. Indeed, to the extent that increasing seal abundance could add to their pressure on their food supplies, it might cause the individual seal to be more anxious to take the bait from a lobster pot or fish from other fishing gear, and damage might increase faster than abundance.

The supposition of proportionality is probably true as it relates to accidental encounters with the gear, an example of which is the increased entanglement of young harp seals observed in the last few years. Many cases of damage, however, may well occur as a result of the deliberate act of a seal in approaching the gear to take fish. It seems reasonable to suppose that the habit of taking fish from traps or gill nets is not spread evenly through the seal population. The extent of damage will then be more closely linked to the number of these "rogues" (though this may not be the best term to apply to them) than to the overall abundance. In that case, making reductions in the total abundance of seals may not be the most effective way of reducing the number of "rogues" or the damage they cause. The problem of reducing the negative effects of seals on fisheries by some form of population control is discussed further in Chapter 29.

The most drastic approach to reducing the number of "rogues" was formerly used in Scotland, where strychnine was placed in dead fish which were then placed in the nets. This method certainly was effective in killing seals, but it was inhumane and could result in the poisoning of other marine life. It has been banned in Scotland, and it should not be used in Canada. Shooting can also be effective in reducing the number of "rogues", and if carried out properly, should carry little risk of inflicting undue pain. (See Chapter 20.)

Discussion

Damage to gear and loss of fish are highly visible, and in most cases it is clear that the damage is done by seals, though occasions when seals may be used as scapegoats for bad weather or other animals should not be ignored. The extent of losses, expressed as a percentage of the total value of Canadian fisheries, is very small, but losses are concentrated in certain places where they can represent an appreciable part of the income of some individual fishermen. If no action is taken, these losses can be expected to increase as the stocks of grey seals (which appear to be the main source of loss in eastern Canada) and other species increase. It is possible that seal stocks will stabilize at equilibrium levels before losses pose a serious threat to the livelihoods of fishermen. Nevertheless, it is asking a great deal of fishermen to expect them to accept an increasing loss without government taking some action in their interest or allowing them to take action themselves. In evidence before the Royal Commission, most spokesmen for fishermen made it clear that while they accepted the presence of some seals and the losses that the seals cause, they believed that some action had to be taken to prevent an unlimited increase in seal populations (e.g., Fisheries Association of Newfoundland and Labrador Limited, 1985; Fisheries Council of B.C., 1985). The Fisheries Council of Canada (1985) declared explicitly that its members believed that the abundance of grey seals was approaching the limit of acceptable numbers.

The evidence on the current level of seal damage (especially on the extent of very serious loss to fishermen's livelihoods), on the degree to which this damage would increase if no measures were taken to control the seal population, and on the effectiveness of culling or bounty programs, is insufficient to justify government engagement in such programs on the basis of gear damage alone. This evaluation might change if the combined effects of gear damage, nematode parasites and competition for fish are taken into account. (See Chapter 29.)

The Royal Commission is of the opinion, however, that fishermen who have reason to believe that they are suffering particularly from seal damage should be allowed to take some action. This action could take the form of shooting seals seen in the vicinity of certain types of fixed gear. Permission to take this action should be subject to conditions applying to the number of seals shot, and the type of gun and ammunition used, so as to minimize the chances of the seals suffering and the risks to other persons present. Measures should also be taken to encourage the reporting of material (e.g., lower jaws) and information that will assist research into seals and their dynamics.

Conclusions

1. Seals remove fish from nets and other gear, take bait from lobster traps, and damage gear either in taking fish or from accidental encounters. The annual losses for gear damage alone in Atlantic Canada could be $2 million or more. The costs of gear damage and loss of fish on the Pacific coast may be considerable, especially to salmon gill-netters (where the loss may be $700,000 annually), but the total loss cannot be estimated with any precision. The estimates of damage and loss are very approximate, and more data are needed to increase their precision and to determine total losses due to seals.

2. This damage, while small in relation to the total Canadian fish catch, is concentrated in certain areas and certain types of gear. The most vulnerable types of gear are gill nets, fixed traps and fish-culture cages. For the fishermen most affected, the damage can represent a threat to their livelihood.

3. Damage on Canada's east coast is probably caused primarily by grey seals, and to a lesser extent, by harbour seals. In the last couple of years, entanglement of young harp seals in bottom gill nets has become significant around Newfoundland. On the west coast damage has been caused by harbour seals and both species of sea lions.

4. Damage can sometimes be reduced by modifications to the fishing gear, such as the use of stronger twine in gill nets, but this remedial approach is not feasible in all situations.

5. Other things being equal, it must be expected that increasing seal numbers will be associated with increasing damage. However, because many of the destructive encounters are the result of individual seals learning where they can obtain fish, other factors may be equally or more important than overall seal abundance. No significant relation was found in a Scottish study between increasing numbers of grey seals and the rate of damage to salmon in gill nets.

6. A number of methods of controlling the extent of seal damage, ranging from shooting to acoustic scaring devices, have been used to protect fixed nets and fish-culture operations. The success of these methods has been variable.

Recommendations

1. Further data should be collected to identify more precisely, according to time, place, and type of gear, the fishing operations that are particularly vulnerable to seal damage, and the specific situations in which increased seal damage would pose a threat to the continuing economic viability of an operation.

2. In the interests of threatened operations, studies should be made of possible technical means, such as modifications to the gear, that would reduce both damage caused by seals and the level of incidental mortality caused among them.

3. Further studies should be made of the degree to which damage may be directly related to overall seal abundance. These should include attempts to identify whether particular individual seals are involved in a relatively high proportion of incidents.

4. The impact of seals on fishing operations should be taken into account in determining the desirability of controlling the populations of seals. (See Chapter 29.)

5. Bearing in mind the localized nature of much seal damage, operators of fixed gear and of fish-culture operations may be licensed, subject to appropriate controls, to shoot strictly limited numbers of nuisance seals which closely approach these operations, with provision for a reward for return of biological material of value to research programs.

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Chapter 26

Transmission of Parasites

Recent study of the incidence of sealworm ... indicates that this parasite has become far more abundant in cod in the eastern Scotian Shelf area and Sydney Bight than it was 25 years ago (Fisheries Council of Canada, 1985).

Introduction

Infection of fish with nematodes (roundworms) is a major problem facing the commercial fishing industry along the eastern coast of Canada. Larval nematodes occur in the flesh of many commercially important fish species and make fillets unsightly and unappealing to consumers. To improve marketability, attempts are made to remove these parasites from fillets but this is a costly process. In some cases, levels of infection are so great that entire catches cannot be sold. While a number of nematode species are involved, the most important is one that matures and reproduces in seals, the usual definitive or final host of the parasite. Since numbers of this parasite are often thought to be proportional to numbers of seals, especially grey seals, it has been suggested that control of seals is a means of controlling intensities of infections in fish.

Several species of nematodes mature in the stomach or gastro-intestinal tracts of marine mammals; some of these species use fish as an intermediate host and are consumed by the marine mammal as part of its normal diet. Most of these nematodes are not important to the present problem because they encyst within the body cavity of fish. However, *Pseudoterranova decipiens* (*P. decipiens*) and *Anisakis* spp. (usually *A. simplex*), commonly occur in the flesh of fish. *Anisakis* is a small whitish or flesh-coloured nematode, whereas *P. decipiens* is considerably larger and of greater bulk. In addition, the latter species is yellowish and sometimes reddish-brown in colour, making it much more visible to the consumer. In areas where there are great numbers of *P. decipiens*, these nematodes are much more abundant than *Anisakis* in the fillets. Thus *P. decipiens* usually presents the chief problem in the marketing of nematode-infected cod and other groundfish, especially when filleted (Templeman et al., 1957). Moreover, its final host is typically the seal, whereas the usual final host of *Anisakis* is a cetacean. Because of the specific objectives of the Royal Commission, information is presented on *P. decipiens*, except when it is necessary to mention the relative importance of *Anisakis*.

This chapter examines the following points:

- the life history of *P. decipiens*;
- its occurrence in seals and fish;
- temporal changes in infection rates;
- relationship between the species and numbers of seals and infection rates in fish;
- dangers to human health;
- costs of parasitism to the fishing industry;
- options for dealing with the parasite problem.

The taxonomy of *P. decipiens* is briefly reviewed in Templeman (1986). *P. decipiens* has been called either codworm or sealworm, but will be referred to here by its scientific name, *Pseudoterranova* (or *P.*) *decipiens*. The genus *Pseudoterranova* has formerly been treated as *Phocanema, Terranova* or *Porrocaecum*.

Parasites

Nematodes, or "roundworms", are a highly successful and extremely widespread group of animals. They have a simple, smooth, cylindrical, nonsegmented body structure, easily distinguishable from other worms. Free-living forms occur in soil, and in fresh and salt water; parasitic forms infect most organs of many species of plants and animals. *Pseudoterranova decipiens* and *Anisakis simplex* are nematodes of the suborder Ascaridata, of the Anisakidae family, which are relatively large nematodes. Ascaridoids are dioecious (i.e., the sexes are separate) and the adults normally feed on the intestinal contents of the host, as well as on mucus and discarded intestinal cells. All nematodes undergo a series of four moults after hatching before reaching maturity.

Life-Cycle

The representation of the life-cycle of *P. decipiens* in Figure 26.1 gives the reader a broad idea of how the nematode is transmitted from host to host. A more detailed description of the process follows, taken primarily from McClelland et al. (1983a).

The eggs of *P. decipiens* are 45–50 micrometres in diameter when passed out in the faeces of the seal. They settle in sea water, adhere to the substrate and develop to the second, or possibly the third, larval stage within the egg in 8–52 days, when they hatch. Development and hatching are known to occur at temperatures as low as 2°C. The larval nematodes, which are about 200 micrometres in length at hatching, anchor themselves to the substrate by their caudal extremities. The post-hatch survival period for these free-living larvae ranges from about two days at 20°C to 140 days at 5°C. It is thought that these larvae are usually eaten by bottom-related or free-swimming copepods of the suborder Cyclopoida or Harpacticoida, although no naturally infected copepods have been found. In the body cavity (haemocoel) of experimentally infected copepods, the nematodes grow 60%–130% in length in 7–35 days, depending on temperature. They do not moult or undergo significant morphological changes in the copepod host.

Known natural second intermediate hosts for *P. decipiens* include crustaceans (amphipods, cumaceans, decapods, isopods and mysids), polychaete worms and nudibranch molluscs, but infection probably occurs in many other benthic macroinvertebrates that eat infected copepods. Under experimental conditions, larval *P. decipiens* grow rapidly in the amphipod haemocoel, reaching 2–3 millimetres in length within 30 days at 15°C, 60 days at 10°C and 140 days at 5°C. The nematode reaches 7–10 millimetres after 90 days at 15°C. In amphipods, *P. decipiens* becomes sexually differentiated and can reach the stage where it may be directly infective to seals, completing its life-cycle without a fish host (McClelland et al., 1983a). The relative importance of this pathway is, however, unknown.

Larval *P. decipiens* more than 2 millimetres long infect fish that eat infected invertebrates (or fish containing the parasite). The larvae escape from the partially digested food and in two to three hours penetrate through the stomach wall into the body cavity or visceral organs of the fish. After 24 hours many will have reached the muscles of the fish, where they continue to grow up to a length of 50–60 millimetres. They then become encysted in the flesh of the fish, where some die, but most remain alive and potentially infective.

Figure 26.1
Life Cycle of the Parasitic Nematode *Pseudoterranova decipiens*

Adult *P. decipiens* are found in the stomach of the seal. Eggs are passed out in seal faeces, hatching into larvae which attach to the bottom substrate.

→

Larvae are eaten by benthic, epibenthic and free-swimming copepods. Larvae within the haemocoel of the copepod do not moult or significantly change in form.

↓

Copepods containing *P. decipiens* larvae are eaten by amphipod, isopod, polychaete, or other macroinvertebrate hosts. Larvae grow in the haemocoel of crustaceans, the coelom of polychaetes and the visceral mass of molluscs.

↓

Mainly benthic macroinvertebrates containing *P. decipiens* larvae are eaten by small fish. Larvae invade the body muscles of fish.

←

Small fish or mainly benthic macroinvertebrates containing *P. decipiens* larvae are eaten by larger fish. Larvae then migrate to body muscles of fish, and after attaining their full growth in the fish, they encyst.

↑

Larger or smaller fish or macroinvertebrates containing infective larval *P. decipiens* are eaten by the seals.

↑

Source: Adapted from McClelland et al. (1983a).

When fish or invertebrates infected with larval *P. decipiens* are eaten by seals, the parasite escapes from the tissues of the intermediate host and attaches itself to the stomach wall of the seal. The larvae again moult, twice, and become sexually mature adults at lengths of about 80 millimetres (female) or 65 millimetres (male). The female contains between 200,000 and 500,000 eggs, and may lay several thousand daily; these are passed out in the seal's faeces to repeat the cycle. The average life span of an adult *P. decipiens* is about 35 days.

The life cycle of *Anisakis simplex* is similar to that of *P. decipiens*, except that the first intermediate host is a euphausiid, and the definitive host is usually a whale or porpoise, although seals may also be infected.

Parasite Hosts

As discussed in the previous section, the first and second intermediate hosts of *P. decipiens* are probably copepods and benthic macroinvertebrates respectively. Little is known about naturally occurring infections of the parasite in these hosts. The following discussion deals with the occurrence of the nematode in the third intermediate hosts (fish) and the final hosts (seals). Larval nematodes in fish and immature specimens in seals are generally not identified to species, as they do not possess the necessary structures for positive identification, but it can be assumed that specimens referred to as *Pseudoterranova* sp. larvae are *P. decipiens*, as this is the only species of the genus identified in the areas under discussion.

Mammalian Hosts

The final, or definitive, host of *P. decipiens* is normally a marine mammal, particularly grey, harbour and harp seals (Table 26.1). Grey seals are typically most heavily infected, with 3–13 times as many parasites as harbour seals and up to 74 times as many as harp seals (Scott and Fisher, 1958b; Mansfield and Beck, 1977). Other hosts for *P. decipiens* in both Atlantic and Pacific waters include bearded, ringed, hooded and northern fur seals, Steller and California sea lions, common porpoise, and white and sperm whales. In many of these incidental hosts, infections are of low density, and the nematode is often immature.

Table 26.1
Mean Numbers of *P. decipiens* in Stomach or Gastrointestinal Tract of Seals and Cetaceans[a]

Location	Period	No. of Seals	Mean No./Seal Adult	Mean No./Seal Immat.	Ref.
Grey Seal					
Northwest Atlantic					
Sable Island, N.S.	1983–84	162[b]	(145)+	(374)+	1
	1949–56	3	48	35	2
Ecum Secum, N.S.	Jan–Feb 1975–78	19	76	461	3
	Apr–Jun 1975–78	6	196	521	3
	Sep–Oct 1975–78	5	483	601	3
Amet Island, N.S.	Jan 1975–78	5	1	197	3
E Northumberland Strait	Sep–Oct 1975–78	9	389	351	3
Northumberland Strait, Gulf of St. Lawrence	N/A	49	212	640	4
E Cape Breton Island, N.S.	N/A	18	172	378	4
Miramichi Estuary, N.B.	1949–56	29	187	84	2
Bras d'Or Lakes, N.S.	1949–56	3	169	2727	2
NE Nova Scotia	1949–56	17	60	99	2
Northeast Atlantic					
N North Sea	1964	6	38	–	5
Orkney Islands, Scotland	Oct–Nov 1966	8	179	556	6

Table 26.1
Mean Numbers of *P. decipiens* in Stomach or Gastrointestinal Tract of Seals and Cetaceans[a] (continued)

Location	Period	No. of Seals	Mean No./Seal		Ref.
			Adult	Immat.	
W Isles, Scotland	Sep–Oct 1966–68	9	38	97	6
	Mar 1969	2	4	17	6
Shetland Islands, Scotland	Feb–Apr 1969	10	8	17	6
E Anglia, England	Feb–May 1968	7	2	3	6
Iceland	1975–1977	6	188	507	7
<u>Harbour Seal</u>					
Northwest Atlantic					
Sable Island, N.S.	1983–84	39	42	181	1
	1949–56	2	9	2	2
Ecum Secum, N.S.	June–July 1975–78	5	2	79	3
Northumberland Strait, Gulf of St. Lawrence	1949–56	5	6	10	2
Magdalen Islands	1949–56	8[c]	8	88	2
Bras d'Or Lakes, N.S.	1949–56	5	43	308	2
NE Nova Scotia	1949–56	8	21	31	2
SW Nova Scotia	1949–56	1	11	63	2
Lower Bay of Fundy, N.B.	1949–56	76	13	34	2

Table 26.1
Mean Numbers of *P. decipiens* in Stomach or Gastrointestinal Tract of Seals and Cetaceans[a] (continued)

Location	Period	No. of Seals	Mean No./Seal Adult	Mean No./Seal Immat.	Ref.
Northeast Atlantic					
N North Sea	1970	1	0	45	5
Orkney Islands, Scotland	Oct 1966	1	17	28	6
W Isles, Scotland	Mar 1969	11	1	12	6
Shetland Islands, Scotland	Feb 1969	1	50	5	6
E Anglia, England	Apr–May 1968–69	6	0.8	1	6
Iceland	Jan–Feb 1975–77	5	74	175	7
	Mar 1975–77	8	45	68	7
	Apr–May 1975–77	15	12	42	7
	June–July 1975–77	3	6	12	7
	Nov 1975–77	5	30	23	7
Harp Seal					
Magdalen Islands	Mar–May 1956	195	0.4	4	8
	Mar–Apr 1954–56	61	0.03	5	2
	Apr–May 1952–56	237	5	10	2
Port Hood, N.S.	Feb 1950	4	110	140	2
Blanc Sablon	June 1953–55	274	0.2	0.1	2
E Coast Nfld./Lab.	Mar–May 1949–51	43	0	0.3	2
	Mar–Apr 1983	68	0	0	2
La Tabatière, P.Q.	Jan 1950	21	0	0	2

Table 26.1
Mean Numbers of *P. decipiens* in Stomach or Gastrointestinal Tract of Seals and Cetaceans[a] (continued)

Location	Period	No. of Seals	Mean No./Seal Adult	Mean No./Seal Immat.	Ref.
Common Porpoise					
Lower Bay of Fundy	1955–56	51	0	0.7	9
White Whale					
Mace's Bay, N.B.	June 1952	1	0	80	9
Sperm Whale					
S Denmark Strait	Aug 1967	3	0.3	0	6

References:
1. McClelland et al. (1985), McClelland (1985);
2. Scott and Fisher (1958b);
3. McClelland (1980);
4. Mansfield and Beck (1977);
5. van Banning and Becker (1978);
6. Young (1972);
7. Pálsson (1977);
8. Myers (1957);
9. Scott and Fisher (1958a).

a. Seals less than one year old and uninfected cetaceans are omitted.
b. Ninety seals averaging more than 2,000 *P. decipiens* each had not been analysed.
c. One highly parasitized seal not included.

N/A not available.

Geographical and Temporal Distribution

Infections by *P. decipiens* have been reported in most populations of grey, harbour and harp seals studied (Table 26.1), but it is apparent that great differences have been found in numbers of the nematodes, not only among species of seals and among areas, but also in a particular species of seal in the same area at different seasons. McClelland (1980) reported, for instance, that grey seals at Ecum Secum, N.S., were infected with a mean of 76 adult *P. decipiens* in January–February, 196 in April–June and 483 in September–October. These periods correspond respectively to grey seal whelping, moulting and feeding periods. Immature nematodes were apparently not as much reduced during the fasting periods (whelping and moulting) as were the adults. In harbour seals, Scott and Fisher (1958b) found no obvious temporal variation in the total numbers of *P. decipiens*, except that the lowest numbers in the lower Bay of Fundy were found in July–August, during moulting. Pálsson (1977) examined harbour seals in Iceland and found mean adult *P. decipiens* infections of 74 in January–February, 45 in March, 12 in April–May (prior to whelping), 6 in June–July (when moulting may be taking place) and 30 in November (Table 26.1).

Available information thus suggests that infections of adult *P. decipiens* in seals are lower during non-feeding periods; it is possible either that the immature nematodes are not as sensitive to fasting of the host and are not lost to the same degree, or that development of the larva to the adult stage does not occur as readily when the hosts (and thus the parasites) are not feeding. In experimental and natural infections of fasting grey and harbour seals, the anterior ends of the nematodes were embedded in the stomach wall and the nematodes were less prone to being passed from the stomach. During feeding periods, adult *P. decipiens* tend to be free in the stomach, whereas immature stages remain attached to the stomach wall. Thus replacement of adult nematodes (which may have a shorter life span when food is scarce) would not occur until the host started to feed again.

Recent data from Sable Island indicate an increase in numbers of *P. decipiens* per seal (Table 26.1); however, lack of information on the months when seals were examined renders the information suggestive rather than conclusive. A small number of Sable Island grey and harbour seals examined in the 1949–1956 period contained mean numbers of 83 and 11 nematodes respectively (Scott and Fisher, 1958b); a larger number in the 1983–1984 period contained mean numbers of 519 and 223 respectively (McClelland et al., 1985). The 1981–84 data represent an underestimate of the actual mean numbers of nematodes per seal; they excluded 90 heavily parasitized grey seals which contained more than 2,000 nematodes each (McClelland, 1985).

Infection Rates

Studies involving the experimental introduction of known numbers of larval *P. decipiens* into the stomachs of grey and harbour seals (McClelland, 1980) have demonstrated that this nematode is better adapted to the grey seal than to the harbour seal (Table 26.2). Some of the differences between infections in grey and other seals may be attributable to the larger size of the grey seal: they are at least twice the weight and one and a half times the length of harbour seals, while harp seals are of intermediate size.

Table 26.2
Experimental Infections of Seals with *P. decipiens*

	Adult Female *P. decipiens* at Six Weeks			
Host	% Survival	Length (mm)	Mean No. of Eggs per Female	Egg Production per Day
Grey seal	48	82	366,000	11,000–27,000
Harbour seal	9	61	156,000	3,000–11,000

Source: Data from McClelland (1980).

Fish Hosts

Species Infected and Geographical Distribution

Specific studies on larval infections of *P. decipiens* in fish have concentrated on commercially valuable species in the Atlantic Ocean, but low infections have been reported for many other fish in other regions. Canadian Atlantic records show infections occurring in Atlantic cod and other fish species in all divisions of Sub-areas 2, 3 and 4 of the Northwest Atlantic Fisheries Organization (NAFO) Convention Area (Figure 26.2), with the exception of Flemish Cap in division 3M, from which few fish have been examined specifically for nematodes. Fish species in eastern Canadian waters, other than Atlantic cod, which are known to be naturally infected by *P. decipiens*, include spiny dogfish, winter and thorny skates, rainbow smelt, goosefish, Greenland cod, haddock, white hake, Atlantic tomcod, ocean pout, cunner, redfish, American plaice, longhorn, shorthorn, moustache and ribbed sculpins, sea raven, Atlantic halibut, and yellowtail, smooth, witch, winter and windowpane flounders (Margolis and Arthur, 1979).

Infections of the following species have been reported in the Pacific Ocean off British Columbia: Pacific cod, black cod, lingcod, Pacific halibut, rockfish, ocean perch, walleye pollock and sockeye salmon (Margolis and Arthur, 1979), and off Alaska: walleye pollock, Pacific cod, rock greenling and red Irish lord (Stiles and Hassall, 1899; Scheffer and Slipp, 1944; Schiller, 1954).

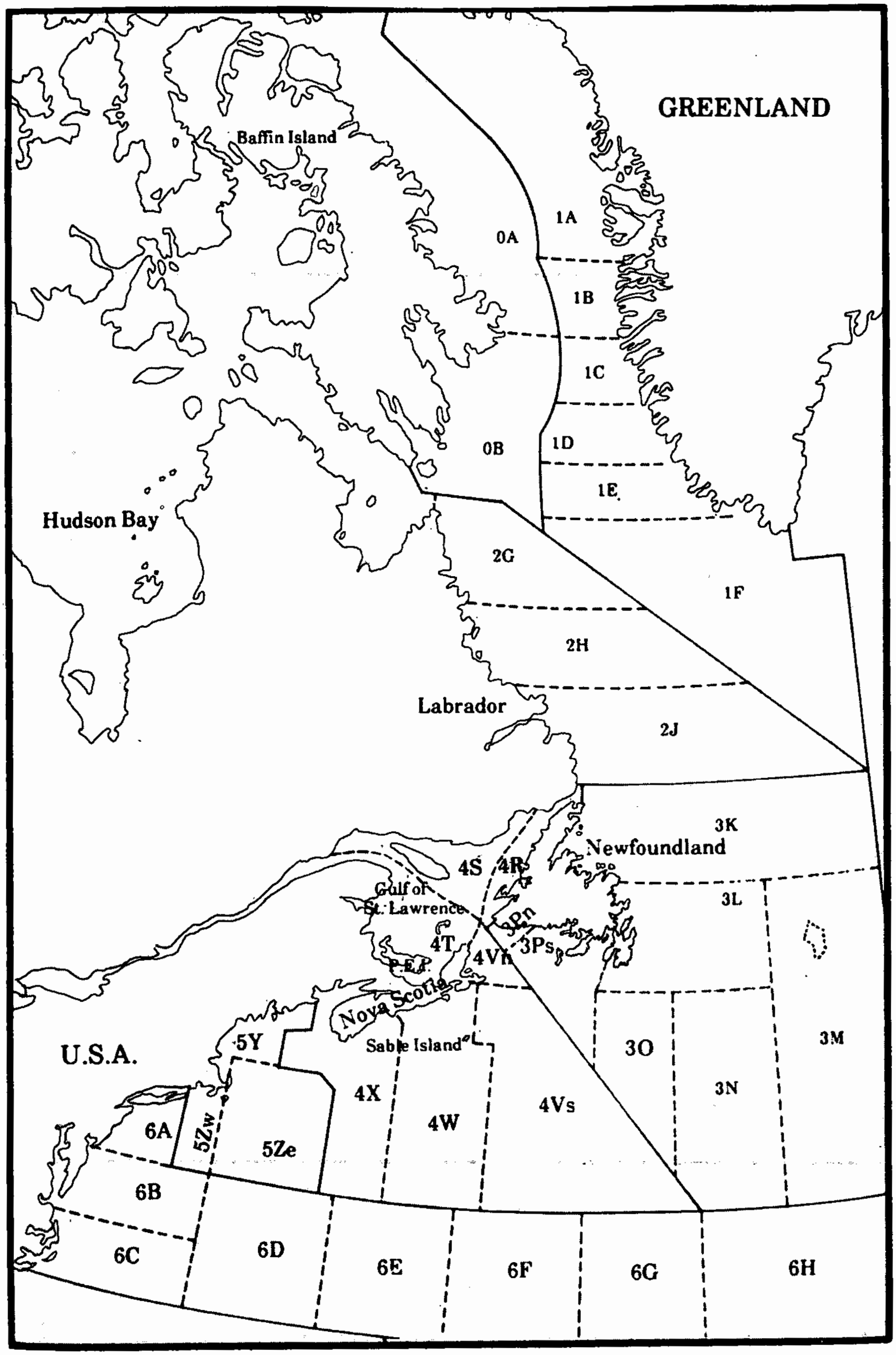
Heavy infections in European waters occur in Atlantic cod from the west coast off Scotland, the Irish Sea, the Bristol Channel, the west English Channel, the northeast coast of England, the Faeroe Plateau, Iceland and the southern coast of Norway (Young, 1972; Platt, 1975; Bjørge et al., 1981). Other fish species from Europe reported to have infections of *P. decipiens* include American plaice, witch flounder, haddock, whiting, poor cod and dragonet; the latter reports come from isolated inshore locations in Scottish waters (Wootten and Waddell, 1977).

Anisakis simplex has been identified in fish from the Pacific (Pacific hake) and from the Atlantic (alewife, Atlantic cod, Atlantic herring, Atlantic salmon, silver hake and Atlantic mackerel), and is probably the species usually identified as *Anisakis* spp. in capelin and many other species of fish in both the Atlantic and Pacific Oceans (Margolis and Arthur, 1979).

Location of Parasites Found in Fish

Infections of *P. decipiens* in cod are chiefly present in the fillets. McClelland et al. (1983a), when studying Atlantic cod taken from the southern Gulf of St. Lawrence (4T) and the Breton Shelf (4Vn) (see Figure 26.2), found 90% of the parasites in the fillets and the remainder in the flesh surrounding the body cavity (belly flaps or napes; 6.8%), liver (0.7%), pyloric caeca (1.5%), and other viscera (1.2%). Distribution of the parasite varies with the length of the host: the larger the fish, the lower the percentage of *P. decipiens* in the fillets and the higher the percentage in the flaps. In the same study, no significant differences between infections in male or female fish were detected. In a recent study, McClelland et al. (1985) found that a significant majority of *P. decipiens* in the flesh of cod occurred in the nape and fillet in the left side of the body: nematodes in the left side outnumbered those in the right by 50%.

Figure 26.2
Sub-areas and Divisions of the Northwest Atlantic Fisheries Organization (NAFO) Convention Areas



The greatest infection levels of the less visible *Anisakis* spp. were in the liver (60.7%) and pyloric caeca (31.0%), with only low incidence in the fillets (1.1%) and flaps (1.2%), according to McClelland et al. (1983a).

Infection Rates

McClelland et al. (1983a), Templeman (1986) and others have noted that comparisons between recent and earlier studies on *P. decipiens* infections in commercial fish are extremely difficult for reasons centred on the following points:

- Research methods are not comparable. Some early studies used results from commercial candling procedures (described later in the Candling and Trimming section) which are less than half as efficient as those that include cutting the fillets into thin slices before candling, followed by systematic destruction of the slices. Even the latter method missed at least 13% of the *P. decipiens* and 68% of the *Anisakis*, as has been demonstrated by a peptic digestion experiment on fillets of cod (McClelland et al., 1983a).

- Units of expression are not comparable. Units used in recording worm infection are inconsistent and sometimes misleading. For example, average numbers of nematodes per fish, per fillet or per fillet weight do not take into account the skewed distribution (i.e., many fish are only lightly infected).

- Samples are not comparable. Different studies have involved different ages, weights or sexes of fish. In some cases, specific length ranges are mentioned; in others, the cod are only separated into "scrod", "market" or "steak". In addition, age/length relationships differ geographically, and hence data based on age of fish taken from different areas may not be from equivalent size classes of fish, and vice versa; time of year of sampling often differs among and within collections; and different populations of fish may have been sampled in the same location, but cannot be compared directly.

- Statistical methods used to test data may be inappropriate. Statistical studies on biological systems are based on many assumptions, some of which are violated because of the low numbers and natural variability in available data.

McClelland et al. (1983a, 1983b) compared intensities of infections of *P. decipiens* in commercial fish from the eastern coast of Canada. Given all the above limitations to analysis of present and past data, they still concluded that the variations in abundance of *P. decipiens* in relation to host length, season, year and geographical location were, for the most part, highly significant. Comparisons were made between and within the southern Gulf of St. Lawrence (4T) and the Breton Shelf (4Vn), and between and within Sable Island and Western banks (4W) and Banquereau (4Vs). (See Figure 26.2.) Their conclusions were as follows:

- The parasite was most numerous in inshore cod in both 4T and 4Vn.
- Mean counts of *P. decipiens* in cod from 4T and 4Vn offshore did not differ significantly, but counts of this nematode in 4Vn winter and summer samples were significantly different.
- Infections in 4W cod and flatfish were higher than in 4Vs cod and flatfish; parasite abundance increased with proximity to Sable Island.
- Infections of cod in 4T were similar to those reported 25 years ago.
- Cod and flatfish infections in 4V and 4W were much higher than they were 25 years ago.

These and other comparisons between early and recent studies are shown in Table 26.3.

Larval nematode infections in cod, American plaice, grey sole and yellowtail flounder were more recently reported for a broader area by McClelland et al. (1985). They concluded that *P. decipiens* was most abundant in fish from the southeastern Gulf of St. Lawrence (4T), Breton Shelf (4Vn), eastern Scotian Shelf (4Vs–4W), northeastern Gulf of Maine (4X) and lower Bay of Fundy (4X). *P. decipiens* had also become increasingly numerous in cod and flatfish from southeastern Newfoundland (3P–3O), the northern Gulf of St. Lawrence (4R–4S), and the southwestern Scotian Shelf (4X) (Figures 26.3 and 26.4).

By far the largest breeding colonies of grey seals in eastern Canada are located on Sable Island and in the southeastern Gulf, and each corresponds with a very high infection rate of cod with *P. decipiens* in the vicinity. The infection rate of cod with *P. decipiens* has risen greatly in the vicinity of Sable Island in relation to the 17-fold increase in grey seals (based

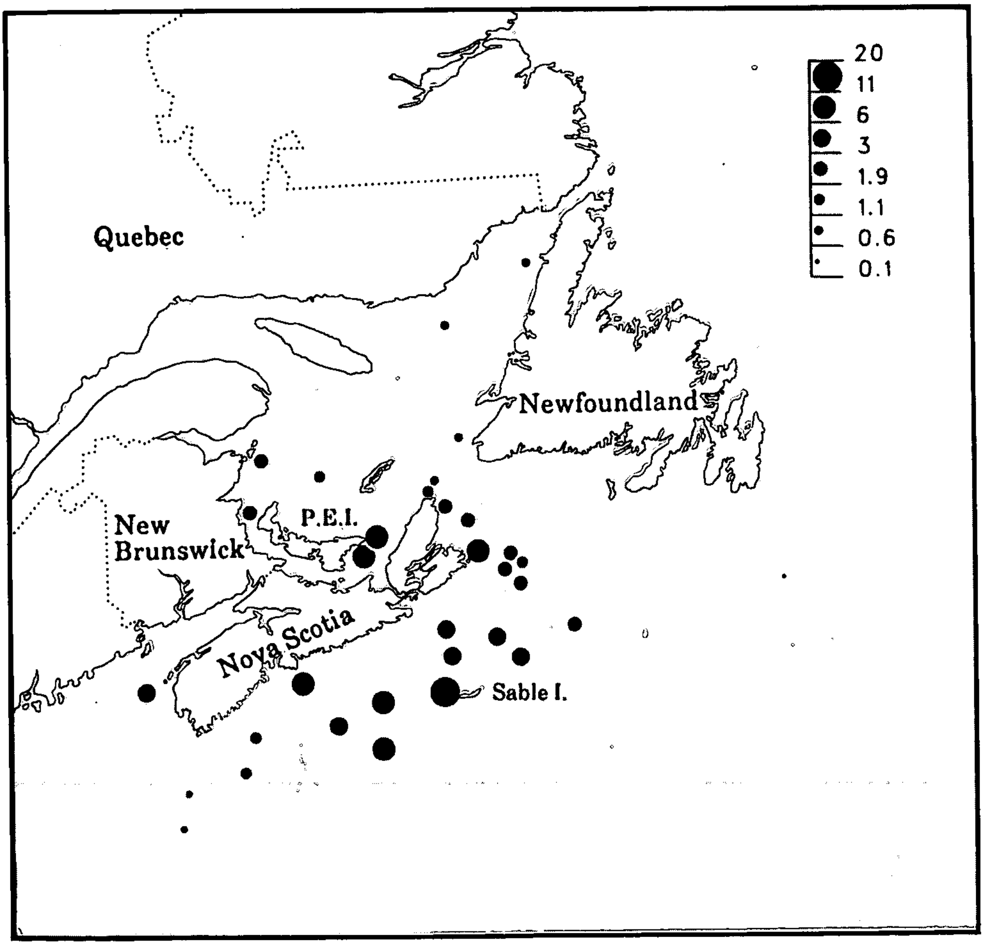
Table 26.3
Comparisons of *P. decipiens* Infections in Cod (or Plaice where Noted) between Early and Recent Studies

Location	Dates: Early	Dates: Recent	Comparison of Infection Rates
Sable Island/Banquereau	1950–52	1982	Much higher in 1982
Scotian Shelf (4Vs & 4N)	1946–56	1982	Much higher in 1982
Bradelle Bank–S Gulf of of St. Lawrence	1947–53	1981	Similar infection rates - smaller fish lower, larger fish higher, in 1981
Souris	n/a	1980–81	No early data; very high 1980–81
Cheticamp	1946–56	1980	Possibly lower in 1980
Shediac/ Point Escuminac	1957	1980	Lower in 1980
St. Paul's Island/Ingonish	1946–56	1980	No evidence of difference
S Gulf (4T) & Cape Breton (4Vn)	1950s	1980–81	No evidence of difference
SW Grand Bank (3O)	1947–53	1984	Much higher in 1984
N Gulf of St. Lawrence	1947–53	1984	Higher in 1984
S Scotian Shelf (4X)	1946–56	1983	Higher in 1983
Point Escuminac (plaice)	1949–53	1981	Much higher in 1981
NE Scotian Shelf (4VW) (plaice and witch flounder)	1947–53	1982	Higher in 1982
SW Grand Bank (3O); St. Pierre Bank (3P); N Scotian Shelf (4V) (plaice)	1947–53	1983–84	Higher in 1983–84
Bradelle Bank (plaice)	1947–53	1983–84	Lower in 1983–84
Miramichi, Cape Breton Shelf, Banquereau, Sable Island and Western banks (plaice)	1980–82	1983	Higher in 1983

Source: Templeman (1986) with comparisons of data in Templeman et al. (1957); Scott and Martin (1957, 1959); McClelland et al. (1983a, 1983b, 1985).

on pup counts; see Chapter 21) on this island between 1962 and 1984. It is not certain, however, whether the cod of the southern part of the Gulf of St. Lawrence, which were heavily infected with *P. decipiens* 30–40 years ago, have been more highly infected in recent years than they were formerly. This uncertainty results from the lack of equivalent earlier and later samples which are comparable for location, monthly date, method of examination, and fish size, as well as from difficulties relating to the comparable earlier and later numbers of grey and harbour seals, and the comparative role of harp seals. These questions were examined in detail in Templeman (1986).

Figure 26.3
Abundance of *P. decipiens* in Eastern Canadian Cod[a,b]



Source: Modified from McClelland et al. (1985).

a. Cod 51–70 cm in length, 1980–84.
b. Diameters of symbols are scaled according to mean nematode abundance per fish.

Studies in Scottish waters by Rae (1960, 1963), Wootten and Waddell (1974), Smith and Wootten (1979) and Wootten (1985) demonstrated the following:

- increases in incidence of infection by *P. decipiens* in cod of North Minch, South Minch and north of Scotland between 1958 and 1965 (1966–1967 for north of Scotland) and between 1971 and 1973;

- uncertain or no increases in Moray Firth and northern North Sea (between 1958–1961 and 1971–1973);

- a decrease between 1959–1970 and 1971–1972 in the Firth of Clyde.

Further examination of some of these areas in 1978–1979 showed a slight, but non-significant increase in the incidence of *P. decipiens* in smaller cod from the north coast of Scotland, and a decrease for North Minch. *Anisakis* infections for the north coast of Scotland had increased from 24% to 59% in the same period, but were reduced in North Minch (from 49% to 22%). Cod from the north coast of Scotland were examined again in 1981 and found to have a much lower incidence of *P. decipiens* infection (12.5%) than that from samples taken in 1978–1979 (34.1%) and in 1971–1973 (23.8%).

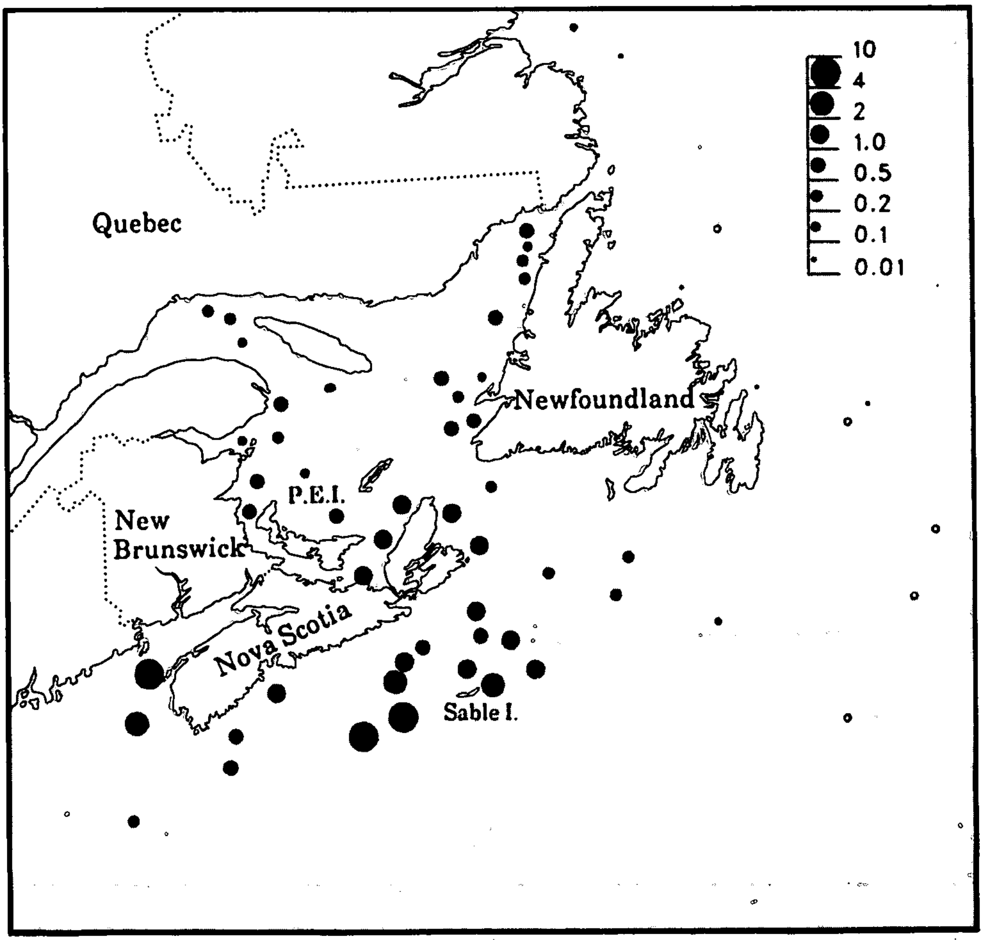
Host Specificity

From the information given above, it can be seen that *P. decipiens* does not exclusively infect any one host in any of its life stages; that is, it is not host specific, especially in its younger stages. However, adult *P. decipiens* have not been reported from many marine mammals other than seals. Young (1972) found adult stages of the parasite in the stomach of a single sperm whale in South Denmark Strait, and Schmidt-Ries (1939) found that adult *P. decipiens* was the most important nematode in two common porpoises in the Baltic Sea. There is little doubt that seals along the eastern coast of Canada are by far the most important host for development of the parasite to the adult stage.

Relationships among *P. decipiens*, Fish and Seals

The preceding review of the life history of the parasite and its presence in seals and fish shows that it is reasonable to believe that the occurrence of parasites in fish and the associated problems of the fishing industry are linked to the presence of seals on the fishing grounds. Before examining the evidence bearing on this statement, and the more specific question of the degree to which changes in seal abundance may result in changes to the numbers of parasites in fish, one complication should be noted. This complication is the existence of time lags in the system.

Figure 26.4
Abundance of *P. decipiens* in Fillets of American Plaice from Eastern Canada[a, b]



Source: Modified from McClelland et al. (1985)

a. Plaice 31–40 cm in length, 1983–1984.

b. Diameters of symbols are scaled according to mean nematode abundance per fish; open circles indicate zero abundance.

Given the time span for development of *P. decipiens* from an egg in the seal's faeces to a larva in fish flesh (Table 26.4), a minimum of about two months appears to be necessary between the production of eggs by an adult worm in an infected seal in the area and the presence of visible larvae in a fish. A maximum time from seal to fish cannot be as easily estimated, as much depends on the life span of the first and second intermediate hosts, but at least one and a half years could elapse between egg production and the appearance of infections in fish.

Table 26.4
Length of Time Required for Each Stage of Development of *P. decipiens*

Development Stage	Number of Days		
	Minimum	Mean	Maximum
Egg to hatch	8	N/A	52
Hatch to ingestion by first host	2	N/A	140
Growth in first host	7	15	35
Growth in second host to 2–3 mm	30	60	140
Growth in second host to 7–10 mm	N/A	90	N/A
Migration to muscle in fish host	N/A	2	N/A
Growth of larvae in fish	N/A	56	N/A
Growth and maturation in seals (until initial egg production)	15	N/A	25
Life span as adult	N/A	35	75

Source: McClelland et al. (1983a).
N/A = data not available.

After reaching the fish host, the larval worm in the flesh may remain infective to a seal for many years, perhaps for the life of the fish, although occasional encysted dead and disintegrating worms are found in older fish. A considerable amount of time could elapse, however, between infection of the fish and reinfection of the seal, and the complete cycle from seal back to seal (or fish back to fish) could take from several months to several years. Thus, changes in any one part of the system, such as reductions in seal populations, would not necessarily lead for some time to any noticeable effect in other parts of the system. General considerations of the life-cycle of *P. decipiens* lead to the conclusion that if the number of eggs of the nematode were greatly reduced, large reductions in its intensity of infection of fish would not be evident in the fishery until older, heavily infected members of the fish population and their food fishes were replaced by younger, presumably more lightly infected individuals. Thus, the length of time required for major changes to take place depends on growth rates of each species of fish, the age and size at which they are recruited to the fishery, the age to which they survive, and the age at which they became infected with *P. decipiens*.

These time lags are probably not important for interpreting past data when comparisons are being made over a period of decades, but they could be significant in considering future policy. The current infection rate in fish could represent the equilibrium parasite load corresponding to the seal population of some years ago. It must also be expected that if action is taken to control grey seals or other seal species, the results of that action will only become apparent slowly and gradually in the fish-processing plants.

Differences among Seal Species

The data presented in Table 26.1, together with the information on the numbers of seals given in Chapter 21, allow us to make rough estimates of the numbers of parasites in each seal species. Table 26.1 indicates that the parasite load for each species varies geographically and with time. For both grey and harbour seals the numbers of adult *P. decipiens* per seal at Sable Island increased (from 48 to 145+, and from 9 to 42 respectively) between the two periods 1949–1956 and 1983–1984. There are also indications that, for both of these species, the parasite load from 1949–1956 was higher in the seals from the coastal areas of Nova Scotia than it was in seals from Sable Island. Four harp seals taken at Port Hood, N.S. contained an average of more than 100 adult *P. decipiens*, while those taken near the Magdalen Islands averaged 0.03–5.0 nematodes per seal, and those caught near Labrador and along the north shore of the Gulf of St. Lawrence contained no adult and 0–0.2 adult *P. decipiens* respectively.

These geographical and temporal effects are confounded with the seasonal changes in infection rate, and few data are available. It is not possible at this time, therefore, to determine to what extent, if any, the infection rate in seals has increased, and to what extent it varies among areas. Given the changes that have occurred in the infection rates of fish and the differences among areas (and hence in the number of these nematodes that the individual seal will ingest in its food), it would be surprising if such differences between *P. decipiens* infections in seals did not exist.

For the purpose of comparison among species, it may be reasonable to take the figures from Table 26.1 and, for grey and harbour seals, to average the mean number of adult *P. decipiens* in each sample (i.e., 178 for grey and 17 for harbour seals). In the harp seal data, however, four individuals averaged 110 nematodes each, while all other samples ranged from zero to five *P. decipiens* per seal. The arithmetic mean (14.4 nematodes per seal) for these data could clearly be misleading. The omission of the four heavily infected seals results in an average of 0.8 *P. decipiens* per seal. The parasite load of harp seals from the Gulf of St. Lawrence may also have changed to a greater degree than that for other species of seal. The herring stock, which was a favoured food item of seals, and which contained very few *P. decipiens*, has declined greatly. Therefore, harp seals may have turned their attention to other, perhaps more heavily infected, fish. For the purpose of comparison, a figure of one *P. decipiens* per harp seal will be used.

Before combining the data for the number of *P. decipiens* per seal with the estimates of present-day seal populations from Chapter 21, two adjustments should be made to the data. The nematodes found in harbour seals are much smaller than those found in grey seals and have a correspondingly lower rate of egg production. Since the number of eggs produced is presumably the factor that is important to the effect on infection rates in fish, the numbers of adult *P. decipiens* per seal should be adjusted accordingly. On this basis, the mean number of *P. decipiens* found in harbour seals should be halved (i.e., to 8.5 nematodes per seal) to give a number equivalent to that for grey seals. The size of the adult *P. decipiens* found in harp seals has not been reported, but if the same relationship exists between nematode size and seal size, one adult *P. decipiens* in a harp seal might be equivalent to 0.75 adult *P. decipiens* in a grey seal.

The size of the harp seal population should also be adjusted because the parasite is only transmitted to and from those animals that enter the Gulf of St. Lawrence (an average of about one-third of the total harp seal population; Fisher, 1955; Sergeant, 1976; Winters, 1978). These animals remain and carry adult *P. decipiens* in this vicinity for only a part of the year (perhaps one-third), and so the equivalent population size might be estimated at 220,000 harp seals.

The total parasite load for each of the three species of seals is calculated in Table 26.5.

Table 26.5
Estimates of the Total Numbers of Adult *P. decipiens* Found in Canadian Grey, Harbour and Harp Seal Populations

Seal		P. decipiens	
Species	No. (thousands)	Equivalent No. per Seal	Total No. (thousands)
Grey	70	178.0	12,460.0
Harbour	13	8.5	110.5
Harp	220	0.75	165.0

Despite the crude nature of these calculations, the dominant role of the grey seal - 98% of the total number of nematodes - is clear. Therefore the following section is couched entirely in terms of grey seals.

Relationship between Grey Seal Abundance and Infection Rate

The life history of *P. decipiens* (Figure 26.1) indicates that the presence of seals or other marine mammals is essential for the presence of the parasite. However, the number of eggs produced by a single adult female *P. decipiens* is so large that the presence of only a few female nematodes in a few seals could result in significant infections of fish stocks. Above a particular level, an increase in seal numbers might not materially alter the rate of infection of fish stocks. The beliefs that an increase in numbers of seals causes an increase in the infection rate of fish, and that a reduction of the seal population would be the best way to reduce the infection, are supported by two sets of correlations: those pertaining to space and to time.

Figures 26.3 and 26.4 show that the distributions of parasites in cod and plaice are similar, and both match the distribution of grey seals, with peak densities in the area near Sable Island, where a large breeding herd of grey seals is located; and secondary peaks in the southeastern Gulf of St. Lawrence, where there is another large breeding herd of grey seals. The trends of increasing abundance of *P. decipiens* infections in cod – from offshore to inshore in divisions 4T and 4Vn, and towards Sable Island in 4W and 4Vs – match the trends in seal abundance.

To some extent this picture may be blurred because of the movements of cod so that the observed infection of cod in one area is the result of the cod feeding on infected fish or invertebrate intermediate hosts in a different area. Those areas where cod populations are relatively sedentary may give a better estimate of the importance of local seal stocks. Some stocks of cod have a very high rate of infection by *P. decipiens* when there are only small colonies or concentrations of harbour and/or grey seals present (Scott and Martin, 1959; Scott and Black, 1960).

Similarly, a broad correlation between areas of high densities of grey seals and *P. decipiens* infections has been found in the eastern Atlantic. Studies have been carried out in the United Kingdom on the relationship of *P. decipiens* infections in cod to seal populations (Rae, 1960, 1963). Correlations have been observed between the coastal grey seal breeding colonies in northwest Scotland and the high incidence of *P. decipiens* (and *Anisakis* spp.) infections in cod (41%–55% coastally and 32% west of the coastal region). Grey seal colonies also exist close to other areas of high infection in the Shetlands (28% cod infected) and the Farne Islands off the east English coast (32% cod infected); intermediate and adjacent coastal areas through which seals from these colonies migrate showed intermediate incidence of infections in cod (13%–21%). Incidence of infection in the northern and southern North Sea were 4% and 0% respectively; these areas are progressively more distant from the main breeding colonies of grey seals.

The infection rate around the Faeroe Islands, where the number of seals is much higher than on Faeroe Bank (which is some distance to the west and is an area where seals are infrequently found), is 61% of cod, while on Faeroe Bank, only 1% of cod are infected (Platt, 1975).

A correlation also exists on a relatively fine scale. Bjørge (1985) presented information on the rate of infection of seals along the central coast of Norway. The areas where fish with high infections were found were always close to breeding colonies of seals.

Taking the geographic evidence as a whole, the conclusions seem fairly clear: the presence of some seals (or other marine mammals) is necessary for the presence of parasites, and the increasing numbers of seals are clearly related to the increasing infections in fish.

The evidence of the time-series data is less clear. Between 1962 and 1984 there was a 17-fold increase in the numbers of pups of grey seals on Sable Island. There has also been an apparent increase in *P. decipiens* larval infections in cod and flatfish fillets over the past 30 years in the area around Sable Island (Table 26.6), and a significant increase in cod and flatfish infections in relation to closeness to Sable Island (McClelland et al. 1983b, 1985; Figures 26.3 and 26.4).

Table 26.6
Number of *P. decipiens* per kg of Fillets in Cod Samples from Sable Island Bank and Banquereau

Fish Length (cm)	Early Samples[a]	Recent Samples[b]
35–50	0.88	6.12
51–70	0.74	8.39
≥71	0.09	10.68

Source: a. From Templeman et al. (1957).
b. From McClelland et al. (1983b).

It may be suggested that the change in the rates of infection of fish by *P. decipiens* may be simply a reflection of some changes in the natural environment which have happened to coincide with an increase in grey seal numbers. This possibility is somewhat strengthened by the apparent increase in the numbers of *P. decipiens* per seal observed in the Sable Island colony during the same period. Of the known environmental factors which may affect numbers of *P. decipiens* in seals and fish, water temperatures have, on the average, become somewhat colder since the 1930–1950 period and *P. decipiens* have become more plentiful in the interdependent cycle between seals and groundfish.

Even if the increases in seal numbers and in parasites do represent cause and effect, there are few data points for the intermediate years, and it is difficult to consider with any precision the relationship between intermediate numbers of *P. decipiens* in groundfish and intermediate numbers of seals.

In the eastern Atlantic, Wootten (1985) concluded, from his group's studies in Scottish waters, that the grey seal population had increased over the past 20 years around Scotland, but that the *P. decipiens* burden of the individual seal had remained much the same. Although the infection rate of larval *P. decipiens* apparently increased in fish between 1958 and 1973, no further increase was apparent between 1973 and 1979. The subject is discussed in considerable detail in Templeman (1986), where it was concluded that the small sample size and the lack of information on the relationship between distance from seal colonies and the location in time and space of the samples greatly reduced the value of the conclusions. In addition, the relative amounts of groundfish and pelagic species in the seals' food in earlier and later periods are unknown. Sand lance, a favourite food of the grey seal in Europe, has increased greatly in recent years off the Canadian and U.S. Atlantic coasts since its major predator, the cod, has been reduced in numbers. This increase in sand lance abundance may be also a factor in Europe, providing a change in the food of seals which might lead to fewer *P. decipiens* in the seals.

On the empirical evidence presented above, it can be stated that the evidence is in favour of the hypothesis that more seals will, on average, mean more parasites, but there are few data on the question of how much the parasite load in fish will change as a result of a given change in seal abundance to an intermediate level.

Human Health Hazards and Social Aspects of Nematode Infection

The public health aspects of human infection by the nematode *P. decipiens* were reviewed by Margolis (1977). That nematode and *Anisakis* spp. cause Anisakiasis, which produces severe epigastric pain, and may cause vomiting and other severe abdominal discomfort. Confirmed or presumed infections from *P. decipiens* had to that time been reported in 46 cases (of which 37 were in Japan, where raw fish is part of the normal diet, six from the United States, and one each from Canada, England and Greenland). All of these cases were linked to the consumption of raw, lightly salted or marinated fish. Cooking at 70°C for seven minutes or freezing at -20°C for 24 hours is lethal to *P. decipiens* larvae in fish flesh. It appears that present methods of preparing fish for the table in Canada preclude the probability of high human infection rates with *P. decipiens*.

Human infections and even deaths from infection by *Anisakis* spp. have been reported from Holland in people who ate lightly salted raw herring (van Theil et al., 1960). This form of Anisakiasis is common in Japan also; over 1,200 cases were reported in the world between 1962 and 1977, mainly in Japan (Myers, 1970; Smith and Wootten, 1978).

The main public concern in North America with respect to nematode infections in fish flesh is the visibility and unsightliness of the parasite. Increased awareness of the public to health hazards from food and food products has probably contributed to an increase in complaints about the parasite. On the other hand, more people are becoming more adventurous in their eating habits, and the consumption of raw fish in Canada may be growing. Consideration of Japanese infection rates, however, leads to the conclusion that *P. decipiens* is probably not a major health hazard, especially when compared to *Anisakis* spp.

Economic Implications of *P. decipiens*

The occurrence of *P. decipiens* in fish flesh adds to the costs for the fishing industry, including the costs for candling the fish fillets in order to remove the parasites, trimming and discarding badly infected portions of the fillets, reduced quality of the fish products resulting from the presence of parasites, and the abandonment of some fishing areas because of their very high infection rates.

Candling and Trimming

Candling involves a visual examination of the fillet for the presence of nematodes. A light source is placed under a frosted glass surface on which the fillet is placed, and the parasites are removed individually with the tip of a knife. In large, thick, potentially high-quality fillets that are heavily infected with *P. decipiens*, it is impossible to produce an acceptably nematode-free fillet without slicing the fillet thin, which downgrades the final product. Candling also removes bones, scales, blood clots, *Anisakis* spp. and other parasites, and consequently much of the fish would have to be candled even if there were no *P. decipiens* present (George, 1986). Thus the cost of candling cannot be attributed to *P. decipiens* alone.

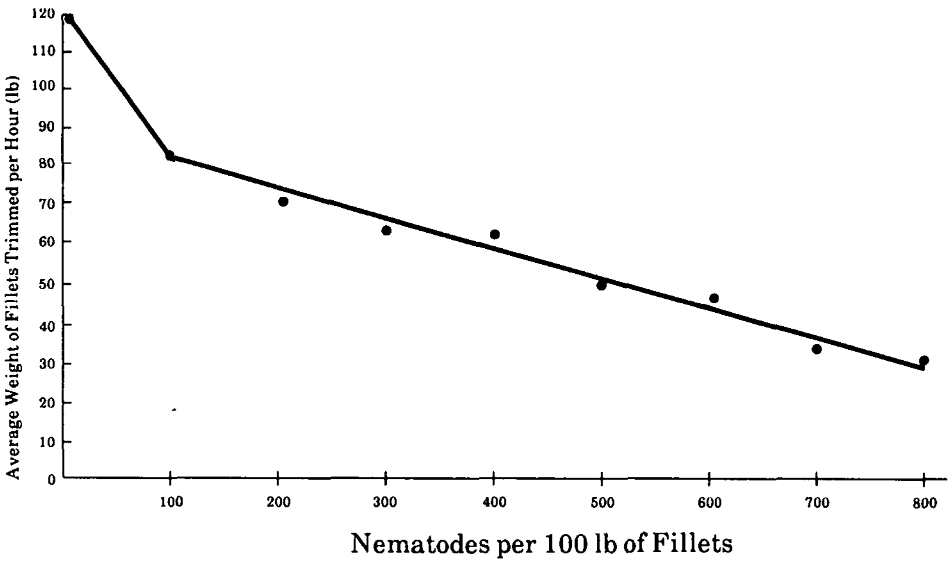
When trimming fillets containing significant numbers of nematodes, processors often cut away the napes (belly flaps) because of heavy concentrations of the parasites. In the past, the napes of cod were routinely discarded, but increases in the price of fish in recent years have made it profitable to retain part of the nape as part of the fillet. The Task Force on Seal Borne Parasites (Canada, DFO, 1983) estimated that removal of highly infected napes reduced the fillet yield by about 10%, or 3.5% of round weight, but reduced the value of the fillet by an amount somewhat less.

Candling does not remove all of the nematodes from fish fillets. At input levels of 500–800 nematodes per 100 pounds of fillets, candling removed 90%–95% of the nematodes at a N.S. plant (O'Neil, 1985), a considerably higher level than the 75%–85% reported by the Task Force. The Department of Fisheries and Oceans has an unofficial tolerance limit of 33 nematodes per 100 pounds of finished product, above which the fish is declared unwholesome and must be downgraded to meal or salted (O'Neil, 1985). At a 95% removal rate, all fish with more than 660 nematodes per 100 pounds of uncandled fillets would be processed as meal or salted.

When dealing with market cod containing large numbers of parasites, a bottleneck occurs in the trimming and candling area that severely affects the plant capacity and increases the costs of the whole throughput operation. Figure 26.5 shows the decrease in throughput with increasing parasite load for a N.S. processing plant (O'Neil, 1985).

Data from Frick (1956) for four groups of filleting plants in the Maritimes in 1954–1955 (Table 26.7), demonstrate that the higher the ratio of candlers to filleters, the lower the percentage of nematodes remaining in fillets. The efficiency of nematode removal at these plants, however, was much lower than that reported by O'Neil (1985). In southern and western Nova Scotia at that time candling in many plants was only intermittent, and a high percentage of nematodes (48%) were not removed. In eastern mainland Nova Scotia, the candler/filleter ratio of 0.33 appeared adequate, resulting in an acceptable level of unremoved nematodes (25/100 lb fillets); it is likely however, that the plants in this area received some cod from the Grand Bank that contained relatively few nematodes and required little candling. In the Gulf of St. Lawrence, the infection density and the candler/filleter ratio were the highest, and the percentage of nematodes remaining in fillets was the lowest (26%); but the numbers of nematodes remaining were the highest (60 per 100 lb).

Figure 26.5
Through-put of a Trimmer at a Nova Scotian Processing Plant



Source: O'Neil (1985).

Table 26.8 summarizes information supplied by one of Nova Scotia's largest fish-processing plants on the costs of candling cod fillets relative to the numbers of nematodes present (O'Neil, 1985). The direct labour costs are given from the time the fish are unloaded until the finished product is frozen (including filleting, candling, trimming and packing); they do not include the costs of indirect labour, such as supervision and administration, or the application of overheads. The direct labour costs increased from approximately $27 per 100 pounds of fillets, at a level of zero infection, to approximately $59 per 100 pounds, at a level of 800 nematodes per 100 pounds. The cod which had the lowest level of infection were caught near Labrador (division 2J); those cod which had higher levels of infection were caught near Newfoundland (divisions 3K, 3L, 3O, 3Ps); and those which had the very high levels were caught on the northern part of the Scotian Shelf (divisions 4Vn, 4Vs, 4W) (O'Neil, 1985). These labour costs are for the removal of all nematode parasites, as it is not possible to provide separate costs for *P. decipiens* alone.

Table 26.7
Numbers of Candlers and Filleters for Cod, and the Nematode Content of Fillets Before and After Candling

	E Cape Breton	E Mainland Nova Scotia	S & W Nova Scotia	P.E.I. & N New Brunswick	All Plants
1955					
No. plants surveyed	7	9	9	9	34
No. filleters	171	251	92	142	656
Production of fillets/ filleter/8-h day	770	800	780	760	780
Ratio of candlers: filleters (cod)	0.71	0.33	0.25	1.41	0.65
Finished product wt. (cod fillets, blocks & sticks) in 1954 (× 1000 lb)	6,267	17,540	3,715	5,627	33,149
1954/1955					
No. plants surveyed	3	3	3	8	17
No. nematodes/100 lb:					
Before candling	120	94	88	233	129
After candling	41	25	42	60	44
Nematodes remaining (%)	34	27	48	26	34

Source: Frick (1956).

It has been argued that the removal of nematode parasites creates jobs in Atlantic Canada (Earle, 1985; McDermott, 1985). As Chapman (1985) pointed out, however, in his testimony for the Fisheries Association of Newfoundland and Labrador Ltd., the cost of removing nematodes from fish comes directly from the gross margin earned by processors. To keep the product competitive with export markets, processors have been dropping their gross margins, and some have been pushed close to, or into, bankruptcy; consequently, prices paid to fishermen have decreased. The cost of nematode removal thus results in lower prices to fishermen.

Table 26.8
Direct Labour Costs for Cod Fillet Production at a Nova Scotia Fish Processing Plant, January–June 1985[a]

Nematodes per 100 lb fillets[b]	Fillets Candled and Trimmed (1000 lb)	Direct Labour Costs ($ per 100 lb fillets)	Costs in Addition to Base Costs at Zero Nematodes ($)	Savings per 100 lb Fillets ($)[c]
800	30	58.9	32.2	–
700	33	54.8	28.1	4.1
600	44	45.6	18.9	9.2
500	50	42.1	15.4	3.5
400	60	37.7	11.0	4.4
300	63	36.3	9.6	1.4
200	70	34.3	7.6	2.0
100	80	31.9	5.2	2.4
0	115	26.7	0.0	5.2

Source: Modified from O'Neil (1985).

a. For filleting, candling, trimming and packing (from unloading to freezing).
b. Values are rounded to the nearest hundred pounds.
c. Calculated as the difference between the dollar values for the upper and next-lower nematode levels.

Other Costs

In addition to the direct labour cost of removal of parasites and the lost yield caused by discarding heavily infected napes, there are several other costs to the fishing industry resulting from the presence of the parasites. There are several ways in which the quality of the fish products may be downgraded as a consequence of the nematodes. Thin slicing of heavily infected fillets for candling results in a less desirable product, and the cutting and the lengthened processing time cause a deterioration in the quality of the fish flesh. Fillets with nematodes remaining in them are sold at lower values than fillets that are virtually nematode free.

Some fish are diverted to lower value packs because adequate removal of parasites cannot be accomplished without the incremental costs exceeding incremental value. Fish may have to be sold in the cheaper block form rather than in the more valuable fillet form, or if the infection levels are too high, the fish may have to be salted or processed as meal. In the Canadian fisheries statistics for 1982, exports of frozen cod fillets were valued at $35 per 100 pounds more than frozen cod blocks (Canada, DFO, 1984). Factors other than the presence of parasites, such as the size and quality of the fillets and the market requirements for fillets or blocks, also enter into the decision concerning which form to produce. Production of blocks may incur considerably more labour costs than production of fillets (Frick, 1956).

According to the Seafood Producers Association of Nova Scotia (1985), no comprehensive study had been made to determine downgrading losses caused by nematodes, but these costs are significant, as are sales lost because of consumer fears. Commercial buyers may also downgrade prices or refuse shipments, ostensibly because of nematodes in the fish; they may, however, be using the presence of parasites as a bargaining lever, in order to purchase the product at a lower price (Canada, DFO, 1983). The result is a lower market value for the fish.

Several additional costs may be associated with candling and trimming. The Task Force on Seal Borne Parasites stated that there were costs attributable to the capital outlay for candling tables and the potential expenses of plant modification to accommodate the candling process, as well as additional costs for training and supervision (Canada, DFO, 1983). George (1986) included an overhead cost to cover variable expenses such as additional workers' wages for processing heavily infected fish; but he discarded the capital costs of candling tables and plant modifications because the annual costs of the candling tables were insignificant, because the candling process would be needed even in the absence of *P. decipiens*, and because fish processing is not a capital-intensive operation.

There are some areas of eastern Canada where *P. decipiens* is so plentiful in fish flesh that it is unprofitable to use the fish commercially for fillets or blocks. In essence, this reduces the area available for commercial fishing. On the Scotian Shelf, for example, cod in the 46–50 centimetre range, caught off the East Bar of Sable Island Bank, contained 1,900 *P. decipiens* per 100 pounds of fillets (McClelland et al., 1983b), and plaice from the Western Bank contained 4,570 *P. decipiens* per 100 pounds of fillets (McClelland et al., 1985). These parasite loads are too high for the fish to be sold as fresh or frozen; instead it must be produced as low-priced saltfish or fishmeal. With the increasing numbers of grey seals and the increasing prevalence of *P. decipiens*, it seems likely that the areas where commercial fishing is unprofitable will be extended.

Total Cost of *P. decipiens* to the Fishing Industry

Atlantic Canada

The Task Force on Seal Borne Parasites (Canada, DFO, 1983) estimated the 1982 cost to the Atlantic fishery for the removal of parasites from cod and the discarding of infected napes of cod to be $29,273,000. Of this total amount, approximately $26,000,000 was attributed to *P. decipiens* and the remainder to the presence of *Anisakis* spp. The incremental labour costs for candling and trimming were estimated at $14,249,000 (Table 26.9). The loss of yield from the discarding of heavily infected napes of cod was estimated to be $15,024,000 (Table 26.10). This calculation was based on assigning the napes the approximate weighted average market price for Canadian cod products in 1982 (Canada, DFO, 1983), which may have resulted in the napes having slightly too high a value.

In a more recent study made for the Royal Commission, George (1986) estimated the costs and losses of revenue incurred during the processing of cod, flatfish and other groundfish from Newfoundland and Nova Scotia as a result of the presence of *P. decipiens* in the fish. His estimate is summarized in Table 26.11, and his detailed calculation is presented in Appendix 26.1. The study is restricted to the costs that can be attributed to *P. decipiens*; it does not include the costs derived from other parasites or other reasons for candling. Included in the total estimate for cod are the cost of candling fillets, and the losses of revenue from the downgrading of fillets and the discarding of napes. For flatfish and other groundfish, the estimate covers the cost of candling.

The total costs attributable to the presence of *P. decipiens* in cod and flatfish from Newfoundland and Nova Scotia were estimated at $26.6 million for 1984 (George, 1986). Costs for Newfoundland cod were estimated at $12.4 million, and costs for Nova Scotia cod and flatfish were estimated at $14.2 million.

The study did not include estimates for New Brunswick, Prince Edward Island or Quebec. Most of the cod and flatfish landed by these provinces inhabit heavily parasitized areas of the Gulf of St. Lawrence; however, the catches of cod and flatfish for these provinces are low relative to those of

Table 26.9
Labour Costs for Candling and Related Trimming Attributable to the Presence of Nematode Parasites in Cod, 1982

Nematode Parasite	Location (NAFO Div.)	Approx. No. of Parasites per 100 lb Fin. Prod.	Finished Product Weight (lb)[a]	Cost of Candling and Labour per 100 lb Fin. Prod.	Total Candling and Trimming Costs
P. decipiens	4VW	250	54,127,000	9.40	$5,088,000
P. decipiens	4RST, 3Pn	150	112,474,000	7.20	8,098,000
P. decipiens	3Ps	40	23,274,000	3.50	815,000
Anisakis	2J, 3KL	22	70,958,000	0,35[b]	248,000
Total labour costs resulting from presence of nematodes					$14,249,000

Source: Adapted from Canada, DFO (1983).

a. Weight after filleting, but before trimming.
b. Incremental cost per 100 lb of napes.

Newfoundland and Nova Scotia. On the assumption that circumstances in New Brunswick, Prince Edward Island and Quebec approximated those in Nova Scotia, it is estimated that the costs attributable to *P. decipiens* for those three provinces would be about $3.1 million, for a total annual cost of $30 million for eastern Canada (Table 26.11).

Some costs have not been included in the estimate prepared by George (1986). They include: the downgrading of heavily infected cod for meal or salting, losses resulting from non-fishing of heavily infected areas, and the costs of a reduction in plant capacity and fillet production because of the plant capacity devoted to trimming and candling. It is not possible to estimate these additional costs.

Other information on costs in Atlantic Canada was provided to the Royal Commission by: the Nova Scotia Department of Fisheries (1985), which estimated that removal of nematodes from cod and plaice added close to $0.20 per pound (1984 dollars) to the processing costs (based on a newspaper interview with a fish processor); by the Fisheries Council of Canada

Table 26.10
Costs of Discarding Napes of Cod Heavily Infected with Nematode Parasites, 1982

Nematode Parasite	Location	NAFO Div.	Napes Discarded (%)	Round Weight (lb)	Cost of Discarding Napes[a]
P. decipiens	NE Scotian Shelf	4VW	40	164,022,000	$3,743,000
P. decipiens	Gulf St. Lawrence, St. Pierre Bank, S Coast Nfld. and adjacent bank	4RST 3P	35	411,359,000	8,214,000
Anisakis	Labrador Shelf, NE Nfld. Shelf, East Coast Nfld. and N Grand Bank	2J 3KL	25	215,024,000	3,067,000
Total for lost yield					$15,024,000

Source: Adapted from Canada, DFO (1983).

a. Based on 3.5% loss of round weight yield at an average price of $1.63/lb.

(1985), which estimated that candling can add up to $0.10 per pound to processing costs; and by the Seafood Producers Association of Nova Scotia (1985), which estimated that the reduced yield and labour costs associated with nematode removal from cod had risen to between $40 and $50 million by 1984.

The magnitude of the problem caused by *P. decipiens* to the Canadian Atlantic fishery has been increasing over the years as the parasite has become more prevalent. The Task Force on Seal Borne Parasites stated that the occurrence of parasites in flatfish was restricted geographically, but expressed concern that the problem in flatfish would increase and become a generalized east-coast problem (Canada, DFO, 1983). The Seafood Producers Association of Nova Scotia stated that they foresee considerable risk of increased costs if seal herds increase still further, and if the recent trends in

Table 26.11
Costs and Losses of Revenue ($million) to Fish Processors in Eastern Canada due to the Presence of *P. decipiens* in Fish, 1984

	Newfoundland	Nova Scotia	Total
Cod: candling fillets	8.46	6.56	15.02
candling napes	0.72	0.33	1.05
downgrading fillets	1.38	3.08	4.46
discarding napes	0.22	0.94	1.16
Flatfish: candling fillets	a	0.61	0.61
Other groundfish: candling fillets	1.40	2.40	3.80
Claims due to excess *P. decipiens*	0.10	0.10	0.20
Training costs	0.15	0.15	0.30
Total costs and losses in Newfoundland and Nova Scotia	12.43	14.17	26.60
Total costs and losses estimated for New Brunswick, Prince Edward Island and Quebec: cod, flatfish and other groundfish			3.09
Total costs and losses in eastern Canada			29.69

Source: Adapted from George (1986).

a. Flatfish landed in Newfoundland are not significantly affected by *P. decipiens*.

parasite prevalence and geographical expansion of both seals and *P. decipiens* infections continue.

Pacific Coast

This chapter has concentrated on the costs of *P. decipiens* to the Canadian Atlantic fishery because of the magnitude of that problem. Information on the problem on the Pacific coast is available from the Prince Rupert Fishermen's Cooperative Association (PRFCA, 1985). Candling of fillets of cod, halibut, rockfish, ocean perch, sablefish and other species of fish in order to remove parasites (mainly *P. decipiens*) costs the Cooperative \$100,000–\$200,000 annually in labour costs and reduced yield. At times, fish cannot be marketed because of the nematodes. Whole deliveries of groundfish have been rejected for market and have had to be reduced to fishmeal. Major losses have not been incurred in the processing plants, but they have occurred in the market place through loss of customers and decrease in product value. The estimated total loss to the B.C. fishing industry from parasites is potentially in excess of \$1 million according to PRFCA (1985).

Northeast Atlantic

The ICES (1979) working group on interactions between grey seal populations and fish species noted that high levels of *P. decipiens* in cod added a great economic burden to the fishing industry in Scotland and elsewhere. The Royal Norwegian Ministry of Fisheries (Øritsland, 1985) stated that the most severe seal-related problems and economic losses to fishermen and processors in Norway were caused by the presence of *P. decipiens* in fish.

Options for Dealing with *P. decipiens* Infections

The increasing prevalence of *P. decipiens* in fish flesh is clearly causing a major problem for the Canadian Atlantic fishing industry, and it would be highly desirable if the numbers of *P. decipiens* could be reduced. Several options have been suggested to reduce the infection rates of *P. decipiens* and/or to combat the problem through changing fishing practices or fish-processing methods.

Reduction of Seal Populations

Reduction of seal populations is the most frequently suggested option to reduce *P. decipiens* infections in commercial fish, given the assumption that more seals mean more nematodes and vice versa. The chief target for suggested culling is the grey seal, because it is the main final host for *P. decipiens*, and because its numbers have been increasing dramatically in the last 20 years.

A limitation to seal culling is that small numbers of seals are capable of maintaining high incidences of *P. decipiens* in cod, at least in some circumstances. The cause appears to be the wide-ranging habits and high parasite loads of some seals, and the high fecundity of adult female *P. decipiens* (Scott and Martin, 1959; McClelland, 1980; Beck, 1983). In addition, migrating stocks of cod may acquire their parasite loads in distant areas (Scott and Martin, 1959; Platt, 1975). A reduction in seal numbers would probably need to be of a considerable size before any effects could be observed in the numbers of *P. decipiens* in fish.

Another major uncertainty is the relative contribution of harp seals to infections of commercial fish by *P. decipiens*, as compared to the contribution by grey seals, the usual target suggested for culling.

A scientific working group of the International Council for the Exploration of the Sea (ICES, 1981) concluded, with reference to grey seals in the United Kingdom, that it was impossible to say whether levels of seal-borne infection by *P. decipiens* would show a significant reduction after a reduction in seal numbers, because of the high fecundity of the parasite and the existence of alternate hosts. The Committee on Seals and Sealing (COSS, 1985), while recognizing in its brief that the grey seal appears to play a significant role in transmission of *P. decipiens* to commercial fish stocks, believed that it was not clear whether the parasite would find a substitute host if action were taken to reduce drastically the number of grey seals. COSS called for more work on methods of controlling the transmission of parasites and of removal of parasites from fish fillets, rather than assuming that the problem would be solved by eliminating the grey seal.

May (1985), in testimony for the Department of Fisheries and Oceans, suggested that "the only way to find the answer would be to do it" (i.e., control grey seals). Earle (1985) suggested that "before the adoption of such drastic management schemes, experiments should be conducted on a limited scale to determine the effects that altering seal population levels would have, both on the incidence of anisakids in commercial fish, and on the productivity of the seal population." These experiments could include long-term monitoring of the incidence of *P. decipiens* in seal and fish populations in areas where seals have and have not been reduced, along with life-history studies on the seals in both sets of areas.

Control through Eggs, Larvae or Invertebrate Hosts

Most of the detailed knowledge of *P. decipiens* infections in intermediate hosts has been gained from laboratory experiments (McClelland, 1982; McClelland et al., 1983a) in which high infection rates were induced in copepods (from one to 39 nematodes per copepod with averages as high as 18) and an amphipod species (100% infection with an average of 60 nematodes per amphipod). *P. decipiens* is found much less frequently, however, in natural samples taken at sea. A sample of 2,000 amphipods taken from the sea produced only three that were infected, each with only a single *P. decipiens* larva (McClelland, 1982; McClelland et al., 1983a). In the Bras d'Or Lakes, 8,000 mysids were found to contain 110 nematodes, of which only one was definitely identified as *P. decipiens* (Scott and Black, 1960). In an area near a large Norwegian grey seal colony, Bjørge (1979) found one *P. decipiens* larva in 84 specimens of the isopod *Idothea neglecta* that were taken in good condition from cod stomachs. The larval stages of *P. decipiens* are thus comparatively scarce in their invertebrate intermediate hosts under natural conditions and are unlikely to be harming these hosts through being too numerous in them.

Chemical or physical control of these small invertebrate hosts is impractical, because of their vast numbers and wide distribution, and because *P. decipiens* does not appear to be limited to one or a few such species. Chemical or physical control would also adversely affect other organisms, including commercial crabs, shrimps and lobsters, and the food species of many fish.

It might be more practical to conduct research into methods for destroying possible concentrations of eggs and larvae of *P. decipiens* attached to the bottom substrate near seal colonies, but it would be necessary first to determine whether such concentrations exist.

Control through Small-Fish Hosts

Smelt, which spend most of their marine life in sheltered coastal locations that are often near harbour seal colonies, are heavily infected with

P. decipiens (Scott, 1954; Templeman et al., 1957). Further research on these and other small fish that may act as intermediate hosts could be carried out near seal colonies and elsewhere. Depending on the results, it might be possible to fish these small fish intensively in order to reduce the population of *P. decipiens*. Such a practice would probably be effective only for localized infections, however, and it could have unwanted effects on larger fish or other species that feed on these small fish.

Alteration of Fishing Practices

It has been suggested that in European waters, fishing be directed toward larger and older fish because larger cod have fewer nematodes per unit weight of fillet (Young, 1972). Although the same is true of American plaice in Canadian waters, cod fillets tend to contain increasing numbers of *P. decipiens* larvae per unit weight as their size increases (McClelland et al., 1983a, 1983b, 1985). Thus there is an advantage in taking smaller cod in areas of high infection rates in Canadian waters. It is also much easier to detect and remove the parasites from smaller cod fillets. The disadvantages of doing so include: the capture of small, heavily infected plaice in the small-mesh fishing gear required to take smaller cod; the reduced desirability of small fish to the fishing industry as a source for fillets or salt fish; the reduced total biomass available for commercial fishing; and the reduced recruitment to the spawning population of fish.

Alteration of Fish-Processing Methods

Routine removal of the napes from fish during processing would eliminate some of *P. decipiens* and the majority of the flesh-dwelling *Anisakis*. Better candling techniques, including development of sophisticated ultrasonic or laser detection technology to detect which fish contain nematodes would reduce the parasites in the final product (McClelland et al., 1983a), and reduce costs by enabling processors to concentrate on infected fish. The Task Force on Seal Borne Parasites (Canada, DFO, 1983) described a German technique that combines ultrasound with computer video equipment which can detect, locate and remove nematodes automatically. The Task Force suggested that modern, modified or new technologies be investigated with respect to their effectiveness and costs in removing nematode infections from commercial fish. However, these mechanized methods may be too expensive for small plants to undertake; and even with the best methods the costs will remain high.

Discussion

It is clear from the foregoing information that the presence of nematode parasites in the flesh of fish adds appreciably to the costs of fish processing , and reduces the value of the product. The total cost for Atlantic Canada is at least $30 million annually. It is also clear that there is a high positive association, in both space and time, between high densities of seals, especially grey seals, and high levels of *P. decipiens* infection in fish. From knowledge of the life history of the parasite, it appears highly probable that if there were no seals, there would be so few *P. decipiens* in fish flesh that the economic impact would be close to zero.

Reducing seal populations to a level so low that extinction is a possibility is not a management option that would be acceptable to the Canadian people as a whole, nor is it one that any representative of fishing interests appearing before the Royal Commission has suggested as being desirable. The options open for managing seal numbers are, therefore, either to do nothing and allow seal stocks to increase to levels governed by natural conditions, plus whatever hunting that that course of action might permit, or that might be economically viable; or to establish a level of cull aimed at bringing the seal population to, and maintaining it at, some level below the natural equilibrium.

Grey seals, the main final host, are now increasing rapidly, despite a cull on some of the colonies. (See Chapter 21.) There is no reliable information on the level of abundance that they would reach if there were no cull, though it could be considerably higher than at present.

The effect of such an increase in grey seals on the prevalence of parasites and on their economic impact is equally uncertain. It is conceivable, given the uncertainty about the dynamics of *P. decipiens*, that the degree of infection in certain areas is already at, or approaching, limits set by natural factors other than seals, so that the effect will be minor. It is more likely, however, that higher numbers of seals will result in a considerable increase in infection rate and in related economic loss. It is even possible that the rate of infection, for increasingly larger fishing areas in eastern Canada, would rise to such a level that the costs of processing would be so high and the value of the ultimate yield so low, that it would no longer be worthwhile for fish companies to buy the principal species of groundfish from these areas for processing fresh.

There is no way, at present, to distinguish among this range of possibilities. What can be said, though, is that to allow the stocks of grey and other seals to increase up to an unknown biological limit would pose an additional risk, unquantifiable but probably not negligible, to the fishing industry in a large part of eastern Canada.

If the alternative policy of carrying out a cull is adopted, the choice of cull level will depend on the relationships between the cull and the number of seals in the stock, and between the number of seals and the economic losses caused by parasites.

The first factor is discussed in Chapter 29; the second needs to be examined in two stages: the relationships between the number of seals and the degree of infection, and between the degree of infection and the economic loss. Neither relationship is likely to be directly proportional.

The information available on the relationship between parasite infection rates and economic loss (Tables 26.8 and 26.9) shows that it is desirable to reduce the numbers of parasites at the higher levels of parasite density. Additional costs, including downgrading, loss of plant production, market acceptability and loss of fishing areas are greatest at the higher nematode levels.

The relationship between infection rate and numbers of seals is far less clear. The dynamics of a parasite with several intermediate hosts are complicated, and it is unlikely that the frequency of parasites in one host (e.g., cod) will be related in any simple way to the abundance of one of the other hosts (e.g., seals). The abundance and variety of the intermediate hosts should allow differences in various areas between the infection rates of *P. decipiens* in fish and the numbers of seals. Greatly fluctuating populations of pelagic fish such as herring and capelin that are not infected with *P. decipiens*, may replace, to a greater or lesser extent, groundfish infected with this nematode in the food of the seal, thus leading to fewer *P. decipiens* in the seal's stomach. Depending on the relative amounts of pelagic fish and groundfish eaten, *P. decipiens* may be displaced or crowded out of the seal's stomach by other nematodes, as suggested by McClelland et al. (1985). Moreover, depending on the number of adult *P. decipiens* in seals, there may be differences in the number of the larvae of this nematode in groundfish and vice versa.

The factors that determine the frequency of occurrence of the parasite in the flesh of fish, and how this frequency might be related to the abundance of seals are not clear. There is a considerable literature on the dynamics of the host-parasite system (Anderson and May, 1982; Anderson, 1980). The literature deals mostly with situations where the interest is in the well-being of the final host – humans or their domestic animals – and in methods of control aimed at reducing an intermediate host, for example, the malaria mosquito or the snail that carries the bilharzia parasite, to as close to extinction as possible. The direct relevance of the available literature to the problem of controlling infection in an intermediate host by some control, but not too drastic a control, of the final host is therefore limited.

The available information does, however, provide some insight into the patterns likely to be occurring in the *P. decipiens*–crustacean–fish–seal systems. First, the relationships, for example, between rate of infection in fish and seal abundance, are unlikely to be simple. A proportional relationship is possible, but it is equally likely that changes in seal numbers over the moderate range likely to be acceptable in practice may have very little effect on infection.

Secondly, the host that is likely to have the greatest effect on the dynamics of the system as a whole is the one in which the parasite spends the longest time (Anderson, 1985), that is the fish. If this supposition is true, it suggests that measures to modify the abundance and age structure of populations of cod and other fish may be more effective in controlling infection than the culling of seals. In particular it might be desirable, in areas where infection is a serious economic problem, to consider fishery-management plans which are aimed at a low density of predominantly small fish so that the build-up of parasites in fish, and their transmission through fish to seals and to the next generation of parasites, are reduced. This type of manipulation would be directly opposed to current fishery-management objectives, and it would not necessarily be an effective alternative. For example, *P. decipiens* can become sexually differentiated in its amphipod host and may reach the stage in the amphipod where it may be directly infective to seals, completing its life-cycle without a fish host (McClelland et al., 1983a). The relative importance of this pathway is, however, unknown.

There is far too little information available on these subjects, and it is premature to suggest any modification to existing fishery management plans. A brief examination of the theory of host-parasite dynamics does suggest however, that the possibility exists of limiting parasite damage by other means than that of controlling seals, even though, on currently available information, the latter is the most promising.

A priority must be to conduct more research on the intermediate hosts. This should include further studies on infections of intermediate hosts and the distribution of parasite larvae on the bottom substrate. It is also necessary to collect more information on the degree of infection in fish as related to the age and size of fish, since age can be a significant factor (e.g., Grenfell and Anderson, in press). This research needs to be linked to theoretical studies and modelling of cod–seal–parasite dynamics. Since Iceland, Norway and the United Kingdom are facing the same problem, and the United Kingdom, at least, is considering increased research, it would be highly desirable to integrate future Canadian research on this topic with research on the other side of the Atlantic. This would be particularly desirable and cost effective for the theoretical studies, which should, if possible, be based on existing theoretical host-parasite studies.

Despite these uncertainties, and until further studies are carried out, it is still desirable to consider to what extent the degree of infection is likely to change with changes in seal abundance, either through natural increases or through reductions as a result of a cull. A number of relationships between seal abundance and infection rate in fish are possible. Though a directly proportional relationship cannot be rejected, the most plausible relationship would be a family of S-shaped curves, with infection rate increasing relatively slowly with increasing seal numbers except over a critical range. This curve could have a wide critical range and some change in infection rate with increasing seal abundance, both above and below it. The changes might, on the other hand, be much more abrupt, and most changes in the equilibrium infection rate might occur over a narrow range of seal abundance. In the latter case reductions in seal abundance would have little effect on infection rates, and hence on losses, unless these reductions brought the abundance of seals from above to below the critical level.

In eastern Canada, many of the main groundfish species infected by *P. decipiens* can be identified as stocks. The mature fish are distinct at spawning time, but during feeding seasons and when immature, they overlap somewhat with adjacent stocks of the same species. Grey and harbour seals, too, are more or less localized, with less than complete mixing between areas. These differences are reflected in the different levels of infection and hence different costs of infection in different areas. The effects of changing the overall abundance of seals might therefore be expected to be different in different areas. In some areas, the local density of seals may be near the critical level, above which the infection of fish becomes a problem, assuming that such a level exists, and a small change in seal numbers could result in a large change in infection rate. In other areas, the density may be well above or below the critical level, and small changes in seal numbers would have little effect on infection or on processing losses.

In one sense, these regional differences might simplify management because, if the effects of changes in overall seal numbers are averaged over a number of areas, it becomes more likely that the relationship between infection and losses will be reasonably close to proportional. In another sense, however, management becomes more complex. If the desire is to have the biggest effect on the losses, while at the same time minimizing the costs of management, including the numbers of seals that might have to be culled as part of the management program, then it will be important to concentrate on those particular areas and groups of seals where the benefits will be greatest.

The question of reducing seal populations is considered further in Chapters 29 and 30.

Conclusions

1. Several species of nematode parasites, principally *Pseudoterranova decipiens,* but also *Anisakis* spp., occur in the flesh of cod and other commercial fish in Canadian waters.

2. *Anisakis*, and to a lesser extent *P. decipiens*, can produce the disease Anisakiasis in humans, usually through eating raw fish. Given the usual methods of preparing fish in Canada, this disease is likely to occur very rarely.

3. Marine mammals are the final hosts of these nematodes, which pass through crustaceans or other invertebrates before infecting fish. Seals, especially grey seals, are the most important final hosts for *P. decipiens*. Cetaceans are more important for *Anisakis*.

4. There are strong correlations, on both sides of the Atlantic, between areas of high density of seals, especially grey seals, and infection rates in fish. During the last 30–40 years there have been parallel trends of increasing numbers of grey seals and rates of parasite infection. Both sets of data suggest that increases in seal populations will result in increased infection.

5. The presence of nematodes in fish flesh causes losses to the fishing industry due to the increased processing costs involved in detecting and removing the nematodes and the reduced value of the final product. The current extent of these losses is estimated at over $30 million annually on the Atlantic coast. Smaller losses occur on the Pacific coast. Losses increase with increasing infection, but probably not proportionately.

6. In many areas of eastern Canada where *P. decipiens* is plentiful, catches of cod are rejected for filleting because removal of the parasite is costly, and nematode numbers would exceed Department of Fisheries and Oceans tolerance levels even after candling. The rejected fish are either salted or sent to a meal plant. These practices result in considerable losses, both for processing plants and for fishermen. The American plaice that are caught in some areas near Sable Island are so highly infected that they could not profitably be candled for sale as fillets.

7. Modern methods for the detection and removal of nematodes from fish flesh may have promise for extracting a higher proportion of these parasites and for reducing costs. However, these mechanized methods may be too expensive for small plants to undertake; and even with the best methods, the costs will remain high.

8. Because of the lengthy life-cycle of *P. decipiens*, it may be many years before changes in seal numbers, or other factors that might affect the dynamics of the parasite population, are fully reflected in the infection rate in fish.

9. Though the dynamics of the *P. decipiens*–fish–seal system are not well understood, it is highly likely that increased numbers of seals will result in increased infection, and increased infection will result in increased losses, possibly including increases in the extent of the areas in which commercial fishing for the fresh fish trade for some species is impracticable. Grey seal numbers are increasing, and this is likely to increase losses above the present level.

10. There is no sure way, with present knowledge, to reduce the rate of infection. It is possible that changing the abundance or the size and age composition of the fish populations, or actions aimed at other intermediate hosts might be effective. On present evidence, however, the measure offering the best chance of success would be to reduce the number of seals, especially grey seals. A considerable reduction in seal numbers would probably be needed before any demonstrable effect could be observed in the numbers of *P. decipiens* in fish.

Recommendations

1. Further research on all aspects of the *P. decipiens* problem is urgently needed, particularly to establish more reliably the likely form of the

relationship between the numbers of seals of different species and the frequency of infection, and between infection rate and losses to the industry. Areas of research that seem likely to be useful include: studies of the occurrence of parasites in harp seals; studies of the changes in frequency of occurrence with age or size of fish; detailed study of the geographical distribution of parasites in fish and seals; and the development of models of the dynamics of the seals–fish–parasite system. Consideration should be given to experimental control of seals in a small area in order to gain more insight into the dynamics of the *P. decipiens* problem.

Appendix

Appendix 26.1 Costs and Loss of Revenue Suffered due to *P. decipiens*, 1984

		Units	Nfld.	N.S.	Total
Cod					
1.	Proportion of landings from high infection areas		.09	.46	.21
2.	Napes as proportion of fillets		.10	.10	.10
3.	Fillets from all areas	lb M	153.47	66.98	220.45
4.	Fillets from high-infection areas (1×3)	lb M	13.81	30.81	43.62
5.	Napes from all areas (2×3)	lb M	15.35	6.70	22.05
Candling of Fillets					
6.	Direct labour costs per lb	$	.05	.08	.06
7.	Direct labour costs (3×6)	$M	7.52	5.36	12.88

Appendix 26.1 Costs and Loss of Revenue Suffered due to *P. decipiens*, 1984 (continued)

		Units	Nfld.	N.S.	Total
8.	Proportion of direct labour costs attibutable to *P. decipiens*		.90	.98	.93
9.	Direct labour costs attributable to *P. decipiens* (7×8)	$M	6.77	5.25	12.02
10.	Variable overhead costs as proportion of direct labour costs		.25	.25	.25
11.	Variable overhead costs (9×10)	$M	1.69	1.31	3.00
12.	Total costs (9+11)	$M	8.46	6.56	15.02
Candling of Napes					
13.	Proportion candled if no parasites other than *P. decipiens*		.75	.50	.67
14.	Napes candled (5×13)	lb M	11.51	3.35	14.86
15.	Direct labour costs per lb.	$	.05	.08	.06
16.	Direct labour costs (14×15)	$M	.58	.27	.84
17.	Variable overhead costs as proportion of direct labour costs		.25	.25	.25
18.	Variable overhead costs (16×17)	$M	.14	.07	.21
19.	Total costs (16+18)	$M	.72	.33	1.05
Downgrading of Fillets					
20.	Proportion from high infection areas downgraded		.25	.25	.25

Appendix 26.1 Costs and Loss of Revenue Suffered due to *P. decipiens*, 1984 (continued)

		Units	Nfld.	N.S.	Total
21.	Fillets downgraded (4×20)	lb M	3.45	7.70	11.16
22.	Loss of value per lb	$	.40	.40	.40
23.	Loss of value (21×22)	$M	1.38	3.08	4.46
Discard of Napes					
24.	Proportion discarded (balance after deducting 15)		.25	.50	.36
25.	Napes discarded (5×24)	lb M	3.84	3.35	7.19
26.	Current price/lb	$	.64	.64	.64
27.	Price/lb fall if none discarded	$	.13	.13	.13
28.	Price/lb if none discarded (26 – 27)	$	.51	.51	.51
29.	Revenue lost from discarded napes (25×28)	$M	1.96	1.71	3.66
30.	Gain due to present enhanced price caused by discard (14×27)	$M	1.50	.44	1.93
31.	Net revenue lost (29 – 30)	$M	.46	1.27	1.73
32.	Direct labour saved by not candling (15×25)	$M	.19	.27	.46
33.	Variable overhead saved by not candling (17×32)	$M	.05	.07	.11
34.	Net revenue lost (31 – 32 – 33)	$M	.22	.94	1.16
Flatfish					
35.	Fillets	lb M	–	13.65	13.65

Appendix 26.1 Costs and Loss of Revenue Suffered due to *P. decipiens*, 1984 (continued)

		Units	Nfld.	N.S.	Total
36.	Direct labour costs of candling per lb	$	–	.06	.06
37.	Direct labour costs (35×36)	$M	–	.81	.81
38.	Proportion of direct labour costs due to *P. decipiens*		–	.60	.60
39.	Direct labour costs due to *P. decipiens* (37×38)	$M	–	.49	.49
40.	Variable overhead costs (19×43)	$M	–	.12	.12
41.	Total costs (39+40)	$M	a	.61	.61
	Other Groundfish				
42.	Fillets	lb M	35.00	60.00	95.00
43.	Costs per lb	$	.04	.04	.04
44.	Total costs (42x43)	$M	1.40	2.40	3.80
	All Groundfish				
45.	Claims due to excessive *P. decipiens*	$M	.10	.10	.20
46.	Cost of training candlers	$M	.15	.15	.30
	Summary				
47.	Candling fillets of cod (12)	$M	8.46	6.56	15.02
48.	Candling napes of cod (19)	$M	.72	.33	1.05
49.	Downgrading fillets of cod (23)	$M	1.38	3.08	4.46
50.	Discard of napes of cod (34)	$M	.22	.94	1.16

Appendix 26.1 Costs and Loss of Revenue Suffered due to *P. decipiens*, 1984 (continued)

		Units	Nfld.	N.S.	Total
51.	Candling flatfish (41)	$M	a	.61	.61
52.	Candling other groundfish	$M	1.40	2.40	3.80
53.	Claims due to excess P. decipiens (45)	$M	.10	.10	.20
54.	Training costs (46)	$M	.15	.15	.30
55.	Total costs & losses (47 to 54)	$M	12.43	14.17	26.60

Source: Adapted from George (1986).

a. Flatfish landed in Newfoundland are not significantly affected by *P. decipiens*.
M = 1 million.

Sources of Data and Notes on Computations

1. From data supplied to Atlantic Steering Committee on Parasites (ASCP) by processors.
2. From Task Force on Seal Borne Parasites (Canada, DFO, 1983, p. 4). and processing companies.
6. From processors.
8. An arbitrary assessment to recognize that some (a minor part) of direct labour costs may be attributed to *Anisakis*. A greater proportion of parasites in fish landed in Newfoundland is *Anisakis* than is the case in Nova Scotia.
10. From processor. When a badly infected batch of fish arrives in a plant, processing takes longer and variable overhead costs, such as wages of workers not on the production line, are greater than they would be for a good batch. It is appropriate, therefore, to assign such variable overheads. However, no provision is made for fixed costs. The frames used for candling are cheap, and their annual cost is insignificant. Moreover it appears unlikely that building size would have been greater to accommodate the frames. In any event, frames would usually have to be installed to candle for *Anisakis* and grubs. Further, fish processing is not a capital-intensive operation, and all fixed costs only amount to about two cents per pound of processed fish.
13. Based on data supplied to ASCP by processors, but Newfoundland figure has been increased since *Anisakis* is the main cause of napes of cod from Area 2J and 2KL being discarded.
15. From estimates supplied by fish processors to ASCP. The figure for Newfoundland was 25 cents, but since this referred to cod from an area as free of *P. decipiens* as any, and as

Appendix 26.1 Costs and Loss of Revenue Suffered due to *P. decipiens*, 1984 (continued)

Newfoundland cod is generally less infected than cod landed in Nova Scotia, it was assumed that most of this cost derived from *Anisakis*.

20. From data supplied by a fish processor to ASCP.
22. See item 20.
26. See item 20.
27. Estimate of fall in market price of processed napes if supply were increased as a result of processing all napes.
30. Napes presently marketed fetch a higher price because supply is restricted by *P. decipiens*.
36. Assumed to be same as for cod (line 8).
37. Processor's estimate for Nova Scotia. No entries appear in lines 35–41 for Newfoundland because *P. decipiens* is not present to a significant extent in flatfish landed in that province.
38. Estimate. The remaining 40% is assumed to be attributable to grubs, which occur in great quantities in flatfish landed in Nova Scotia from some fishing areas.
45. Based on experience of processor.
46. Estimate of processor.

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PART VI

Management Issues

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Chapter 27

Objectives of Resource Management

Good management requires clear objectives. Contrasting views about objectives were presented in evidence to the Royal Commission. Some of those giving evidence viewed seals primarily in economic terms, as a resource to be managed in order to maintain a high economic return either from the sale or direct consumption of seal products, or from fisheries (e.g., Government of Newfoundland and Labrador, 1985; Indigenous Survival International, 1985). Others believed that seal management should be more concerned with the seals themselves, and that interference should be kept to a minimum (e.g., Bøe, 1985; T.H. Scott, 1985). The choice and balance between such objectives must be a political decision, but this decision will be helped by an examination of some principles of resource management and of the specific objectives that might be pursued if seal management is viewed primarily in economic terms. The latter examination is divided between objectives in managing a single species and the broader questions of what has been called "ecosystem management".

Management and Conservation Principles

Many organizations have stressed the importance of conservation principles as part of management policy. A rational consideration of all the issues involved in the conservation of seals as a resource leaves no doubt that management policies must be consistent with sound conservation principles; the connection is emphasized by briefs and by the statements made by intervenors to the Royal Commission (e.g., de Haes and Miller, 1984; Hummel, 1984; Fox, 1985).

The International Union for the Conservation of Nature and Natural Resources (IUCN) is an international organization with individual members in 115 different countries (R.F. Scott, 1985). Canada is one of close to 60 countries which are members, and over 120 government agencies, including several from Canada, are also members. The membership also includes almost 340 non-government organizations, both national and international. The World Conservation Strategy prepared by the IUCN, with the support of the United Nations Environment Programme, the World Wildlife Fund, the Food and Agriculture Organization of the United Nations and the United

Nations Educational Scientific and Cultural Organization, defines conservation as:

> *... the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations (IUCN, 1980).*

The World Conservation Strategy recognizes that sustainable utilization of species is compatible with conservation. Such utilization, however, must be based on a scientifically justified management plan.

The World Conservation Strategy sets out three explicit objectives in resource conservation. They are:

- to maintain essential ecological processes and life-support systems on which human survival and development depend;
- to preserve genetic diversity;
- to ensure the sustainable utilization of species and ecosystems.

In considering seals as a harvestable resource and analysing the management approaches to their conservation, the Royal Commission has taken account of the view that seals should be looked upon as more than mere sources of meat, skins and oil. Clark (1981, p. 104) states that "Objectives leading to the overexploitation of species or the unwise use of the physical and other resources they provide receive little sympathy" and that "An approach to the natural world which views it simply as a supermarket is likely to lead to poor conservation and management..."

The International Council of Environmental Law (ICEL, 1985) fully endorses the principles set forth in the World Conservation Strategy. Its concern is primarily "to ensure that the taking of seals in the Canadian Arctic is so carried out as not to endanger the sustained viability of species or populations and not to impose significant distortions on the ecosystems of which the seals taken form a part." ICEL directed the Royal Commission's attention to Principle 4 of the World Charter for Nature adopted by the General Assembly of the United Nations on 29 October 1982 which states:

> *Ecosystems and organisms, as well as the land, marine and atmospheric resources that are utilized by man, shall be managed to achieve and maintain optimum sustainable productivity, but not in such a way as to endanger the integrity of those other ecosystems or species with which they co-exist.*

The World Wildlife Fund (Canada) brief to the Royal Commission, recognizing that utilization of seals is compatible with their conservation, lists the following prerequisites for such utilization: that the total allowable catch not endanger the herd, that waste be avoided and that, if seals are killed, they are killed humanely (Hummel, 1984).

The Committee on Seals and Sealing (COSS) advises the Minister of Fisheries and Oceans. In its brief to the Royal Commission, COSS (1985) restates its basic guideline, adopted when the committee was established in 1971, that the killing of seals must be humane, ecologically sound and economically viable. COSS sees no reason to change these requirements, as it considers them a sound basis for the management of the harp seal as a natural resource.

These viewpoints are incorporated in Canadian government policy as stated in the Department of Fisheries and Oceans brief to the Royal Commission:

> *Seals are considered a natural renewable resource available to be humanely harvested within the limits of sound conservation principles, taking into account its role in the ecosystem, with the objective of gaining the maximum socio-economic benefits for Canadians in general, and those who depend directly on the resource in particular (Canada, DFO, 1985).*

The Royal Commission accepts the principles of management set forth in these declarations of national and international organizations.

In order to move from these general principles to more specific objectives relating to the numbers of seals that should be allowed to be killed, or a target level of total seal abundance, it is helpful to look first at the individual species or stock of seals (i.e., to undertake single-species consideration) and then at these species in their environmental setting.

Single-Species Harvest

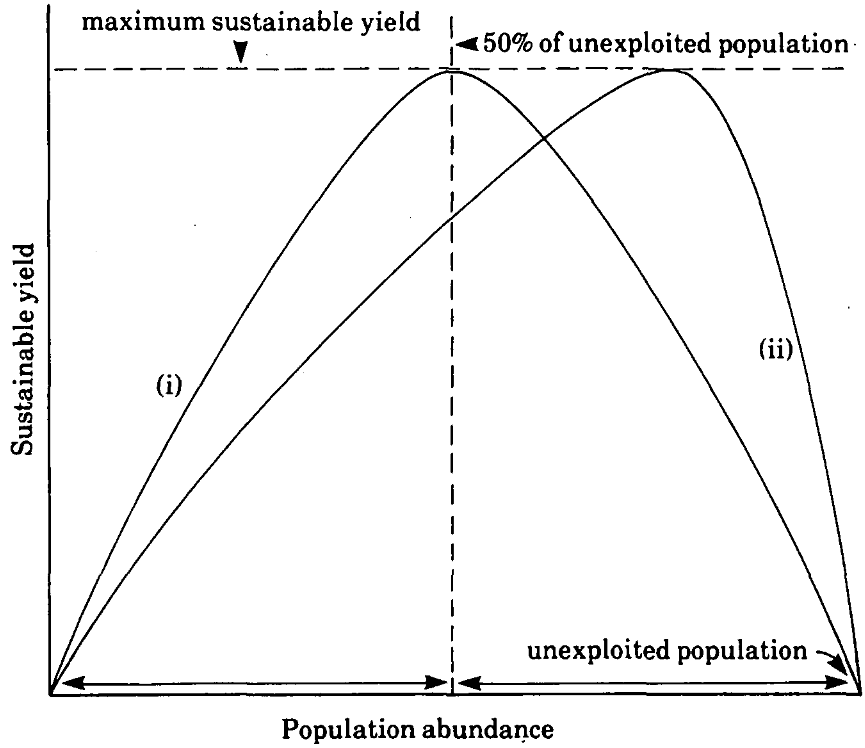
Correct management policy and appropriate target levels of population have been extensively considered in relation to commercial fisheries (e.g., Gulland, 1968; Roedel, 1975; Larkin, 1977). If these fisheries concentrate on harvesting a single species, reasonably direct and simple relationships can be predicated between the amount of fishing, the abundance of the stock and the sustainable yield. The abundance of the stock declines steadily with increasing fishing. The sustainable yield is small if fishing is light and abundance high, as well as when fishing is very intense and abundance low. It reaches a maximum (that is, the maximum sustainable yield, or MSY) at intermediate levels of fishing and stock abundance. For marine mammals the population level giving MSY is often at, or slightly above, half the unexploited abundance.

The sustainable yield exists because the population responds to exploitation. In the absence of harvesting, the population will be in some rough balance with the carrying capacity of the environment, and the number of births will be equal - at least as an average over time - to the number of deaths from disease, predation and other natural causes. Standard ecological theory holds that if harvesting reduces the population below this equilibrium level, conditions will be rather more favourable for the surviving seals. Their effective reproductive rates will increase or their natural mortality rates will decrease, or both, so that there will be a surplus of births over deaths arising from natural causes and a tendency for the population to increase. If the number of seals killed by humans equals this natural increase, the population will remain unchanged and that level of yield will be sustainable indefinitely.

At very large population sizes, the rate of increase will be small, with the result that the sustainable yield will be small. It will also be small at very small population sizes. It will stand at its maximum (MSY) at some intermediate point, with a moderate-sized population. (See Figure 27.1.)

The population level at which MSY occurs, expressed as a proportion of the initial unexploited population, will depend on the nature of the response of the population to changes in abundance. Assuming a simple linear

Figure 27.1
Two Theoretical Sustainable Yield Curves



response, that is, a rate of increase that decreases linearly with increases in population abundance, MSY will occur at exactly half the population. (See Figure 27.1, curve (i).) It is commonly believed (see, for example, many contributions to the Scientific Committee of the International Whaling Commission) that MSY for marine mammals occurs at a higher population level because the response is uneven and concentrated at the higher levels of abundance. (See Figure 27.1, curve (ii).)

The sustainable yield, expressed as actual numbers, from a stock of seals, will, for a given population size, depend on what ages and sexes of seals are harvested. An adult female will contribute more to the population in its next few years of life than a pup, which may not breed for five or six years. Killing a given number of females will therefore have the same impact on the population as killing a substantially larger number of pups, which means that the sustainable yield of seals taken as pups is larger than the sustainable yield of adults. The precise arithmetical equivalents for a range of situations are calculated in Chapter 21, Appendix 21.1. For animals that maintain harems, such as fur seals and sperm whales, the situation is more complicated. Provided that enough males are left to satisfy the females, an appreciable number of males can be taken without reducing the breeding rate or the number of pups born. (See Chapter 22.)

Taking MSY while keeping the population at the MSY level is an obvious management option, and one that has been written into a number of fishery-management agreements. It does have disadvantages, however, and it is now generally rejected as a preferred management objective (Larkin, 1977). If, for example, the stock abundance varies because of environmental changes, attempts to take exactly MSY each year can lead to dangerous instability. Maintaining the population at a level a little above that which produces MSY can reduce this risk and has other benefits, such as higher catches per unit effort and hence better economic performance.

It has therefore become common to consider the population that produces MSY as a lower limit of the acceptable target level, and to aim for what has been called "optimum yield" and the "optimum sustainable population" (OSP). This concept is entrenched in the United States *Marine Mammal Protection Act of 1972*, which is an ambitious attempt to codify national policy for the management and conservation of marine mammals and is relevant to Canadian policy considerations. Section 3(9) of that Act defines optimum sustainable populations as "the number of animals which will result in the maximum productivity of the population of species, keeping in mind the optimum carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element". If productivity means "net productivity" in the sense of the amount produced less natural losses, it seems to be equivalent to MSY. If it means gross production, that is the total number of births, it probably occurs at the maximum, unexploited, population abundance.

In practice, OSP and the U.S. legal requirement that populations not fall below OSP have been interpreted as designating a range extending upwards from MSY, which means that the population should be maintained at the level giving MSY or at a higher level. Because the maintenance of a population at the OSP or within OSP range is a legal requirement in the United States, it is of both theoretical and practical interest. It affects, for example, any question of exporting marine mammal products to the United States. Since a population might be maintained at a level well above that producing MSY, and since at that level the sustainable yield may be small, the concept of OSP recognizes that achieving a high physical yield is not the only possible objective of management. However, if management abandons high physical yield as its prime objective, there seems little reason to keep the MSY level as the lower bound of target-population levels. If there are reasons, such as the reduction of competition between seals and fishermen, favouring a relatively small seal population, then a population well below that producing MSY might be acceptable, provided that it is not so low as to threaten the continued existence of the stock.

An objective similar to OSP and closely tied to MSY has been adopted by the International Whaling Commission (IWC) in its New Management Procedure. This procedure prohibits virtually any catching of whales from stocks below those producing MSY. Stocks at or above the MSY level can be harvested, and the details of the procedure, which includes some allowances for uncertainty, imply that the abundance will tend to a level somewhat above that giving MSY, that is, in the OSP range. The procedure makes very high demands on the information about stock sizes and sustainable yields, and the IWC has found it virtually impossible to obtain sufficient information to apply it.

In certain circumstances (low costs of harvesting, high discount rates which give little economic weight to costs or benefits that occur in the distant future, and low population rates of increase), narrow economic interests could favour action to deplete a population to levels well below that producing MSY, possibly even to extinction (e.g., Clark, 1976). In these circumstances, better returns flow from a large immediate harvest, the proceeds of which earn interest, than from a possibly larger harvest to be taken some time in the future.

National policy obviously should give full weight to future interests, and the argument for taking high short-term yields is not a valid reason for abandoning MSY for seal stocks as a minimal management option. In any case, MSY and its near relatives, such as OSP, are reasonable objectives only if the animal population functions as an economic resource. If the product lacks a market, or if the costs of harvest exceed the value of the product, there is no purpose in considering ways to maximize the yield.

Other Considerations

The Royal Commission has been given various reasons for not adopting MSY or OSP for seal stocks. To most Canadian fishermen, for example, seals are pests, some species more so than others (e.g., Eastern Fishermen's Federation, 1985; Fisheries Association of Newfoundland and Labrador, 1985). They spread parasites, damage fishing nets and compete with fishermen for fish. However, no suggestion was made to the Royal Commission by any group that they would like to see seals exterminated because they are a pest. Fishermen accept seals as part of the natural system and are fully prepared to live with a "reasonable" population of seals, although they definitely prefer a small seal population to a large one. What represents the size of a "reasonable" population of any specific stock of seals or, to put it another way, the level of abundance above which a stock of seals causes an unacceptable amount of damage, is not clear. It is possible that a modified benefit-cost analysis, in which the marginal costs of keeping down the seal population are balanced by the marginal benefits of limiting the damage caused by seals to the fisheries, might shed light on this question. It should be emphasized, however, that such an exercise is based solely on economic criteria.

Possible relations between seal population abundance and the loss to fisheries are sketched in Figure 27.2. The loss of or damage to gear might be proportional to the abundance (curve (i)). The relation could be more complex (curve (ii)), as might be the case for infection by *P. decipiens*. Such costs as those of candling and trimming might increase slowly at first, when the infection is not noticeable, then increase rapidly as the infection rate makes the candling of each fillet necessary, and later increase slowly.

The two relations (of sustainable harvest and losses to fisheries) can be combined, in dollar terms, for example, to give the net economic effect of seals. The net benefit will be the difference between the positive return from the seal harvest (e.g., the curve (i) of Figure 27.1, repeated as a broken line in Figure 27.2) and the losses to the fishing industry (curves (i) and (ii) in Figure 27.2). These are shown in Figure 27.3, using curve (i) of Figure 27.1 and the two curves of Figure 27.2. As drawn these have their highest points at a population size less than that corresponding to MSY. This will always be true for likely relations, providing that positive benefit is possible. These curves should be treated as illustrations. Because other factors such as discount rates and costs of catching seals need to be taken into account, the maximum in this curve will almost certainly not be the optimum, even in economic terms. It will, however, be nearer such an optimum than MSY.

MSY has not played a critical role in the circumstances of Canadian sealing. Most participants in the sealing industry, especially the Inuit and sealers in the outports of Newfoundland, whose interests are directly affected, have been concerned with harvesting and selling enough seals and seal products to satisfy immediate economic needs. Their costs of harvesting probably have changed little with changes in stock abundance, and so a high

Figure 27.2
Possible Relations Between Seal Population and Losses to Fisheries

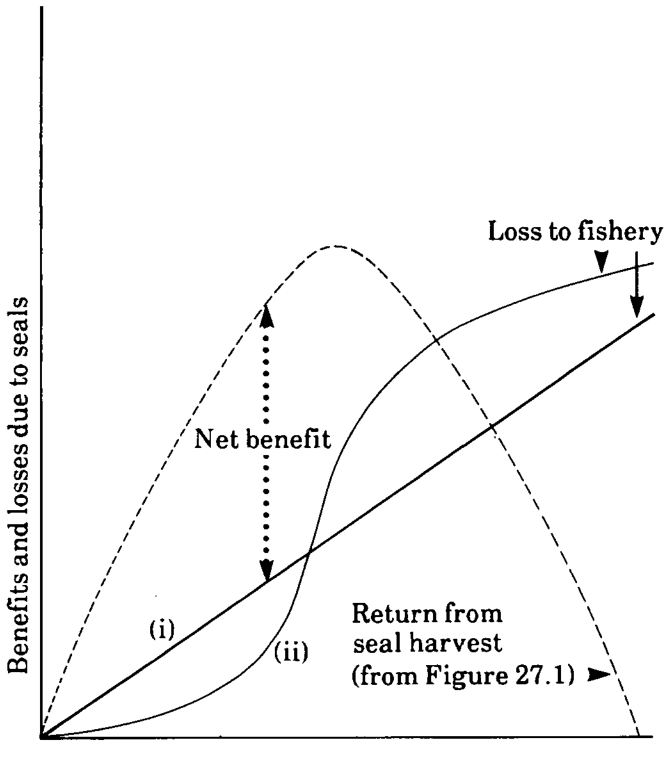
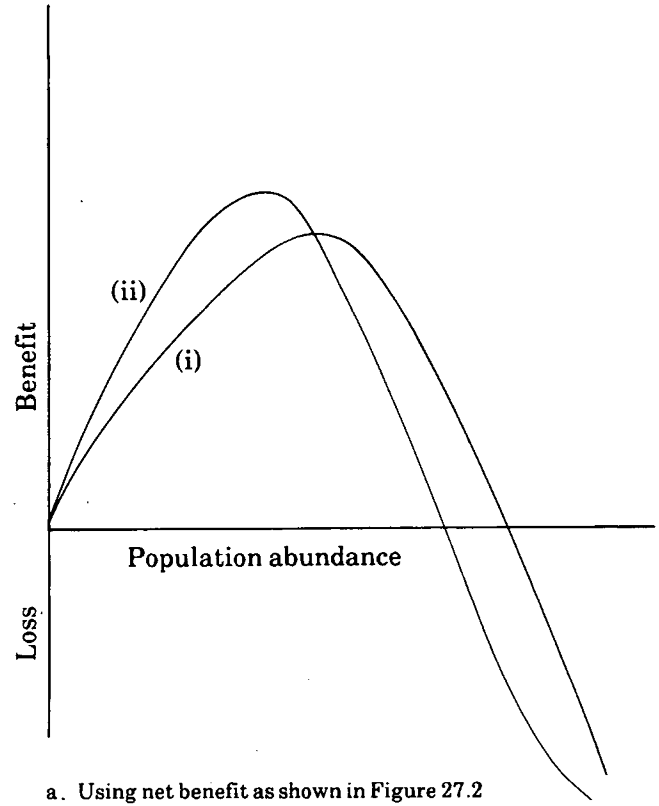


Figure 27.3
Net Economic Effect of Seals[a]



a. Using net benefit as shown in Figure 27.2

stock abundance is not important to their economic success. While each individual sealer would like his harvest to be high, it does not seem to be particularly important to keep the total harvest as high as possible.

Thus there are difficulties, even in simple single-species economic terms, of defining a unique target level for population abundance. Instead of looking to see whether a proposed management action moves the population towards some poorly defined optimum, one might examine the benefits and costs of the proposed action and then compare them with the benefits and costs of other possible actions, including the possibility of doing nothing or that of maintaining the present policy. Any upward change in population numbers will involve some costs (e.g., more seals will eat more fish) and can produce some benefits (e.g., more seal products, more seals to watch and enjoy), even though not all the "costs" and "benefits" can easily be expressed in simple economic terms. Many of the factors affecting costs and benefits will change, for example, with changes in the market for seal products or in the weight given to the "benefit" of having more seals in the sea. Thus the optimum, taking all factors into account, is unlikely to be constant.

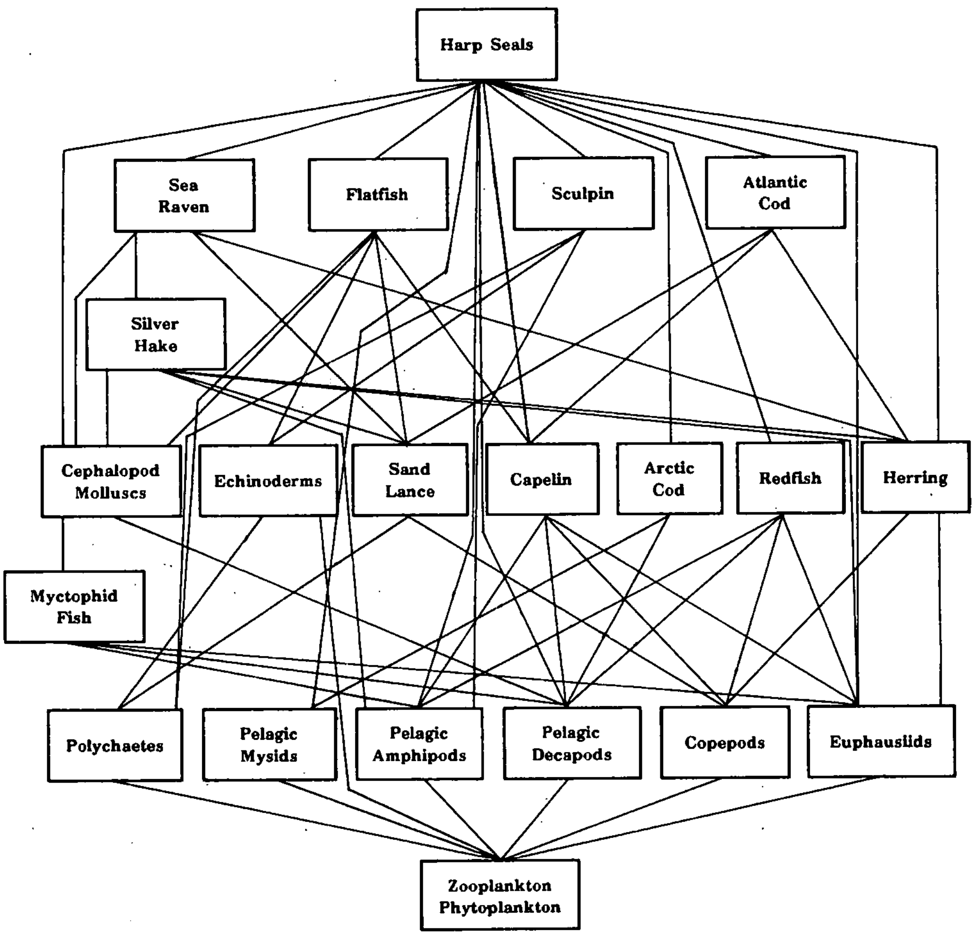
Ecosystem Management

Seals do not live in isolation. Any interventionist policy for managing seals and sealing should take account of their interactions with the other species that make up the ecosystem in which they live. An ecosystem consists of all the constituent elements that affect it and, in the case of seals, includes the following elements:

- the seals themselves;
- other marine mammals;
- all fishes in the water inhabited by the seals;
- the plants that feed the animals on which the fish feed;
- the salinity and other chemical constituents of the water;
- geographic and climatic features such as the proximity of land, the presence of ice and variations in temperature.

All these elements interact, and such interactions are complex. For example, Figure 27.4 illustrates just one kind of interaction: that among harp seals, the animals on which they feed and the food of the latter.

Figure 27.4
Simplified Trophic Web for the Harp Seal



Source: Lavigne et al. (1982)

The public and scientists are much more aware of the importance of these interactions than they have been in the past, and this awareness is reflected in the emphasis now being given to the concept of ecosystem management to complement, rather than replace, single-species approaches. To some extent, criticisms of single-species approaches are unfounded, since the models used implicitly take account of the interactions with other species, for example in determining the values of the carrying capacity used in the simple production type of model. However, a more explicit recognition of ecological relations is needed. To examine this question the World Conservation Strategy is again considered.

The conservation and management principles set out in the World Conservation Strategy and cited at the beginning of this chapter focus concern on genetic diversity, human need and the maintenance of essential ecological processes. Provided that the total populations are not so reduced as to impoverish the gene pool, genetic diversity is not threatened by recent Canadian sealing policy, inasmuch as sealing, especially the taking of pups, is unselective. The objective of ensuring a sustainable utilization of species and the ecosystem reflects the long-term interests of sealers and users of seal products. Any policy aimed at managing seals in those interests would need to satisfy this objective. The first objective, that of the maintenance of ecological processes and life-support systems on which humans depend, is not addressed in the preceding treatment of single-species considerations. It is dealt with in the following section.

Maintaining Ecological Processes

Exactly what is meant by maintaining essential ecological processes, and how many seals are required to comply with this condition, is not clear. A decline in numbers of seals would be expected to have some effect on the animals on which they feed. In relation to some species of marine mammal, such an effect could bring about a substantial change in the ecosystem. An example is the predation by sea otters on sea urchins. Sea urchins are very efficient consumers of kelp and, if they are common, kelp is scarce. A reduction in sea otter abundance can virtually eradicate thick kelp beds and change the whole appearance of the ecosystem (Estes and Palmisano, 1974).

There is no evidence that any Canadian species of seal plays such a critical role. Undoubtedly, changing seal abundance will change the relative abundance of other species but, since seals feed on various species of fish, they are unlikely to affect any one species to a critical extent. At the same time, their catholic diet may play an important role in damping out large fluctuations by switching attention towards any unusually abundant species and away from species in decline. However, these effects seem unlikely to be so important that a decline in seal stocks would affect essential ecological processes.

A suggestion was made in evidence to the Royal Commission that seals play an essential role in the ecosystem because the nutrients they excrete are vital in maintaining primary productivity (Watson, 1985). Seals do recycle some nutrients, but the amounts constitute a very small proportion of the total nutrient supply from recycling through animals or from other sources (upwelling, river inflow, etc.) If there were no seals, the animals seals eat would themselves be recycling nutrients. It is hardly conceivable that the abundance of seals has any influence on primary production or, through it, on the other elements in the ecosystem.

A pervasive misconception sometimes used as an argument for killing seals is that seals need to be controlled for their own good or for the good of the ecosystem. According to this view, the absence of hunting will lead to overpopulation and serious damage to the ecosystem. Since seals existed without endangering the ecosystem for a long time before people started to hunt them, this argument seems faulty. There have been instances where the population of a large mammal has expanded so rapidly as to cause serious damage; elephants in African national parks afford an example. High population growth seems to have negative effects only under certain conditions: when the animals can cause long-lasting physical damage to the environment and especially to the plants on which all later production depends (e.g., destruction of trees by elephants), when the animals are confined in a restricted area such as a national park or on an island, and when the expansion is triggered by a sudden change in conditions so that the population expands too fast for normal density-dependent controls to take effect. For a full discussion of the scientific problems of overabundant species, see Jewell and Holt (1981).

These conditions, except possibly the last, do not apply to seals in the sea. The first may apply when seals come ashore to breed. Grey seals on the Farne Islands in the North Sea have occurred in such high densities on the most favoured islands that they have destroyed the vegetation and the breeding sites for puffins (Bonner and Hickling, 1971). A similar conflict between the expanding fur seal population and breeding albatrosses may be arising on one of the islands around South Georgia. In these cases a by-product of the early exploitation has been to change the geographical distribution of the stocks so that the same total numbers can cause problems of overabundance in some restricted localities. This problem does not seem to affect any Canadian seal population. Boal (1980) reports a case of some effect of harbour seals in California on the algae and other organisms on the rocks on which they haul out, but the extent of this effect on the area as a whole seems to be trivial. If the problem did exist in Canada, there might be solutions, such as disturbance or barriers, other than killing seals.

It is also argued that, at the high population densities which would probably occur if there were no hunting, the seals would suffer a higher incidence of disease, reduced breeding success and other negative effects. Undoubtedly, some changes of this type would occur. Unless they did, the population would increase without limit. Such density-dependent changes are entirely natural. To the extent that at a high density some biological features of populations, such as mortality and breeding success, change with negative effects, it would be reasonable to talk about a stock suffering from overpopulation.

What should properly be termed "overpopulation" depends on the viewpoint. To a sheep farmer or a cattle rancher, most national game parks are badly overpopulated. There is less vegetation, and the animals are in poorer condition, than would be the case if the abundance were kept lower by harvesting or culling. A larger crop of animals would be possible at a lower population. However, the situation does not represent overpopulation in the sense that there are more animals than would exist under natural conditions undisturbed by humans, or that action should be taken to reduce their number or to prevent the abundance reaching such a high level. The farmer or rancher probably envisages some population level similar to MSY, when net production or sustainable yield is high. This population will be smaller than the unexploited abundance level.

Apart from the question of natural ecological processes, it can be argued that overpopulation may cause distress to individual animals. Some density-dependent changes, such as a delay in the age at maturity, may slow down or halt a population increase but have little effect on the well-being of the individual animals. Others, such as increased disease or greater injury from intra-specific competition, presumably make life less pleasant for the individual seal.

At this stage, other considerations enter the picture, some concerning fundamental attitudes to the relation between people and other animals. If humans have dominion over animals and dominion includes the responsibility to adjust matters, where possible, to minimize the aggregate discomfort experienced by seals or other animals, culling to reduce harmful effects of overcrowding might be argued for. On the other hand, if people should refrain from interfering with animals unless their intervention is absolutely essential, a cull should not take place. Almost certainly, a decision will take account of other factors. A significant factor in deciding on a cull on the Farne Islands in the 1970s was the shock to human visitors of seeing large numbers of starving pups (Bonner, 1982).

Associated and Dependent Species

The wider ecological effects of harvesting one species include possible consequences to other non-target species associated with, or dependent on, the target species. Concern has been expressed in connection with the growing krill harvest in the Antarctic. It is feared that, if this harvest increases, the reduction in the abundance of krill would harm the many species for which krill is the major food item and, in particular, might threaten the recovery of the large baleen whales. These concerns and the objectives that should be followed in such a situation are spelled out in the Convention establishing the Commission for the Conservation of Antarctic Marine Living Resources. Of special interest is Article II, which is probably the most careful attempt to codify the principles of ecosystem management. This, *inter alia*, requires (Article II 3(b)) the maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources.

The Antarctic case relates to the effect on predators of increased exploitation of a prey species. Probably the only predators that might be affected by a high seal harvest are the polar bears that prey on ringed seals. There is no evidence that the effect on polar bears of too high catches of ringed seals should be a matter of major concern.

Much more concern has been expressed about the effect of a reduced seal harvest, and hence increased seal numbers, on the species that seals eat. It is highly unlikely that increasing numbers of seals will significantly disrupt the ecosystem. Seals have co-existed with their prey for millions of years. The real issue is that more seals may mean less fish for fishermen. This conflict is discussed in detail in Chapter 24. Where seals and men catch the same species of fish, increased numbers of seals will mean a smaller catch for fishermen, but the arithmetic of the matter is not simple. The loss in catch is unlikely to be exactly equal to the weight of fish eaten by seals. It might be more or a great deal less. Factors that affect the answer include the sizes of fish taken by seals and fishermen, the times and positions of the seals' consumption relative to the fishery and whether the consumption by seals of non-commercial species has any indirect effect on fishing success. These factors will vary among species of seals and from fishery to fishery, and the effects must be estimated separately for each fishery.

With respect to managing the ecosystem as a whole, there is no uniquely or objectively "correct" abundance of seals. Despite differences in seal abundance, the essential features of the ecosystem are the same, and there is no compelling ecological reason to take action either to increase numbers by restricting the harvest or to reduce numbers by culling.

Uncertainty and Variability

Two factors not explicitly considered in the preceding sections are the uncertainties in any estimates of population size or population parameters, and the variability in the natural environment. Recent considerations of policies for managing marine mammals and marine resources generally have emphasized these factors. For example, a statement on new principles for the conservation of wild living resources (Holt and Talbot, 1978) has as its second principle, "Management decisions should include a safety factor to allow for the facts that knowledge is limited and institutions are imperfect." The IWC, under its New Management Procedure, deliberately set quotas below the estimate of MSY.

Both these examples argue that because of uncertainties, catches should be less than amounts that scientific estimates, taken at their face value, would permit. The same view is that for too long, the perceived interests of fishermen and sealers have been given too much weight. Then, in cases of doubt or uncertainty, catches tended to have been set at the upper end of a given range, allowing fishermen the benefit of the doubt. Now many persons believe that seals and other marine mammals should be given the benefit of the doubt, and that catches should be set deliberately low. The scientific basis for this argument is that the effects of management are not symmetrical. High catches can, at their worst, render the stock extinct, and thus be irreversible. It may take a very long time for an overexploited stock to recover. The effect on a stock of taking too little can, however, be quickly corrected by a short period of high catches.

For serious errors, which involve large departures from the desired condition, this asymmetry definitely exists and justifies a definite bias toward setting catch quotas or similar controls lower than the best or central estimate. The asymmetry usually arises because the effects on future sustainable yields of acting on over- and underestimates of current sustainable yield are not the same, even when the extent of the over- and underestimates are the same. The drop in sustainable yield arising from an overestimate, and hence excessive catches and falling population, is more serious than that arising from an underestimate and catches below the sustainable yield.

This may not be true for small errors which result in small displacements of the population's target level. For such relatively small changes, there seems no reason to suppose that errors in one direction should be easier to correct by appropriate adjustment to later catches than should errors in the other. Deliberately adjusting allowable catches downwards is, therefore, not necessarily the best reaction to uncertainty, even if it were clear - and it is usually not clear - what size of adjustment would be appropriate for a given degree of uncertainty.

A much better reaction to uncertainty is to develop scenarios of the events that would occur in the worst possible case, as well as for the most likely set of population estimates. Such scenarios would take account of the ability of the management system to detect that the estimates were wrong and to take appropriate corrective action. Proposed action, such as setting a catch quota at a given level, will be acceptable if there is evidence that even under the most unfavourable combination of values, any departure of the population from the desired condition will be detected, and that mechanisms exist which should ensure that effective action will be taken to restore the population to the desired condition, within a reasonable period.

Conclusions

It is not possible to define on biological grounds a unique optimum level of population abundance which should serve as a long-term target of management policy. The MSY level can give a reference level but, taking account of the possibly negative effect of seals on fisheries, the economically optimum population level could be well below the MSY level. Sustainable utilization of the seal population is compatible with conservation.

Account should be taken in principle of the interactions between seals and the rest of the natural ecosystem in which they live. Apart from the possible direct effects of seals on fisheries, these interactions are unlikely in practice to alter significantly the management policies for seals based on the simple, single-species, biological models.

Some degree of uncertainty will exist in any analysis of a seal stock, and all seal stocks are subject to some variations because of changes in the natural environment. Management policies should take these uncertainties into account.

Given the difficulties of defining an optimum population level, and often of determining the position of the current population relative to that level, attention may be focused on the costs and benefits involved in changing the population size. In focusing on this factor it would be important to include all the social benefits or costs, both direct and indirect, and not just the immediate economic effects.

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Chapter 28

International Aspects

Canada is not the only country with seals, a sealing industry and a seal problem. A review of the experiences with seal management in other countries can put the Canadian situation in some perspective. Moreover, Canada does not act in isolation with respect to its own seal stocks. Some of the stocks are shared with other countries by virtue of the seals' disrespect for international borders. Historically, the products from sealing in Canada have served an international market. Over the years, Canada has participated in joint management of some seal stocks and, in the process, assumed responsibilities within bilateral or multilateral conventions and agreements. This chapter considers some of these international aspects of seals and sealing.

Certain categories of experience in other countries, such as the alternative employment opportunities for Norwegian sealers and for aboriginal peoples in Greenland, are closely related to specific points in the Royal Commission's terms of reference. These categories are discussed in detail elsewhere in the Report. (See Chapter 19.) The present chapter describes other countries' approaches to their seal problems through a series of regional reviews and provides an account of the different international mechanisms used to co-ordinate the management of seal stocks.

Seals and Sealing in Other Regions

Antarctic and Sub-Antarctic Seals

Stocks

The seals of the southern oceans may be conveniently divided into two main groups, the true antarctic seals that breed on ice surrounding the antarctic continent and the fur seals and elephant seals that breed on the islands of the sub-antarctic.

The former group did not become well known until the present century. Their numbers have been estimated as follows (Anonymous, 1981):

crabeater seals	15,000,000
Weddell seals	730,000
leopard seals	220,000
Ross seals	220,000

These seals have never been commercially exploited. It is not known to what extent their numbers vary because of natural causes, but it is believed that crabeater seals have recently been increasing as a result of greater availability of krill (their main food), following the depletion of the large baleen whales.

Fur seals of one or other species (*Arctocephalus gazella* or the slightly more northerly *A. tropicalis* or *A. forsteri*) are found on many of the antarctic and sub-antarctic islands; Marion Island has both *A. gazella* and *A. tropicalis*. Bonner (1982) gives a clear description of the way in which, during the 19th century, the islands and their large seal colonies were discovered; the discovery was rapidly followed by exploitation and depletion of the seal stocks, often close to the point of extinction.

Fortunately, extinction does not seem to have occurred anywhere, and after nearly a century of protection most stocks are recovering. The antarctic fur seals at South Georgia have recently been increasing very rapidly, at a rate of nearly 17% per year (Payne, 1977). This stock is probably approaching its original level of abundance of about one million animals, although its distribution over different breeding sites is not the same as it was previously. Although this rate of increase is exceptional, quite high rates have been observed elsewhere; a rate of 10.5%, for example, has been recorded at Marion Island (Condy, 1978).

The other important sub-antarctic seal is the southern elephant seal. This very large seal - the male may weigh up to three or four tonnes - is found on many of the sub-antarctic islands, with large groups at South Georgia, Kerguelen and Macquarie Islands. Like the fur seals, this species was heavily exploited and depleted in the 19th century, but never to the same extreme extent as the fur seals. After most killing stopped, about the beginning of the 20th century, stocks seem to have recovered. Most appear to be stable at present, though there are indications that the stock at Kerguelen is decreasing (Pascal, 1985). The total numbers probably stand at about 600,000: half at South Georgia, 200,000 at Kerguelen, and 100,000 at Macquarie (Laws, 1960). Pascal (1985) suggests that these figures underestimate the Indian Ocean population, which may consist of about 280,000 animals.

Utilization

When one of the largest colonies of fur seals in the southern hemisphere, that is, the colony on the Juan Fernandez Islands, was first discovered, Dampier (1729), quoted by Bonner (1982), wrote: "Large ships might here load themselves with Seal Skins and Trane-oyl; for they are extraordinarily fat." Nevertheless, the fur seals seem to have been harvested almost exclusively for their skins. In contrast, elephant seals have been killed almost exclusively for their oil.

The meat from southern ocean seals has been little used commercially, but in the so-called "heroic age" of antarctic exploration, at the beginning of this century, seal meat was important as food for men and sledge-dogs. The liver was (and is) particularly appreciated. Scott (1905) noted that, on his first expedition, he and his men were tempted to kill seals for their livers only.

Interaction with Fisheries

The chief food of several species, particularly crabeater seals and fur seals, is krill. The harvesting of krill has recently commenced on a scale which, although large, is still only a fraction of the potential level. While it is logical to expect that the abundance of seals would affect the amount of krill that could be caught, the principal concern has been from the other direction: it focuses on the degree to which harvesting of krill might affect seals and other consumers of krill, particularly baleen whales (May et al., 1979; Mitchell and Sandbrooke, 1980).

There is some indication that fishing has already had an impact on elephant seals, which eat fish and squid. The elephant seal stock around Kerguelen may have decreased lately, possibly in response to the increased catches of fish made there during the last 15 years (Pascal, 1985). The data, however, are not conclusive. In any event, the impact of seals on fish stocks is not an issue in the southern ocean.

Management Policy and Practice

The exploitation of fur seals and elephant seals was unmanaged until early in the 20th century, with predictable results. The fur seals were reduced to near extinction, and the number of elephant seals declined. Since the elephant seals were less attractive economically, they were not brought to such a low level. In the first decade of this century, in connection with the birth of modern antarctic whaling, the British established effective jurisdiction over South Georgia and extended existing sealing legislation from the Falklands to South Georgia. This move involved setting a licence fee and an annual quota. Later scientific analysis (Laws, 1960) showed that those regulations were not sufficiently effective, and modified regulations were introduced in 1962. These reversed the negative trends in the populations. They would have allowed sealing to continue indefinitely if the whaling industry, to which sealing served as a profitable adjunct, had not collapsed. The antarctic sealing industry ended in 1964 (Bonner, 1982).

For the true antarctic seals, the interested countries, largely the Antarctic Treaty Consultative Powers, have taken the unusual and very positive step of setting up a management mechanism in advance of any commercial harvesting. In 1972, the Convention for the Conservation of Antarctic Seals was signed in London. Under this Convention, precautionary measures, including provisional quotas, have been agreed upon. It seems unlikely, however, that any commercial sealing will develop in the Antarctic in the immediate future, and these arrangements remain untested.

Research

With the upsurge of interest in the Antarctic in recent years, a considerable amount of research has been done on the seals of the southern ocean. This investigation is in addition to research that has been in progress for many years, notably by the British Antarctic Survey, on the fur seals and elephant seals of South Georgia. For the more accessible sub-antarctic seals, the research covers a wide spectrum, and there now exists a good understanding of general biology, distribution and/or numbers, as well as some very detailed information, such as that on depth of diving and feeding behaviour. The seals living on the ice are not so easy to reach, and research on them has been less comprehensive. Though some detailed studies have been made, it is still difficult to obtain an accurate estimate of the total numbers of the seals, and to determine how these numbers may be changing.

South African and Namibian Seals

Stocks

One species of seal, the Cape fur seal (*Arctocephalus pusillus*), is found in the waters off southern Africa in significant numbers, though occasional wanderers from the antarctic and sub-antarctic stocks of seals visit South African waters (Shaughnessy, 1982; from whose work most of the information in this section has been taken). Current (1983) population abundance has been estimated as about 1.2 million fur seals, with an annual pup production of just fewer than 300,000 (Stander, 1985). These seals are spread out over some 20 breeding sites, mainly small islands, along the coast of Namibia and South Africa as far east as Algoa Bay, and they have been commercially exploited since 1610. Although there have been some great reductions in their numbers, the stocks as a whole have not fallen to extremely low levels. The lowest level of abundance was reached at about the end of the 19th century; since then numbers have probably increased about tenfold (Shaughnessy and Best, 1982). Numbers are still probably increasing at a rate of approximately 4% per year, although, as Table 28.1 shows, there are differences among colonies, and the present population is some 50% higher than the estimate given by Shaughnessy (1979) in the report of the Advisory Committee on Marine Resources Research arising from that body's consultation on marine mammals. It is probable that, as a whole, the population is less abundant than it was when commercial exploitation began; Shaughnessy and Best (1982) suggest that the current stock is in the range of 30%–90% of the original population, but some local stocks may be above the original level. Seals now cover the whole of Seal Island in False Bay, whereas when the island was visited in 1687, it also accommodated many gannets (Shaughnessy, 1984).

Utilization

The Cape fur seal has been harvested, principally for its fur, more or less continuously for more than three centuries. Recent annual harvests, until 1982, took about 60,000–80,000 young animals and a small and variable number (2,000–3,000) of bulls. The total take during the whole of the 20th century was 2,390,000 young and 138,000 bulls (Best, 1973; and more recent information from the Sea Fisheries Research Institute). In addition to processing the fur, the sealers extract oil from the blubber of most of the seals killed. The young animals are taken after completion of the first moult, at

Table 28.1
Growth in Cape Fur Seal Population at Southern African Breeding Colonies, 1983

Colony	Estimated Pup Production 1983	Annual Rate of Increase 1971–1983 (%)	Observed Rate of Entanglement[a] 1977	1978	1979
Cape Cross	20,226	1.44	0.56	0.57	0.66
Wolf Bay	33,483	6.69	0.56	0.01	0.01
Atlas Bay	83,663	9.77	0.00	0.00	0.01
Kleinsee	85,697	9.60	0.06	0.01	0.04
Van Reenen Bay	4,355	1.29			
Lions Head	4,647	3.37	–	–	–
Marshall Reef	118	–16.68	–	–	–
Staple Rock	1,396	–8.17	–	0.53	–
Boat Bay Rock	476	–12.49	–	–	–
Dumfudgeon Rock	303	–18.63	–	–	–
Long Island	16,050	1.12	0.00	0.53	0.00
Albatross Rock	6,043	4.63	0.00	0.00	0.00
Sinclair Island	10,829	–3.17	0.02	0.10	0.09
Elephant Rock	1,329	–3.73	–	–	–
Robbesteen	347	–17.80	–	–	–
Seal Island (False Bay)	9,880	–2.53	–	0.22	0.34
Geyser Rock	7,978	6.65	–	0.00	–
Quoin Rock	338	–19.65	–	–	–
Seal Island (Mossel Bay)	222	–23.04	–	–	–
Hollams Bird Island	1,556	–11.04	–	–	–
Black Rock Nam.	391	7.95	–	–	–
Jacobs Reef	3,283	–4.38	–	–	–
Black Rocks S.A.	123	–18.69	–	–	–
Total	292,733				

Source: Stander (1985) and Shaughnessy (1980).

a. In nets and other debris.

any age between six and 10 months (Shaughnessy, 1979). Occasional attempts to use the carcasses for pet food, human consumption or meal production have not been successful.

The composition of the catch changed in 1984, and a greater proportion of bulls is now taken. With the collapse of the European market for seal products, however, the immediate future of the South African sealing industry is bleak. The director of the Sea Fisheries Research Institute notes, in a letter dated 2 January 1985, that "the sale of bull genitalia will probably provide only a short term reprieve before the market becomes saturated" (Stander, 1985).

Several colonies are visited by tourists and Shaughnessy (1979) estimated that, in the 1970s, some 68,000 visitors came to view the seals each year, adding about R70,000 to the local economy. By comparison, the first-hand value of the 1972 harvest amounted to R982,000 (Best, 1973). In 1975, 17,000 people visited Seal Island in Mossel Bay in a five-week period, during which 1,638 young seals were killed. On this occasion hunting and tourism were compatible (Best, 1973).

Interaction with Fisheries

Purse-seines and trawls contain a good supply of available food, and seals take large quantities from the nets, occasionally even following the trawl up the stern ramp of large factory trawlers. Their feeding results in the loss of fish that have already been caught, as well as in damage to nets. No quantitative estimates of the extent of the loss to the fishermen seem to have been made, but that loss is substantial and unarguable. There are also losses to the seal population. Seals get entangled in nets and drown, apparently more often in trawl nets of side-trawlers than in those of stern-trawlers. In 1976, 16 seals were killed in 356 drags by small South African trawlers.

Attempts have been made to scare seals away from nets by using explosives, but they have had limited success. Transmission of killer whale sounds and the use of other devices have not had lasting success (Shaughnessy et al., 1981). Undoubtedly, some fishermen take more direct action with a rifle to protect their catches. Additional mortality probably occurs as a result of entanglement with discarded or lost nets, lines and other objects (Shaughnessy, 1980). The rate of entanglement, based on the estimated percentage of animals observed with objects round their necks, varies considerably from area to area, but it is in the same general range (between 0.1% and 0.6%) as that observed for northern fur seals. It has been suggested that a recent and otherwise unexplained decline in abundance of seals in the Pribilofs is the result of an additional mortality, especially among juveniles, caused by entanglement. (See Chapters 22 and 23.) It is therefore notable that when the data on entanglement and the rate of increase of abundance of each colony are compared (see Table 28.1), those colonies at which no entanglement was observed were also those with the highest rate of increase.

Another and less direct interaction arises because seals eat the same species of fish as fishermen catch. Cape fur seals feed mainly on fish (about 70% by volume); most of the rest of their food consists of squid. About 1970, the annual consumption was estimated at some 154,000 tonnes (Best, 1973), considerably less than the 2.2 million tonnes taken by fishermen in the southeast Atlantic. Seals seem to be fairly catholic in their tastes, varying their consumption according to the relative abundance of the different species of fish. This is fortunate because of the great changes that have occurred in the stocks of pelagic fish (pilchards, horse mackerel, anchovy), at least partially as a result of fishing (Murphy, 1977; and recent reports of the International Commission for the Southeast Atlantic Fisheries). Though consumption by seals probably has some long-term effect on commercial fish catches, this effect is likely smaller, and certainly less obvious, than the direct effect of taking fish from nets. The divergence in this respect from the situation in Atlantic Canada arises from a difference in the extent in which the seals seek out fishermen's catches, as well as differences in the seals' natural diets and in the dynamics of the fish stocks involved. The effects of fishing on the seals' diet are probably much greater than are the effects of seal predation on commercial fish catches. Seals and humans presumably have an effect, also, on the large populations of birds that feed on the same fish.

Management Policy and Practice

In South Africa and Namibia, fur seals have generally been seen either as a resource to be managed for sustained high harvest or as pests to be kept at a low level. Management policies have been formulated accordingly. There is considerable interest in wildlife in South Africa, but it has focused more on the preservation of species and the natural system as a whole, especially in national parks, with little emphasis on the prevention of all killing. Some seal colonies attract tourists, but compared with some other countries there is little awareness of sealing as an issue and little opposition to the controlled killing of seals.

Legislative authority for current controls exists in the *Sea Birds and Seals Protection Act of 1973*, and in the sealing regulations of 1976. Unlike some other acts or international conventions, these do not make any explicit statement of the measures' objectives, other than that the law provides "for the protection, and the control of the capture and killing, of sea birds and seals." These measures are consistent with controls that have existed since the early 1890s. The management scheme includes concessions to individual companies for exclusive rights to the harvest from specific seal colonies for periods that range from five to 25 years. These concessions encourage the companies concerned to take a responsible long-term interest in the well-being of the seal colony. They are now generally accompanied by explicit quotas on the annual catch.

Research

Active research into the seal stocks of South Africa and Namibia has been carried out for a long time by what is now the Sea Fisheries Research Institute of the Department of Environment Affairs. The location of the marine mammal laboratory has ensured that the work is closely linked with research on fish stocks and the general ecology of the area.

Particular emphasis has been placed on estimating the abundance of fur seals by tagging and direct census from aerial photography. These methods have given consistent results. It appears, from ground-verification studies, that the aerial surveys miss some pups (those between rocks, not yet born or already dead, for instance) and that the aerial counts should be increased by a factor of 1.31 (Rand, 1959, 1972; Best, 1973). Estimates have also been made of the various population parameters and mortality rates, and models have been used to predict the results of different exploitation patterns (Shaughnessy and Best, 1982). These models predict that the maximum yield would be obtained by harvesting about 33% of the female pups reaching the harvesting age (six to ten months) and a rather higher proportion of males. The population would start to decline rapidly at harvesting rates much above 40%–45%.

A significant feature of general ecological research is the instability of the pelagic system, like that of other major upwelling areas of the world, such as Peru and California. Though the immediate cause of the recent collapse of the pilchard stocks off South Africa and Namibia has been overfishing, these stocks are also subject to significant natural fluctuations. It would be reasonable to expect these fluctuations to have some effect on the seals, despite their ability to change diets. Morrell (1832), for instance, reported finding some half million dead seals on Possession Island. Though this report has been challenged, it is likely that the abundance of seals would not remain precisely constant in the absence of exploitation.

South American Seals

Stocks

Three species of seals are found in South American waters: the South America sea lion, *Otaria flavescens*; the South American fur seal, *Arctocephalus australis*; and the Juan Fernandez fur seal, *A. philippi*. The information on the two former species has been reviewed by Vaz-Ferreira (1982a, 1982b). Both species are distributed widely along the Atlantic and Pacific coasts of the continent, but only in Uruguay are they now being regularly harvested. The Uruguayan seal populations numbered some 30,000 sea lions in 1954 and 250,000 fur seals in 1972. The sea lion population had changed little by the early 1970s. Estimates of population sizes in Uruguay and elsewhere are summarized in Table 28.2.

Table 28.2
South American Seal Population Estimates,[a] 1954–1976[b]

	South American Sea Lion		South American Fur Seal	
Uruguay	30,000	(1972)	250,000	(1972)
Argentina	170,000	(1954)	2,700	(1954)
Falkland Islands	19,000	(1965)	15,000	(1965–66)
Chile[c]	20–25,000	(1965–71)	40,000	(1976)
Peru	13–20,000	(1964–75)	12,000	(1968)

Source: Vaz-Ferreira (1982a, 1982b).

a. Original estimates have been rounded.

b. Approximate dates to which estimates refer are given in parentheses.

c. Excludes southern coast.

Both sea lions and fur seals have varied significantly in abundance, not always in any obvious relation to increases or decreases in the rate of exploitation. The fur seal has been increasing significantly in Uruguay since 1950, even though it has been harvested, while numbers of sea lions on the Falklands decreased greatly between the 1930s and 1965–66, in the absence of any large-scale exploitation.

The Juan Fernandez fur seal is found in the Humboldt current. Perhaps as many as three million were killed in the Juan Fernandez Islands in the 18th century (Bonner, 1982). The species was reduced to very low numbers and was believed by some to be extinct, but now seems to be recovering, though its numbers are still only in the low hundreds (Aguayo, 1979).

Utilization

Europeans have used fur seals and sea lions from the early 16th century for their skins, blubber (oil) and meat. A cargo of fur seals was sent to Seville in 1515, and Drake killed 200 sea lions to provision his crews in 1577. Though at present seals are harvested only in Uruguay, they have been heavily exploited in most parts of their range at one time or another. The sorry history of most of the stocks has been reviewed by Bonner (1982).

In Uruguay, a government agency (*Industrias Loberas y Pesqueras del Estado*) has the sole right to harvest the seals. Current annual kills number some 12,000 fur seals and about 3,000 sea lions, principally males. In addition to the skins, oil is extracted from the blubber at most locations, and on the Isla de Lobos the meat is processed into meal.

Some Uruguayan sea lion colonies attract tourists, and guided tours from nearby Punto del Este visit the rookery at Isla de Lobos daily in the summer. Visits to the fur seal rookeries in the same colony are prohibited, however, to avoid disturbing the animals.

Interaction with Fisheries

Both fur seals and sea lions eat commercial species of fish and squid, which must have some effect on the fisheries catch, though the extent of this effect is unknown. The sea lion, but not the fur seal, is well known for its habit of following fishing vessels and taking fish from nets, as well as causing damage to gear, particularly trammel nets and fishing lines. Again, no estimate of the extent of the damage is available. While fishing in Uruguay was of relatively minor importance, these losses did not affect the policy relating to seals. With a growing fishing industry, more account may have to be taken of the impact of seals on fishing operations. Fur seals are reported to have been drowned in trammel nets, but there is no information available on the extent of these accidental deaths or on their effect on the dynamics of the seal population.

Management Policy and Practice

Uruguay has a long history of management of seals. As long ago as 1825, Weddell noted the slaughter of seals on the sub-antarctic islands and called for a system of control, particularly to confine the kill to males. He stated:

> *This system is practised at the River of Plata. The Island of Lobos, in the mouth of that river, contains a quantity of seals, and is farmed by the Governor of Monte Video, under certain restrictions, that the hunters shall not take them but at stated periods, in order to prevent animals from being exterminated (Weddell, 1825, cited in Bonner, 1982).*

At the time that Weddell was writing, the Uruguay seal harvest had already been going on for some three centuries, though it is not clear whether harvesting took place in all the intervening years. During the present century, at least, there have been considerable fluctuations in the total catch. The important feature throughout the whole period is that there has been some institution responsible for the seal stocks, with the interest and authority to control the harvest. In the early years this authority was very direct: the Governor of Montevideo had the personal right to the harvest, which gave him a direct interest in maintaining the stock (Bonner, 1982). The actual controls may have been concerned more with ensuring that no unauthorized person took seals than with more sophisticated measures such as catch quotas based on scientific analysis, but they have been effective in maintaining the stocks.

Provision exists for licensing of sealing in Argentina, and for controls of sex and ages of any animals killed in Peru, but there is no current significant harvesting. In Chile seals are protected, though there may be some poaching there and elsewhere.

Research

While little full-time research has been done by seal specialists, all the countries concerned have carried out research on seals, either in the universities or as part of general fishery studies. Past research has concentrated on the basic biology of the seals. Vaz-Ferreira (1982b) defined the major research needs as the identification of possible stock separation of both sea lions and fur seals, and studies of the population dynamics of sea lions and their interaction with fisheries.

Seals of the United Kingdom

Stocks

Two species of seals are commonly found in U.K. waters; these are the grey seal and the harbour seal (known as the common seal in the United Kingdom). Some northern seals have been found infrequently. Neither of the two species migrates over long distances, and the British stocks are probably, for the most part, independent of the stocks in other countries. Within the United Kingdom the grey seal breeds mainly in a few quite large and apparently independent concentrations such as those of the Farne Islands (which lie off the northeast coast of England), the Orkney Islands and several of the Hebrides Islands. The harbour seal breeds in smaller groups. The general biology of British seals is described in detail by Hewer (1974).

At the beginning of the 20th century, the grey seal was believed to be very scarce; indeed, some people thought that it was "slowly but surely advancing along the road to extinction" because of local killing (Prichard, 1913, quoted in Bonner, 1982; from whose work much of this material is taken). The grey seal was probably never as scarce as was believed. There may have been misidentification of grey seals as harbour seals, particularly because of the vernacular name. Given the more extreme statements about the Canadian harp seal harvest, it is worth repeating Rae's (1960) comment, cited by Bonner (1982), that Prichard's account "set a standard in emotional appeal, in scientific inaccuracy and in illogical reason which appears to have been followed, doubtless under misapprehension, in subsequent press articles and statements on the grey seal." Both the original appeal and the later reaction to it are echoed in the Canadian situation.

Regulations to protect the grey seal were introduced through the *Grey Seal Protection Act* of 1914. Largely as a result of these measures, but possibly, also, because of depopulation of the outer islands, grey seals have increased. Good estimates of numbers are available only from about 1955. Since then, stocks at several of the main breeding sites, the Farne Islands, Orkney and Hebrides' North Rona, have increased at a rate of some 6%–7% per year (Summers, 1978). Recent data from the National Environment Research Council (NERC, 1984) suggest a population of 84,000 grey seals in 1982. This figure represents over half the total world population of this species.

Less attention has been paid to harbour seals. Minimum population estimates from surveys stand at about 20,500 (NERC, 1984). In two areas, the Wash and the Shetlands, the numbers are believed to be increasing, but in three others, the Inner and Outer Hebrides, and eastern Scotland, the status of the stock is unknown.

While the direct effects of human disturbance, including shooting, have been significant, the less direct effects, such as those arising from pollution, seem to be of little significance to British seal stocks. This situation stands in contrast to that in Dutch waters and in the Baltic, where seal stocks have seriously declined, and where high concentrations of pollutants have been found (Summers et al., 1978).

Utilization

There has never been large-scale commercial hunting of British seals. Subsistence hunting of grey seals, especially off western Scotland, probably dates back to prehistoric times. The Venerable Bede, writing in A.D. 731, noted that "Britain is abounding in fish . . . while seals, dolphins and sometimes whales are caught" (Bede, 1968), and Bonner (1982) quotes 16th century descriptions of sealing in the Orkneys and the Farne Islands. Subsistence hunting at Haskeir in the Hebrides aroused Prichard's anger in 1911, and it was probably responsible for keeping the seal stocks at the level from which they are now increasing. This hunting has been stopped.

Until recently, there was a small-scale commercial hunt for both harbour and grey seals. Excessive catches in the 1960s were believed to have caused the decline of some harbour seal stocks. Since the 1970 *Conservation of Seals Act,* which bans sealing during the breeding season (1 June to 31 August) except under licence, catches of harbour seals have fallen from a peak of some 1,500 in the late 1960s to zero. Catches of grey seals in the 1970s numbered between 1,000 and 2,000 (Summers, 1979). While skin prices remained high, these activities were economically rewarding. Even during peak times, however, they employed few people, and the loss of the industry has caused no significant economic problem.

Interaction with Fisheries

Three forms of interaction with the fisheries occur: damage to fishing gear and removal of fish from nets, consumption of commercially valuable fish, and transmission of nematode parasites which causes a loss in the value of the catch. There is little doubt that all three forms occur, but as in Canada, there is considerable scientific argument about the extent of the effects, especially about the degree of competition between man and seals for different species of fish.

Little information is available on the extent of incidental kills of seals in fishing gear. Until recently, this mortality has probably been very minor, although there may have been some increase with the more extensive use of bottom-set gill nets.

The effects on salmon and salmon fishing have attracted special attention (Rae and Shearer, 1965). (See also Chapter 25.) These are more apparent and possibly more important than those on other species of fish. Further, salmon seem to hold a special status among fish, comparable to that held by seals and seal-related activities among other conservation issues. The widespread public concern derives partly from the fact that many salmon anglers and their friends occupy positions at the upper political and administrative levels. There has also been considerable concern about the decline in the numbers of fish, especially the larger fish (i.e., "salmon" as compared to grilse), returning to British rivers. The cause of this reduction is unknown. Increased numbers of seals are among the suspects, together with increased gill-netting in English coastal waters and heavy fishing off Greenland and on the high seas.

Damage to gear and catch is highly visible to fishermen. While the total impact (measured by the percentage of damaged fish entering the wholesale market) may be small, and while the extent of damage to nets has decreased since the introduction of synthetic nets (Parrish and Shearer, 1977), the problem of seal damage is nonetheless real to salmon fishermen in some locations. Recent analysis (NERC, 1984) shows no clear evidence of increased damage corresponding to the recent increases in the numbers of the main culprits, the grey seals. Factors other than the overall abundance of seals may be more important. Thus, reducing abundance within the limits generally acceptable to the public may be less effective than other measures, such as firing rifles to frighten seals away.

More doubt surrounds the effects of the consumption by seals of commercial fish catches. Early studies of feeding were based on the stomachs of seals, many shot near salmon nets. These studies suggested that seals consumed large quantities of salmon. Since the fish were taken just as they were entering the main fishery, seal predation would have had a serious impact on the fisheries (Rae, 1968, 1973). More recent studies (NERC, 1984) show no traces of salmon in the faeces of seals. Rather, the most significant element in most areas consists of traces of sand lance, and there is evidence that various commercial demersal species make up most of the remainder of the food consumed (NERC, 1985, Table 9.3). The NERC studies also failed to find any relationship between the survival of salmon in the sea and the increased abundance of grey seals. There is, however, no proof that such a relationship does not exist. Undoubtedly, some seals eat some salmon at some times, but it is still not clear whether (apart from those removed from nets) they eat enough to cause a significant loss to the salmon fishery or to individual salmon fishermen.

There is less dispute over the impact on fisheries for other species. The 1984 NERC report estimated that seals consume a total volume of some 140,000 tonnes of fish annually. More than half of this amount consists of sand lance and other low-valued species used for fish meal, but nearly 40,000 tonnes were composed of ling, cod and other valuable species. Further studies on the energetics of seals and the species eaten by them may modify this total. The losses to fishermen could be significantly more, or less, than the total consumption by seals, depending on the sizes of fish eaten by seals and the dynamics of each fish species. The impact in absolute terms is substantial, probably representing a loss of millions, or even tens of millions, of pounds annually. However, as a percentage of the total value of the catch and as a percentage of the catch of any one individual fisherman, the impact, except possibly that relating to sand lance and ling, is small. It is reasonable to assume that this impact is roughly proportional to the total abundance of seals, but the truth of this assumption has not been demonstrated.

Similar comments apply to *Pseudoterranova decipiens*. Infection of fish flesh by this nematode causes losses to the processing industry, and those losses may be increasing, but the extent of the loss as a percentage of the total turnover, is not serious at present. Moreover, it has not been publicized because of the possible impact on sales.

Management Policy and Practice

The 1914 legislation was intended to protect grey seals from what was seen as a threat to their existence as a species. The 1970 Act widened the scope of legislation to consider seals as a possible resource or as a threat to fisheries. Killing of seals can be licensed to prevent damage to fisheries, to use a "population surplus" as a resource, or to reduce "a population surplus of seals for management purposes" (*Conservation of Seals Act*, 1970, section 10c). What is meant by a "surplus" or by "management purposes" is not defined, nor is there any requirement for management to aim at some specified level, such as that giving maximum sustainable yield.

Management authorities, that is, the Department of Agriculture and Fisheries for Scotland and the Home Office in England, advised by the National Environment Research Council, have a wide choice of objectives which should be capable of being matched to current public opinion. Nevertheless, management has not been easy.

One problem occurred on the Farne Islands, where the increasing abundance of grey seals was causing crowding and a high mortality rate of up to 25% among pups (Bonner and Hickling, 1971). This increase was also causing physical damage to the vegetation and loss of soil, thus destroying the nesting sites of puffins and gulls. These effects were judged to be undesirable. The management authority interpreting "management purposes" to include attempts to control these ecological effects, issued licences to kill seals. Over 1,000 seals, split roughly between pups and adults, were killed in 1972 and in 1975; and rather fewer were killed in 1977 (Summers, 1979, Table 8). After 1978, the policy was changed to one of active disturbance of seals at the overcrowded colonies. This intervention seems to have had most of the desired effects. After peaking at over 8,000 in 1979, the total number of seals has remained between 7,000 and 8,000. Shooting noises and other disturbances have caused the seals to disperse more uniformly over the islands, with less damage to vegetation, though pup mortality remains high. The killings on the Farne Islands, a nature reserve owned by the National Trust, reawakened public opposition which had previously caused the cessation, in 1965, of culls aimed at reducing damage to fisheries.

However, the National Trust has been able to explain the purpose of the culls, and since the number of animals killed has been reduced as the population growth ceased, the protest has remained within bounds. Much less success attended the 1977 attempt to extend the existing annual kill of 1,500 pups in the Orkneys and Outer Hebrides to adults, in order to reverse the increasing population trend and to stabilize the numbers at mid-1960s levels. This kill was to be carried out by Norwegian sealers under contract to the Scottish Office, but the plan came under very heavy attack. The background of the attack was undoubtedly the general opposition to any killing of seals, and especially to the idea that governments should actively promote increased killing. The attack was based on doubts about the scientific evidence, especially concerning the amounts of fish consumed by seals, and about the impact of this consumption on commercial fisheries. After a season in 1977 which was hampered by bad weather and by on-site protests conducted by Greenpeace and other groups, and after opposing motions had been made in the European Parliament and at the IUCN conference at Ashkhabad, U.S.S.R., in October of that year, further actions to implement the kill were abandoned. The cancellation of the proposed kill was front-page news in all the U.K. papers.

The Orkney seal kill has much in common with the Canadian harp seal story. There was enormous public interest coupled with a lack of public knowledge about the details of the subject. There was confusion between the real basis of much of the public opposition, that is, any killing of seals as a matter of principle, and the apparent issue, that is, the reliability of the scientific evidence. Both situations were coloured by what, in hindsight at least, appears to be ground for serious concern: that the management authority was a fisheries-dominated department. Thus, in a conflict between those wishing to kill seals (for direct use, or to protect fisheries) and those wishing to protect seals, the same institution was both the judge and the chief spokesman for one of the adversaries. The advantages and disadvantages of including the seal-management authority in a fisheries-dominated agency are discussed in Chapter 30.

Research

Government-sponsored seal research is carried out in the United Kingdom by the Sea Mammal Research Unit (SMRU), which is part of the National Environment Research Council. Unlike those in most other countries, this research unit is independent of government-sponsored research into fisheries, which is carried out in laboratories attached to the fisheries departments for England and Wales, and for Scotland. The SMRU is only weakly linked, through the NERC structure, with other marine research. Against the possible disadvantage of lack of close co-ordination, the SMRU has the advantage of being physically located with the British Antarctic Survey, which has a strong tradition of research into whales and seals of the southern oceans and their associated ecosystems.

British research into seals has been extensive and of high quality. Some of it, such as the modelling of seal populations to determine policies which would quickly bring populations to some desired stable level, is immediately relevant to Canadian problems. Nevertheless, the scientific results have not, at least in respect of the proposed Scottish grey seal cull, settled the issue of whether adult grey seals should be killed. Thus the differences between earlier studies and most recent NERC reports, which indicate a much lower consumption of salmon, are seen by some conservation groups to discredit previous proposals for a cull. This view is reflected in the headline "Grey seals versus fisheries: case dismissed?" in *RSPCA Today* (Autumn-Winter, 1984). In fact, the discrepancies are not greatly significant in relation to the question at issue. The interaction of seals with salmon is still an open question; the new report indicates a substantial cash loss to demersal fisheries such as ling and cod. A simple economic comparison between the costs of killing seals and the resulting benefits to fisheries yields the same results whatever set of figures is used to calculate the benefits. The benefits to fishermen are greater than the economic costs of killing seals. The important question, however, is whether some economic benefit to some fishermen justifies killing seals. This question is not easy to answer. Estimates of damage done to fisheries by seals indicate that a kill would yield some benefits to fishermen, but not enough to make the difference between bankruptcy and reasonable profit. The precise value of the benefits makes little difference to the answer. Unfortunately, this last question has not often been publicly addressed, either in the United Kingdom or, to date, in Canada, and there is certainly no answer generally acceptable to the public.

Norwegian Seals

The information in this section has been taken from the brief presented by Øritsland (1985), except where otherwise stated.

Stocks

Six species of seal are found in Norwegian waters, including Svalbard and Jan Mayen. Four species are northern animals: the bearded, the ringed, the harp and the hooded seal. They have not usually been found in significant numbers along the continental coast of Norway, although large numbers of harp seals have recently entered the waters along the Finnmark coast. The other two species, grey and harbour seals, are more southern species and are found along the continental coast; there is a small number of harbour seals in Svalbard.

Norway is the only country that has operated a significant long-distance sealing industry during the present century. This industry has been primarily focused on the harp and hooded seals of the northwest Atlantic, and these stocks are treated at length in other parts of this Report. The Norwegians have shown some interest in antarctic seals. A trial voyage was made to the Antarctic in August–October, 1964, and the participants took 852 seals (Øritsland, 1977), but the economics did not seem promising and no further commercial activity has taken place there.

The main commercial Norwegian sealing has been directed at harp and hooded seals. The trends in the three stocks concerned in the east Atlantic – the White Sea (East Ice) and Jan Mayen Island (West Ice) herds of harp seals and the hooded seals on the West Ice – have been very similar in the past half century to those in the west Atlantic. The same techniques such as marking, surveys and age-composition analysis have been used to estimate abundance and to monitor the status of the populations.

For harp seals, these estimates suggest pup productions of about 200,000 and 50,000 at the East Ice and West Ice respectively; these figures correspond to a total east Atlantic population of about one million. The current pup production of hooded seals on the West Ice is believed to be about 50,000 (Jacobsen, 1984), corresponding to a total population of a little less than a quarter million.

Similar doubts surround these estimates and the corresponding figures for the west Atlantic. Because of the greater public attention paid to the Canadian seal hunt, the data base for the west Atlantic is probably better and has certainly been more carefully analysed than that for the eastern Atlantic so that greater doubts surround the eastern figures. Probably the best that can be said of these latter figures is that they provide a fair representation of the order of magnitude of the current population sizes.

Even greater difficulties surround an evaluation of the recent trends in abundance. It seems fairly clear that the abundance of both harp and hooded seals in the east Atlantic decreased significantly in the 1950s and 1960s. Various measures were then introduced, both unilaterally and through joint action by the U.S.S.R. and Norway. These include protection of adult seals, especially breeding females, and limits on the total catch of pups. Observers directly concerned believe that these measures have resulted in a reversal of the decreasing trend. For example, results of Soviet surveys, quoted by Øritsland (1985), indicated an annual rate of increase of 5% in White Sea harp seals between 1968 and 1976. Others, however, have stressed the uncertainties, and found that it can be concluded with certainty only that the earlier decrease has slowed down (e.g. NCC, 1982). On balance, it seems probable that recent harvests have been below the sustainable yield, though the effects of the recent large incidental kill of harp seals in gill nets in the Finnmark region should be taken into account.

Neither of the other two species of northern seals has been subject to a specialized hunt, though both have been caught incidentally, particularly bearded seals in connection with a polar bear hunt in the Svalbard area. This may have reduced the stocks of bearded seals; however, the polar bear hunt has ceased and the seals now appear to be increasing. There is little evidence of any significant change in ringed seal stocks.

While the two southern seals have not been subject to large-scale commercial hunting, they have probably been subject to local hunting, especially by fishermen. By the early 20th century, the grey seal, which seems more vulnerable to hunting and disturbance than some other species, was, as in most other parts of its range and for similar reasons, at a low level. Recently both species have been fully protected in southern Norway, and a closed season has been declared for harbour seals in northern Norway, from 1 May to 30 November. These measures seem effective and both species seem to be increasing, at rates of up to 13% per year in some grey seal colonies. Total numbers are still relatively small, however, with estimated total Norwegian populations of 7,000 grey seals and 8,000 harbour seals. Nevertheless, the increases have been sufficient to cause concern among fishermen, and a culling program has been introduced for both species. The effect of this program is not yet clear.

Utilization

Norway has one of the world's largest sealing industries. Because, like Canadian sealing, it is concentrated in a few places, it has a local importance greater than its small contribution to the overall Norwegian economy. The shrinkage of the industry, first because of the need to conserve stocks and secondly because of the loss of markets, has caused severe economic problems. These problems and the measures, such as subsidies, taken by the Norwegian government to counteract them are relevant to the problems of the Canadian sealing industry and possible remedial measures; for these reasons they are treated at length in Chapter 19.

Interaction with Fisheries

All the interactions which raise actual or potential problems in Canada also occur in Norway. Seals damage nets, remove fish from them, are carriers of the nematode *P. decipiens*, and are major predators on some species of commercial fish. Some concern, though minor, has also been expressed about the effect of commercial fishing on the availability of food for seals. As in Canada, there are few doubts that such effects exist, but it is difficult to quantify them.

Until recently, these effects may have been a nuisance to the fishermen concerned, but they did not appear to be serious. However, in 1978 and in subsequent years, large numbers of harp seals have appeared along the Finnmark coast in the early months of the year. This change in migration pattern may have resulted from changes in the stocks of capelin, one of the major foods of harp seals and itself the subject of an intensive fishery. The influx of seals occurs early in the year, at the same time as the important gill-net fishery for cod. Many seals become entangled in the nets, and there is evidence that up to 10,000 seals have been drowned in some seasons (Bjørge et al., 1981; see Chapter 23). The cost in damage to gear has been estimated at 0.5 to 1.0 million Nkr, with losses of a similar magnitude attributed to reduction in catches.

Apart from this recent situation, the seals most involved in direct effects on the fisheries have been grey seals, which cause damage to gear, especially traps, and transmit parasites, and harbour seals which cause damage to gear.

Management Policy and Practice

Norwegian policy towards seals has been based on the view that seals, like fish, are a renewable resource to be used responsibly. This seems consistent with the majority view of Norwegians. (See Chapter 11, which details the results of the Gallup Poll conducted for the Royal Commission.) Responsibility for the management of sealing is established by the *Seals and Sealing Act* of 14 December, 1951, administered by the Royal Norwegian Ministry of Fisheries. The Norwegian Sealing Council, in which scientists, the sealing industry and various ministries participate, advises the ministry.

Because the major commercial hunts used to take place in international waters, and other countries harvested the same stocks of harp and hooded seals, Norway has made agreements with the countries concerned. The agreements made with Canada, bilaterally and under the International Commission for the Northwest Atlantic Fisheries (ICNAF) and its successor, the Northwest Atlantic Fisheries Organization (NAFO), concerning the west Atlantic stocks, are described later in this chapter. Norway and the U.S.S.R. concluded a bilateral agreement in 1957, in respect of the east Atlantic, but discussions on seals are now included in the annual discussions on fisheries conducted by the joint Norwegian-Soviet Fisheries Commission established in 1983. Regular consultations with Denmark and Greenland about sealing in the Greenland Sea were initiated in 1984. The International Council for the Exploration of the Sea (ICES) has established a working party to review the scientific information on the state of harp and hooded seal stocks.

The regulations and their impact on the stocks of the west Atlantic harp and hooded seals are described in detail in Chapters 21 and 30. Quotas have been set for the harp seals of the White Sea stock since 1965, and for the harp and hooded seals of the West Ice since 1971. The catches vary from year to year because of changes in ice conditions, and in many years they have been well below the quotas, which serve principally to put a ceiling on the catches in unusually favourable years. Although the quotas have been set at about the level of the central estimate of sustainable yield, they seem to have allowed the stocks to increase, and recently there has been some increase in quotas. The reversal of the decreasing trend observed in the period up to 1965 was also helped by the protection of breeding adults; this protection has applied to harp seals on the East Ice since 1963, to those on the West Ice since 1965 and to female hooded seals (except for compelling safety reasons) since 1969.

Until very recently, the major factor in determining Norwegian sealing policy has been the long-term economic interest of the sealing industry and of the local communities for which sealing has been important. This interest has been the chief justification for the quotas and other management measures and for the economic support given to the industry to counteract the current slump in the market. (See Chapter 19.) Some concern has been given to the well-being of the seals and this has been reflected in regulations governing the use of the hakapik and other killing methods. (See Chapter 20.) However, neither the general conservation movement nor the effect of seals on fisheries has had a major influence on Norwegian sealing policy. This situation probably will change in the future, in the wake of a sustained slump in the market for seal products and an increase in the apparent impact of seals on fisheries.

Comparisons among Regions

Population Dynamics

Experiences in these other areas all tend to confirm the theories of the dynamics of seal stocks and their response to exploitation, which are the basis for assessments such as the sustainable yield. On the negative side, there are several examples of the devastating effects of uncontrolled exploitation. Where the seals were concentrated on a few small islands and there were no marketing or other constraints on the number of seals that could be killed, as was the case with several sub-antarctic fur seal stocks, it could take only a few years from the time of discovery to the time when the stock had been reduced very nearly to extinction. Fortunately, it seems difficult to exterminate a seal species completely by over-exploitation, and despite near misses these fur seal species survived.

The most seriously threatened species today are the monk seals, and the Caribbean monk seal is probably extinct. Monk seals live in warm waters outside the main areas of seal distribution. Although they have been and may continue to be killed, by fishermen for example, they are not now subject to direct hunting. The threats to them seem to come from changes in habitat and general human disturbance, to which they appear more vulnerable than other species.

Depleted populations of seals can show remarkable resilience. For example, the antarctic fur seal stock at South Georgia virtually disappeared as a result of intense exploitation in the 19th century. For the last 30 years, however, the population has doubled every five years, and it now numbers over a million. This extremely rapid growth rate has been said to be the result of the increased availability of krill, thanks to the depletion of the stocks of large baleen whales. This may be part of the reason but the basic constraints that limit the potential growth rate of any seal population still apply. Although only one pup is born each year and sexual maturity is not attained for several years, very rapid growth has been achieved.

The other notable feature of the fur seals at South Georgia is that it seems, though there are too few observations in the relevant period to be sure, that the depleted stock remained for a long time at a very low level, increasing only slowly if at all, before increasing rapidly in the middle of the present century. Conservationists are concerned that this pattern may indicate the existence of a lower limit in the population below which recovery is difficult and may not occur at all. If there is such a limit, it must be very low indeed.

Apart from the dramatic story of the collapse and later recovery of the southern fur seals, there are less extreme experiences showing the ability of seal stocks, under proper conditions, to sustain substantial harvests over long periods. In addition to the traditional subsistence hunts by aboriginal peoples of the Arctic, a commercial hunt for seals in Uruguay has been carried on for four centuries. The northern fur seal at the Pribilofs and the southern elephant seal at South Georgia both recovered from depletion and then were harvested at close to a sustained level for many years.

The last two stocks also demonstrate the need for careful monitoring as exploitation proceeds and the need to adjust management practices as new information becomes available. On the Pribilofs, for example, it was discovered that certain details of population-dynamics theories were incorrect; the population could not sustain as great a harvest of females as had been thought. At South Georgia, the original analyses proved too simplistic and studies of age and maturity showed the need for reducing catches somewhat.

A note of caution is in order concerning the extent to which a seal population can be reduced without jeopardizing its genetic variability. There are two cases in the north Pacific that exemplify this concern. The Guadalupe fur seal was once abundant on the islands of northern Baja California and southern California. It was nearly exterminated by sealing during the 19th century. A few survivors were discovered on Guadalupe in 1954 (Hubbs, 1956), and the population had recovered to more than 500 by the 1970s (Hubbs, 1979). Although large rookeries are known to have existed on open beaches prior to intensive exploitation, the individuals that survived to contribute to the species' recovery had the habit of pupping in caves. Peterson et al. (1968) noted that:

> *It is possible that during the rapid wholesale slaughter of the fur seals a century ago those animals in open rookeries were selectively eliminated. Only a nucleus with secretive behavioral traits may have persisted, thereby modifying the behavior of the surviving population.*

The northern elephant seal was similarly driven to near-extinction by uncontrolled hunting; there may have been as few as 20 individuals surviving by the early 1890s (Bartholomew, 1952). The population has recovered well, reoccupying its former breeding range and numbering in the tens of thousands today. Biochemical studies suggest, however, that the species has lost a pool of genetic variability with which to adapt to changing conditions, making it "especially vulnerable to environmental modification" (Bonnell and Selander, 1974). These concerns about genetic variability relate to populations which probably fell below 100 individuals and do not seem to be applicable to any Canadian seal population (apart from the northern elephant seal which is an infrequent visitor to Canadian waters).

Interactions with Fisheries

All seals eat fish and other marine animals, many of which are harvested or potentially harvestable by humans. Most seals are intelligent enough to recognize that fish caught in nets or on hooks are an easier source of food than are fish swimming in the open sea. Some conflict between seals and fisheries is therefore inevitable.

Complaints from fishermen about the food eaten by seals and the effect that seals' predation may be having on their catches are rare. In part, this may be because exploitation of seals usually precedes or occurs in parallel with exploitation of fish. By the time that fishermen become concerned about declining fish catches, the seal stocks may have been so depleted that competition does not arise as a serious issue. It can, however, become an issue when seal stocks recover and fish stocks do not, often because of continued intensive fishing. This seems to have occurred in the United Kingdom, which is the area outside Canada in which complaints about competition are most obviously a serious issue. The intensity of some of these complaints may be a misleading indication of the real concern of fishermen about competition. Partly, these complaints derive from much stronger complaints about removal of fish, especially salmon, from nets and partly, they are based on biased estimates of the proportion of salmon and other valuable fish in the diet of seals.

The most forceful complaints arise when the fishermen can see the seals taking fish from their nets or when the seals damage their nets. Problems of this nature in some other countries are at least as severe as those in Canada. The Cape fur seal of southern Africa seems to be particularly aggressive in taking fish, often leaping in large numbers into purse-seines to take sardines or anchovies. When attempting to take hake or other fish from trawl-nets, they may even go up the stern ramp of a trawler, either deliberately or because they are entangled in the net. A frightened and angry 500-kilogram male fur seal is not a welcome visitor on the limited space of the deck of a fishing vessel, even a large factory trawler.

Yet, despite the obvious impact of seals on fisheries, the complaints by fishermen rarely contribute to the sort of crisis that has been experienced in Canada in respect of the harp seal harvest. The controversy over the culling of grey seals in the United Kingdom has attracted much notice, but it arose because of public opposition to actions by the government, rather than because of the fishermen's efforts to force an unwilling government to act.

It is likely that complaints by fishermen are generally muted because many of the seal stocks potentially concerned have been depleted or kept in check by past or current harvesting. In addition, most fishermen accept seals as part of their environment, together with bad weather, excessive catches by other fishermen and poor markets. Fishermen complain about these problems without much expectation that the situation will improve.

Many seal stocks are now increasing because of improved management or outright protection; these include grey seals in the United Kingdom, fur seals in southern Africa and several species in the United States. When fishermen experience the effects of increased seal numbers on the fisheries, they may well expect governments to act on their behalf. If the governments are not sufficiently responsive to these concerns, the pressure of protests from fishermen may grow.

Public Concerns

Outside of Canada, the only countries where there appears to be much concern over the killing of seals in national waters are the United Kingdom and the United States. In other countries with significant sealing (Greenland, Norway, South Africa, Uruguay, the U.S.S.R.), sealing seems to be viewed by the public as merely another legitimate use of national living resources and one that arouses little public interest.

In the United States, public concern with seals is bound up with a wider concern for marine mammals in general. Much of this concern has been focused on the depletion of large whales, the very large incidental catches of porpoises in tuna purse-seines during the 1960s and 1970s, and the Canadian whitecoat (harp seal) harvest. Some environmental groups have taken an interest in the Pribilof fur seal harvest but this issue does not seem to have aroused much public interest. Fishermen appear to be the only major group with an outspoken interest in the seal stocks in the lower 48 states. Sealing or the killing of seals as a control measure is not seen as an important domestic issue in the United States. In the Gallup poll carried out for the Royal Commission, 30% of Americans interviewed identified the United States as being involved in sealing, compared with 75% of Canadians and 83% of Norwegians who identified their own national involvement. (See Chapter 11.)

In the United Kingdom, the main public concern is with the culling of grey seals, either as a measure to limit the ecological consequences of overcrowding on the Farne Islands or to reduce competition with fisheries. As with the harp seal protests, it is useful to distinguish between those opposed to any killing of seals, and especially the killing of pups, and those concerned that the scientific basis for the cull has not been sufficiently well established. Together, these two groups have been able to raise public awareness and public concern to a very high level.

The objections of the second group may be met by better research and, particularly, a better presentation of the results of research and the implication of uncertainties that inevitably surround the results of any research. Although the objections of the first group cannot easily be met by argument, they require accommodation in the development of a national policy with respect to seals and sealing that is designed to reconcile the divergent interests and views on the matter.

Management Policy

Countries differ in their approaches to seal management. In most countries where seals are common, they are, as in Canada, included among fish and other marine living resources as part of the responsibilities of the Department of Fisheries or the equivalent branch of government. In contrast, in the United States, seals together with other marine mammals, enjoy a rather special status under the *Marine Mammal Protection Act of 1972*. For seals there, ultimate responsibility still lies with the department that includes the National Oceanic and Atmospheric Administration, which handles normal marine fishery matters, but the immediate responsibility lies with a special Marine Mammal Commission whose main concern, judged by the fields of responsibility of those who nominate commissioners, is with scientific and environmental or ecological matters rather than with the use of a resource.

In the United Kingdom, responsibilities are divided. In Scotland, policy, such as that on culling, has lain with the Department of Agriculture and Fisheries for Scotland (DAFS), while in England the lead authority is the Department of Environment rather than that of Agriculture, Fisheries and Food. In both parts of the nation, the lead responsibility for research lies with the Sea Mammal Research Unit, which is part of the National Environment Research Council and quite separate from the fisheries research laboratories.

The political decision as to the locus of responsibility for sealing management is no longer straightforward. To the extent that seals are viewed as more than a harvestable natural resource, the approach to management of a fishery-oriented administrative authority may be out of tune with public opinion. This happened in Scotland. On the basis of available evidence and with a view to protecting the fisheries, DAFS made a reasonable decision to cull grey seals in the Orkneys. The result was an extremely vocal protest from members of the public who viewed seals as special animals and who, in consequence, demanded a higher level of scientific proof that the cull was necessary. Because the department responsible for seals was also responsible for fisheries, which accounted for much more of its day-to-day work than did seals, conservation groups believed that its decisions were necessarily biased toward narrow fishery interests. The converse can be true when seals are handled by a different department. In areas of the United States where seals are increasing in numbers, many fishermen believe that present arrangements are biased in favour of the seals and of those who wish to protect them.

On the other hand, a close link between fisheries and other marine agencies has definite advantages. For example, the close integration among scientific groups (fishery biologists, seal scientists and, often, oceanographers) studying subjects which are part of, or relate to, the same ecosystem should make for more effective research. So long as the public accepts the proposition that seals may be treated as a harvestable, renewable resource, integration of responsibility for seals and fish is desirable. It should lead to a consistent policy for the utilization of each resource and facilitate the resolution of inter-resource conflict.

Canada's International Commitments

Under a number of international agreements and conventions, Canada has assumed certain rights and responsibilities in relation to seals. These include: agreements wholly concerned with seals and sealing, namely, the North Pacific Fur Seal Commission and the Canada/Norway Sealing Commission; fishery commissions in which seals are treated as one of a number of resources, namely, the International Commission for the Northwest Atlantic Fisheries (ICNAF) and its successor, the Northwest Atlantic Fisheries Organization (NAFO); and conservation agreements in which seals are treated among many other species requiring conservation and protection, namely, the Convention on International Trade in Endangered Species (CITES).

North Pacific Fur Seal Commission

The first international agreement to manage and conserve the north Pacific fur seals (specifically the stocks of the northern fur seal, *Callorhinus ursinus*) was signed by Japan, Russia, the United Kingdom (on behalf of Canada) and the United States in 1911. It was one of the first and, on the whole, one of the most successful international agreements for the rational use of marine living resources. The history of the fur seal stocks, including their collapse and recovery under management, is set out in Chapter 22.

Fur seals breed on a number of Soviet islands (Commander and others) and U.S. islands (Pribilofs) in the Bering Sea and northwest Pacific and have a long history of exploitation. At the beginning of this century they were harvested on these islands by Russian and American nationals and on the open seas by sealers from all four signatory countries. International co-operation was therefore needed to manage the resource. This was achieved under the 1911 convention which restricted harvesting, which has involved almost entirely the taking of young sub-adult males, to the breeding islands. Canada and Japan agreed to abstain from high-seas (pelagic) sealing and in return were guaranteed a share of the proceeds from skins taken on the breeding islands.

This agreement enabled the stocks to rebuild, and it was renewed regularly with some differences in form. It was not renewed in 1984, however, and the North Pacific Fur Seal Commission has consequently been terminated. As long as fur seals were regarded as a harvestable resource and it was possible that in the absence of an international management body pelagic sealing might be revived, Canadian participation in the Commission was fully justified. With the termination of the Commission, and with the changes that have occurred in public attitudes and in the present-day economic realities of sealing, it is now appropriate for Canada to re-examine the forms of collaboration with other countries in relation to the fur seal herds.

Certain groups in the United States which oppose any killing of seals mounted attacks on the North Pacific Fur Seal Commission's existence, which have led to the failure by the United States to renew the Commission's mandate. The groups contend that its chief function was to arrange the orderly killing of several thousand seals every year. The traditional argument that, without the Commission, the seals would be in worse danger from uncontrolled pelagic sealing is no longer as convincing as it once was. There are, however, other problems concerning fur seals which require concerted international action. Entanglement in discarded fishing nets and other debris has come to be recognized as a serious threat to the fur seal population. (See Chapters 22, 23.) Heavy fishing of walleye pollock and other important prey species in the Bering Sea and the Gulf of Alaska may be affecting the fur seals' food supply. At the same time, the large quantities of fish eaten by fur seals and other marine mammals could affect the yield of commercial fisheries.

These problems cannot be tackled effectively by a body concerned solely with seals. In the north Atlantic there is a single scientific body, the International Council for the Exploration of the Sea (ICES), in which all countries bordering on the north Atlantic that are interested in marine research participate and which provides advice on a number of matters, including fisheries management and marine pollution. Such a body in the north Pacific would be in a good position to bring together all the scientific information relating to the fur seals, as well as other marine mammals, and their interactions with fisheries and, to the extent that these interactions are causing problems, it could provide advice on how to deal with these problems. Canada might wish to take action to establish something equivalent to ICES in the north Pacific. Pending progress along these lines, Canada should work at an international level to ensure that effective management of fur seals is maintained. (See Chapter 22.)

Canada/Norway Sealing Commission

This Commission was established under an agreement made between the governments of Canada and Norway in July 1971. Its objectives are to promote co-operation between the two countries in many aspects of seals and sealing, including research, humane killing and conservation of the stocks. The Commission provided a mechanism to permit some continuation of Norwegian sealing on traditional sealing grounds after 1977, when Canada established its 200-mile fishing zone. Though the Commission may make suggestions, it does not have the power to make formal and binding recommendations on the levels of total allowable catch. It originally dealt only with harp seals, but in 1975 the agreement was amended to allow it to deal with hooded seals, bearded seals and walruses.

Despite what appears to be considerable overlap and duplication with ICNAF/NAFO, the Commission played a useful role in the 14 meetings held between 1973 and 1982. It allowed for a broad exchange of views and information outside the framework of ICNAF/NAFO and thus facilitated the making of formal recommendations in the larger multilateral forum. No Norwegian sealing has taken place in the northwest Atlantic since 1982. Because of the depressed market for seal products, there is no immediate prospect of the Norwegians wishing to resume sealing. If they did, it is doubtful that such sealing in the waters under Canadian jurisdiction would be readily acceptable to Canadian public opinion. There may be little for the Commission to do in future. It has not met since an informal meeting was held in January 1983, and it may be best to allow it to die quietly.

International Commission for the Northwest Atlantic Fisheries and the Northwest Atlantic Fisheries Organization

Established in 1949, the International Commission for the Northwest Atlantic Fisheries (ICNAF) was, until the recent changes in the Law of the Sea and the extension of national jurisdictions, one of the typical and also one of the more active regional fisheries commissions. It had broad responsibilities for all fish resources in the region from New England north to the Canadian Arctic and east to Cape Farewell, Greenland. These responsibilities included the compilation of statistics, the promotion and co-ordination of research and the recommendation of management measures. In 1961, it was agreed, on a proposal by the Canadian government, that seals should be included within the responsibilities of ICNAF. This agreement came into force in 1966, when all member countries had ratified it, and a special group, Panel A, was created to consider seals. This panel, like others, discussed the results of the scientific analyses and advice produced by the Standing Committee on Research and Statistics (STACRES) and made proposals for regulatory measures such as closed seasons and levels of total allowable catch.

The arrangements for scientific work within STACRES ran smoothly and were widely recognized as an effective example of international collaboration. There was dissatisfaction, however, especially on the part of the coastal states, with the performance by ICNAF and similar bodies in implementing effective management measures. Decisions had to be reached by consensus. Thus, proposed measures were often seriously weakened before all members found them acceptable, and management actions were taken too late. Though mesh regulations introduced by ICNAF produced some benefits, they failed on the whole to address urgent problems of overexploitation in the 1960s and 1970s.

Disenchantment with regional fisheries commissions was one factor leading to the massive re-examination of the international Law of the Sea and eventually to the United Nations Conference on the Law of the Sea. Though the Convention codifying the conclusions of the conference has recently been signed, it has not received enough ratifications to enter formally into force. However, the concept of a 200-mile exclusive economic zone (EEZ), within which the coastal states have effective jurisdiction over fisheries and other living resources, is now generally accepted. Most coastal states, including Canada, have implemented 200-mile zones of one kind or another.

The general acceptance of the 200-mile limit has changed the nature of international fisheries regulation. To accommodate the changes, a new body, the Northwest Atlantic Fisheries Organization (NAFO), was established to replace ICNAF. In NAFO the two functions of scientific analysis and the recommendation of management measures are separate. Management applies only to stocks that are exploited wholly or partly outside the limits of national jurisdiction. For instance, the cod stocks on Flemish Cap, a bank some 500 kilometres east of Newfoundland, are subject to NAFO management recommendations.

The scientific council of NAFO may discuss any scientific matters concerning the living resources of the northwest Atlantic. At the request of the country or countries concerned, it can give advice on the status of stocks and the management requirements for resources within national jurisdiction. This advice has been frequently requested by Canada and by Greenland, represented by the European Community (EC) or by Denmark, with respect to stocks of animals that move between the two areas, including harp and hooded seals. This advice is not binding and coastal states may follow or ignore it. As the recommendations by ICNAF were binding on members, subject to an objection procedure, ICNAF differed fundamentally from NAFO in this respect.

The present NAFO arrangement has much to commend it. Since substantial numbers of the harp and hooded seals breeding in Canadian waters are caught off west Greenland, it is important to have some formal arrangement for regularly bringing together statistical and other information from the two countries. In the NAFO scientific council, issues are discussed both by specialists studying the resource under review and by a wider group of scientists. This exposure to a range of ideas and experience often improves the quality of the scientific analysis. A similar arrangement exists within the International Council for the Exploration of the Sea (ICES), of which Canada is also a member. ICES is concerned mainly with the northeast Atlantic.

A negative aspect of both NAFO and ICES is that they are closed bodies. The scientists, most of them from government fisheries laboratories and similar institutions, attend the meetings as members of national delegations. The reports of these meetings, containing scientific findings and management advice, are usually not available to the public, at least for some time. Thus action may be taken on the basis of advice that was not subjected to public scrutiny and challenge. If, after the scientific advice becomes public knowledge, it is challenged by competent scientists who were excluded from the discussions, those who defend the management action are in a difficult position. The controversy that arose after publication of the report of the ICES ad hoc working group on assessment of harp and hooded seals (ICES, 1983) is an example of this problem.

One way for Canada to increase the credibility of NAFO's statements concerning seals would be to include in its delegation more scientists from the academic community and various non-government institutions. Widening the participation in the NAFO groups concerned with seal-population assessment would make the scientific basis of seal-management advice less vulnerable to criticism.

Convention on International Trade in Endangered Species

The Convention on International Trade in Endangered Species (CITES) was signed in Washington in 1973 and implemented by Canada in 1975. More than 80 countries now adhere to it. As the title implies, the Convention's aim is to aid the conservation and preservation of endangered species by controlling international trade. Most of the species of concern to CITES are listed in one or the other of two appendices to the Convention.

Appendix I includes all species threatened with extinction which are or may be affected by trade. Trade in these species is subject to strict controls including both export and import permits. One condition for an import permit is that "a Management Authority of the state of import is satisfied that the specimen is not to be used for primarily commercial purposes." Monk seals and the Guadalupe fur seal are listed in Appendix I. No Canadian seal is listed in Appendix I.

There are two circumstances in which a species may be included in Appendix II. First, it may be similar in appearance to an endangered species listed in Appendix I, so that effective control of trade in the endangered species can be achieved only if trade in the non-endangered "look-alike" species is also controlled (Article II.2(b) of the Convention: the look-alike provision). A second rationale for listing in Appendix II is that a species, although not necessarily immediately threatened with extinction, may become so threatened if trade is not strictly regulated (Article II.2(a)). The only Canadian seal listed in Appendix II is the northern elephant seal, which is an infrequent visitor to Canadian waters. (See Table 6.1, Chapter 6.)

An export permit is required for trade in species listed in Appendix II. Import, however, requires only the presentation of an export permit (or re-export certificate) and there are no restrictions on commercial use. An export certificate will be granted only if the export will not be detrimental to the survival of the species.

CITES holds its conference every two years. At the 1981 conference, proposals to include harbour and grey seals in Appendix II were unsuccessful. In 1983, the Federal Republic of Germany proposed that all earless seals not already listed be included in Appendix II. This listing would have included all the Canadian species except the fur seal and sea lions in the Pacific. The proposal was held to be justified on two grounds: hooded seals required protection in their own right under Article II.2(a); and the other species should be included under the look-alike provision. The proposal did not make clear whether the alleged similarity of the other species was to the monk seal listed in Appendix I or to the hooded seal or to both species.

The 1983 proposal was defeated, as was a similar proposal to list hooded seals in Appendix II, that was put forward at the 1985 CITES meeting in Buenos Aires. On the basis of the scientific evidence presented, the decision was probably correct. Considerable doubts exist about the precise status of the hooded seal. Its abundance in the western Atlantic could be decreasing but no evidence was presented to suggest that the decrease was likely to threaten the existence of the species or that strict controls on international trade were needed. The explanation presented to justify the 1983 proposal stated, in part:

> *The proposal . . . is primarily to provide control over a number of species involved, or potentially involved, in international trade and not currently subject to national and international regulations (Federal Republic of Germany, 1983).*

As the harp and hooded seal hunt is subject to Canadian and NAFO regulation, these species would not seem to require the controls sought in the proposal. Although CITES concerns are limited to conservation issues, the CITES proposals were motivated more by political concerns held by the seal-protection movement than by scientific concerns about the status of the stocks. In this situation, the strong Canadian opposition to the CITES proposals was understandable and possibly justified. At the same time, a listing in Appendix II could be seen as a useful complement to the quota regulations, while Canadian opposition to the listing was open to representation as opposition to rigorous conservation of the seal stocks.

Conclusions

1. Seals and sealing industries exist in many areas outside Canada, and the experiences of these areas are often relevant to Canadian situations. Sustained harvesting over a long period is possible, provided that adequate controls are applied. In the first instance (as, for example, in Uruguay), these controls need not be based on sophisticated scientific analysis.

2. Seal stocks can, in due course, recover from very low population levels. In some cases, perhaps aided by favourable conditions, the recovery can be spectacular, as it was, for instance, in South Georgia. If numbers have been reduced to very low levels, say, fewer than 100, there can be a loss of genetic diversity, which could have serious consequences for the long-term success of the population.

3. Where seals and substantial fisheries exist in the same area, there is normally some perception of interaction. The extent of such interactions, especially those that involve competition for fish, is usually difficult to determine exactly, as in Scotland and South Africa, for example. Despite this uncertainty and, particularly in western countries, the special interest of the public in seals, effective fishery management requires that seal stocks be included along with the fish stocks of marine ecosystems in the process of optimizing social benefits. Part of the benefit from seal herds (as of that from salmon runs) may be realized in non-consumptive form. Experience in South Africa and Uruguay has shown that "seal-watching" can be compatible with commercial harvesting.

Recommendations

1. Canada should continue to collaborate with all interested countries in the promotion of research into fur seals and in the co-ordination of management measures. Canada should also take an active part in efforts to establish a new international body with responsibility for all elements of the north Pacific marine ecosystem.

2. Canada should seek to broaden the participation of scientists working outside government institutions in those working groups of the Northwest Atlantic Fisheries Organization concerned with seals.

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