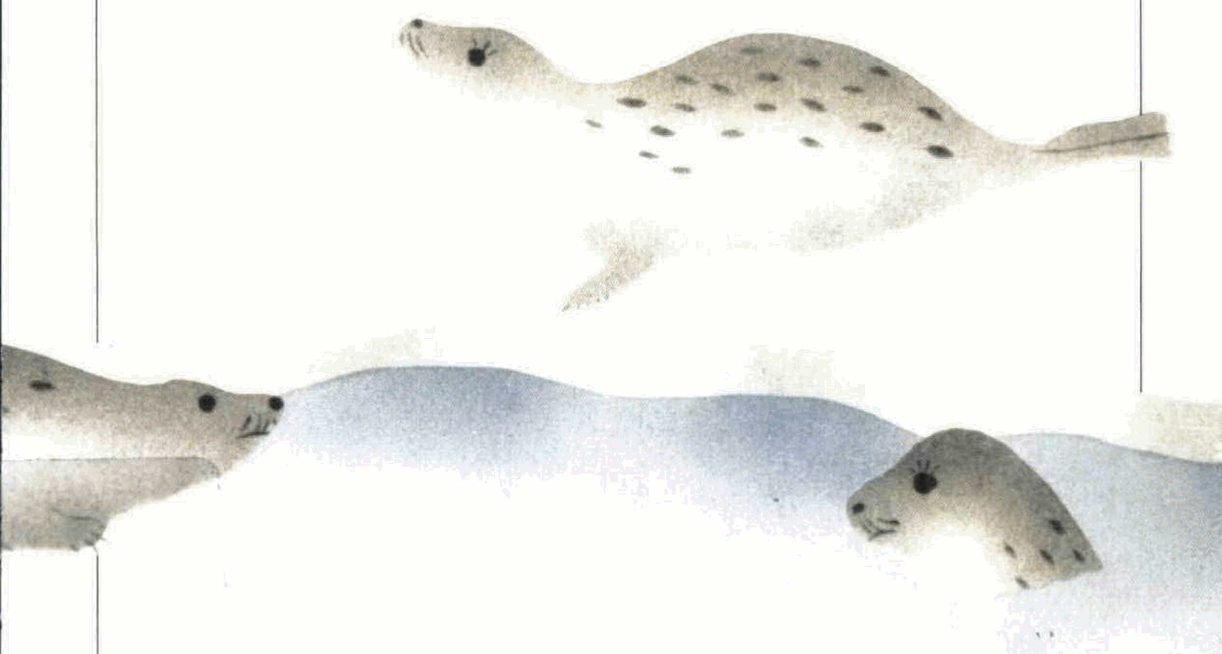
Seals and Sealing in Canada

Report
of the Royal Commission

Volume 3



Canada

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SEALS AND SEALING IN CANADA

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Available in Canada through authorized bookstore agents and other bookstores or by mail from Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

Also available in French
Vol. 1 available in Inuktitut

Printed in Canada

Catalogue No. Z1-1984/1-3E

ISBN 0-660-12130-1 (v. 3)
ISBN 0-660-12127-1 (Set)

Canada:	$ 4.50	(v. 1)
	$25.50	(v. 2)
	$28.25	(v. 3)
Other countries:	$ 5.40	(v. 1)
	$30.60	(v. 2)
	$33.90	(v. 3)

Price subject to change without notice

Canadian Cataloguing in Publication Data

Royal Commission on Seals and the Sealing Industry in Canada
Seals and Sealing in Canada

Issued also in French under title: Les phoques et la chasse au phoque au Canada
Vol. 1 issued also in Inuktitut

Chairman: Albert H. Malouf

ISBN 0-660-12127-1 (set)
ISBN 0-660-12128-X (v. 1)
ISBN 0-660-12129-8 (v. 2)
ISBN 0-660-12130-1 (v. 3)

1. Sealing–Canada. 2. Seals (Animals)–Canada.
I. Malouf, Albert, 1916- . II. Title.
SH362.R69 1986 338.3'729748'0971 C86-090221-8

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Chapter 20

Methods of Killing Seals

As with all slaughter operations, mistakes are made; the system breaks down. I would say it breaks down less at the seal hunt than it does in the majority of our slaughter operations in Canada (Quine, 1985).

Introduction

World-wide, 15 species of seals and sea lions are now killed each year or have been killed until very recently. (See Table 20.1.) These animals are killed in commercial and susbsistence hunts to obtain various seal products, and in bounty programs and organized hunts that are intended to control seal numbers. Although shooting is the most common method of killing the various species of seals, the major commercial seal hunts most generally use clubbing as the means of killing. In some areas seals are also taken in nets; they are harpooned in some subsistence hunts, and they are killed by drug injection in one commercial harvest.

One of the major grounds of objection to the hunting of seals, and particularly of harp seal pups, has been the alleged cruelty of the operations. These allegations have made it necessary for the Royal Commission to examine the issue carefully, and to try to determine how far they are justified. In carrying out these tasks the Royal Commission has considered not only the killing of harp seal pups, but also the killing of all seals under Canadian jurisdiction and killing of seals in other countries.

From one point of view, the killing of any animal by any means can be considered an act of supreme cruelty. Such a view is one aspect of the basic question of humanity's relationship to other animals, and the Royal Commission has considered this matter at length in Chapters 8 and 12. In the present chapter, the concern is with the manner in which the animals are killed, once it has been decided that they are to be killed. The task, therefore, is to examine and describe the methods by which seals are killed in Canada and in other countries, as well as the circumstances under which the killings take place, and to try to draw conclusions about the extent to which the various killing operations can be fittingly described as "humane". It is

Table 20.1
Methods of Killing Seals

Species	Location	Annual Kill[a]	Killing Method[b]	References
Steller sea lion	Alaska	3	S?	Mate (1982)
(Eumetopias jubatus)	Japan	1	S?	Mate and Gentry (1979)
	U.S.S.R	?	S?	Mineev (1975)
South American sea	Uruguay	3	C	Vaz-Ferreira (1979a, 1982)
lion *(Otaria flavescens)*	Chile	2–4	?	FAO (1984)
	Peru	3	C	Vaz-Ferreira (1982)
Northern fur seal	Alaska	5	C	Keyes (1980), NPFSC (1983)
(Callorhinus ursinus)	U.S.S.R.	4	C	U.S.S.R. (1980), NPFSC (1983)
South American fur	Uruguay	4	?	Vaz-Ferreira (1979b),
seal *(Arctocephalus australis)*	Chile	2	?	FAO (1984), FAO (1982)
Cape fur seal	South Africa	5	C	Shaughnessy (1976)
(Arctocephalus pusillus)	& Namibia	3	S	King (1983)
Harbour seal *(Phoca vitulina)*	Canada	2[c]	S	Boulva (1973), Bonner (1979a)
	Greenland	1	?	Kapel (1975)
	Iceland	3	C, N	Einarsson (1978), Bonner (1979a)
	United Kingdom	2[c]	S	Bonner (1979a, 1982)
	Norway	?[c]	S?	Øritsland (1985)
	U.S.S.R.	?	?	Bychkov (1971)
	Japan	2	S, N	Naito (1971)
	Alaska	4	S?	Bonner (1979a)
Larga seal *(Phoca largha)*	U.S.S.R.	4	S	Marakov (1967), Popov (1982)
	Japan	1	S, N	Naito (1971)
	Alaska	3	S?	Bonner (1979b)
Ringed seal *(Phoca hispida)*	Canada	5	S, N	Davis et al. (1980), Canada, DFO (1985)
	Greenland	5	S, N, H	Kapel (1975, 1981)
	Finland	1	S?	Almkvist (1981)
	U.S.S.R	5	S?	Popov (1982)
	Japan	1	S, N	Naito (1971)
	Alaska	4	S	Stirling and Calvert (1979)
Baikal seal *(Phoca sibirica)*	U.S.S.R.	3	S, N	Mineev (1971), Popov (1982)
Caspian seal *(Phoca caspica)*	U.S.S.R.	5	C?	Badamshin (1960), Popov (1979, 1982)

Table 20.1
Methods of Killing Seals (continued)

Species	Location	Annual Kill[a]	Killing Method[b]	References
Harp seal	Gulf (Canada)	5	C, S, N	Reeves (1977), Lavigne (1979)
(Phoca groenlandica)	Front (Canada, Norway)	5	C, S, N	Reeves (1977), Lavigne (1979)
	Arctic Canada	3	S, N	Davis et al. (1980), Canada, DFO (1985)
	Greenland	3–4	S, N, H	Kapel (1975, 1981)
	Jan Mayen (Norway)	4	C?, S?	Lavigne (1979)
	Barents Sea (Norway)	4	C?, S?	Lavigne (1979)
	White Sea	3	C	Barzdo (1980)
	(U.S.S.R.)	4	D	Barzdo (1980)
		?	N?	Sdobnikov (1933)
Ribbon seal *(Phoca fasciata)*	U.S.S.R.	3	S	Shustov (1965), Popov (1982)
	Japan	2	S, N	Naito (1971)
	Alaska	2	S?	Stirling (1979)
Bearded seal *(Erignathus barbatus)*	Canada	3	S	Davis et al. (1980), Canada, DFO (1985)
	Greenland	2	S, N, H	Kapel (1975, 1981)
	U.S.S.R.	4	S?	Popov (1982)
	Japan	1	S, N	Naito (1971)
	Alaska	3–4	S	Burns (1967), Stirling and Archibald (1979)
Hooded seal *(Cystophora cristata)*	Front (Canada, Norway)	4	C, S	Rowsell (1975), Sergeant (1979)
	Greenland	3	S	Kapel (1975, 1981)
	Jan Mayen (Norway)	5	C?, S?	Sergeant (1979)
Grey seal *(Halichoerus grypus)*	Canada	2–3[c]	C, S	Hoek (1985), Canada, DFO (1985)
	Iceland	2	C, N	Einarsson (1978), Bonner (1979c)
	Faeroe Islands	?	S?	Bonner (1979c)
	United Kingdom	3	S	Bonner (1982)
	Norway	?[c]	S?	Øritsland (1985)
	Finland	1	S?	Almkvist (1981)

a. Approximate annnual catches at 1982 or earlier levels.
1 = 1 to 249; 2 = 250 to 1499; 3 = 1500 to 7499; 4 = 7500 to 24,999; 5 = 25,000 or more.

b. C = clubbing; D = drug injection; H = harpoon; N = Nets; S = shooting.

c. In part or in whole a cull or bounty operation to control the population.

also to consider whether the procedures now in use could or should be modified or replaced by methods which would be more humane.

Generally speaking, there is no such thing as an absolutely humane or an absolutely cruel way of killing an animal. All procedures will lie somewhere within a spectrum which, at least theoretically, has no limits. For this reason, the aim in any killing operation should be to move as far as possible towards the humane end of the spectrum.

Finally, this chapter compares the killing of seals with two other activities in which humans kill very large numbers of mammals. These are slaughtering in abattoirs and big game hunting. The purpose of these comparisons is not to determine whether the killing of seals is absolutely humane, but to find out where the seal-killing operations lie within the humaneness-cruelty spectrum as compared to these other major killing operations which are accepted, albeit implicitly, by many members of the public.

Criteria of Humane Killing

The definition of humane killing developed by the Canadian Federation of Humane Societies and adopted by the Committee on Seals and Sealing (COSS) states:

> *A humane death is that in which the animal suffers neither panic nor pain. In practice, this may be achieved by instantaneous death or immediately rendering the animal unconscious with early and inevitable subsidence into death without the regaining of consciousness (COSS, 1978).*

This definition can be viewed as representing the highest achievable point at the humane end of the spectrum denoted above.

There are three main issues to consider in discussing humane killing: pain, stress in the animal about to be killed, and stress in other animals present. The American Veterinary Medical Association (AVMA) Panel on Euthanasia contains the following information about pain:

> *The sensation of pain is initiated by damage to or intense stimulation of almost any part of the body. In tissues, pain receptors react to substances released when tissue is damaged . . .*
>
> *Recognition of pain by an animal depends on impulses from pain receptors traversing pain pathways leading to the thalamus and cerebral cortex. For pain to be experienced, the cerebral cortex and subcortical structures must be functional. An unconscious animal does not experience pain because the cerebral cortex is not functioning. If the cerebral cortex is rendered nonfunctional by any means such as hypoxia, depression by drugs, electric shock, or concussion, pain is not experienced.*
>
> *In an unconscious animal, stimuli that evoke pain will elicit reflex responses manifested by motor movements. For this reason, purposeful or nonpurposeful movements of an animal are not reliable indicators of cerebral pain reception (AVMA, 1978).*

The goal of promoters of humane killing is to produce a method of killing in which, as a first step, the animal is brought as quickly as possible to a state of unconsciousness and insensitivity to pain. As a second step, the method should lead fairly quickly to the death of the animal before it has regained consciousness. Humane killing techniques usually consist of two separate steps taken to meet these two requirements, but in some techniques a single step may sometimes or invariably cause death.

The other important considerations in humane killing are to eliminate, as far as possible, the stress and panic the animal undergoes prior to being killed, and to avoid, as far as possible, stress experienced by any other animals that are in the immediate vicinity and are aware of the killing.

Methods of Killing Seals

As Table 20.1 shows, the three principal methods of killing seals are:

- Clubbing. This method is widely used to kill harp and hooded seal pups, and to kill northern fur seals.

- Shooting. This method is used extensively in Canada in the hunt for hooded and older harp seals. It is the principal method of killing seals in the Arctic and is used in most culling operations aimed at controlling seal numbers.

- Netting. This method has been used locally in Canada in the harp and other seal hunts.

Some other methods which are, or have been, in use among the aboriginal peoples of the Arctic or in other countries are also described in this chapter.

Finally, consideration is given to a number of other possible methods of killing seals, successful or unsuccessful, which have been proposed with the intent of increasing the humaneness of the hunt.

Clubbing Seals

Of all the methods of killing seals, clubbing – in particular, the clubbing of whitecoat harp seals – has been much the most controversial. Many qualified observers have considered clubbing a humane method of killing seals; others have disputed that opinion. Whether or not clubbing is humane, it presents a brutal image, and the image of a sealer clubbing a baby seal has been a major factor in the arguments about the Canadian harp seal hunt. (See Chapter 9.)

Seals are clubbed on land or on ice, where they can move only awkwardly and thus cannot avoid the club. When the method is conducted properly, the sealer strikes the seal on the head with enough force to produce rapid unconsciousness (or sometimes death) either by skull fracture or by hemorrhaging within the brain. The sealer then ensures the death of the seal from exsanguination (bleeding), either by cutting major arteries or by piercing its heart.

Clubbing is used as a method of killing seals in or by Canada, Norway, the United States, the U.S.S.R., Uruguay, South Africa, Namibia and Iceland.

Harp and Hooded Seals

In the Canadian hunt, harp and hooded seals are clubbed on the ice within a few weeks of birth, before they will willingly enter the water. The sealer who follows the desirable procedure for humane killing strikes the seal enough blows on the top of the head to produce unconsciousness. Although a single blow may produce unconsciousness (Rowsell, 1973), the law now requires that the sealer strike sufficient blows to crush the seal's skull. The sealer then checks to ensure that the seal is unconscious before turning the animal over, cutting it open along the midline, and bleeding it, usually by severing the arteries to the forelimbs. The seal's death rapidly follows. Once the seal has been bled, it is skinned (a process more properly termed "flensed" as the fat is removed with the pelt).

Government Regulations on Killing Methods

Although clubbing has always been the main method of kill used in the seal hunt, it was not until 1964 and 1966, when the nature of the sealing operations had begun to attract public attention, that regulations controlling the killing of harp and hooded seals were first introduced; the regulations have been frequently amended since. Many of the amendments derived from recommendations made by veterinarians and other qualified persons who had observed the hunt in behalf of animal-welfare organizations, under the auspices of the Committee on Seals and Sealing (COSS), or in behalf of the government. A chronological review of the changes made to the Canadian Seal Protection Regulations is provided in Chapter 30 from a brief published by the Department of Fisheries and Oceans (Canada, DFO, 1985), and copies of the various regulations and amendments are contained in Appendix XIX of that brief. The principal changes in the regulations since 1964 are reviewed in Appendix 20.1.

The regulations now in force and their dates of introduction include the following:

- gaffs are prohibited for killing seals (1967);
- hakapiks are permitted (Front, 1976; Gulf, 1979);
- hooded seals that are shot must also be clubbed (1977);
- a seal must be struck until its skull is crushed (1984);
- a seal must be dead before being skinned (1964);
- criteria of death are defined (1978);

- a seal must be bled immediately after clubbing (1979);
- use of aircraft to hunt is prohibited (1964; 1970);
- night sealing is prohibited (1967);
- sealers are licensed and power is conferred on fisheries officers to suspend licences (1966; 1967);
- criteria are established for experienced and assistant sealers (1978).

Under the current regulations, seals are clubbed either with a hakapik or with a club. The regulations define these instruments in detail. The hakapik has an iron head mounted on a wooden handle which is 42–60 inches long and 1 1/4–2 inches in diameter. On one side of the iron head is a spike less than 5 1/2 inches long that curves slightly towards the handle. On the other side there is a blunt projection less than 1/2 inch long. The club is a hardwood bat 2–2 1/2 feet long and at least 2 inches in diameter for at least half its length. No metal hook is attached to the club.

The Norwegian sealing regulations that relate to killing methods as of 1968 and 1970 are summarized in Appendix 20.2.

Government Enforcement and Training Programs

When, in 1964, the Government of Canada implemented its humane killing requirements in the Seal Protection Regulations, it also undertook an enforcement program. Since that time fisheries officers have patrolled the seal hunt by using helicopters or by sailing on sealing vessels. Their duties have involved checking licences; examining killing weapons and observing killing techniques; checking to see whether the seal's skull is fractured; and performing other tasks unrelated to humane killing. Fisheries officers have the power to suspend a licence and to order a sealer from the ice, or to lay charges when they observe contraventions of the regulations. The usual practice has been to suspend licences. In 1979, for example, 19 licences of landsmen from the Magdalen Islands were suspended for resorting to improper killing methods (Dudka, 1979).

Still, the number of fisheries officers assigned to the seal hunt is limited: there were 89, for example, in 1979 (Montreuil, 1980). In addition, the area that they must patrol is very extensive, the number of sealers is large, and sealing operations are multifaceted. For these reasons it is impossible to keep all parts of the seal hunt under close supervision at all times.

Many people who have observed the seal hunt to assess its humaneness have commented on the government's efforts to enforce its regulations. The Royal Commission has seen reports from only two observers (Simpson, 1966, 1967a; Jordan 1978, 1985) who considered that the hunt could not be patrolled effectively enough to make it acceptable. The opinions of the other observers have varied greatly, since they have depended on the year and area of their observations. In the mid- to late 1960s, most observers were impressed by the government's efforts to control the seal hunt and by the improvements that they noted each successive year (e.g., Hughes, 1966, 1967, 1968). In other years, the same observers (e.g., Hughes, 1971) have sometimes considered that enforcement efforts should be stepped up. Enforcement has been criticized most severely in years when the fisheries officers could not keep landsmen hunts under control, particularly in 1981 off Prince Edward Island (e.g., Platt, 1981). The next year, however, praise for the enforcement officers was expressed again (Hughes, 1982; Platt, 1982).

Government training programs also form an important part of the effort to promote humane killing practices. Early observers of the seal hunt urged strongly that sealers receive instruction in humane killing methods (Pimlott and Hardy, 1966; Scollard and Hughes, 1966; MacLeod, 1967; St. Onge, 1967; Walsh, 1967; Hughes, 1971). Informal instruction in humane killing was begun in the Magdalen Islands in the early 1970s (Canada, DFO, 1985). In 1975, instructions that included a demonstration were given at eight sites to more than 400 sealers (Ronald, 1975). An educational program that included humane killing was offered more actively in Newfoundland in 1978 (Collins and Curran, 1978). In 1979, the topic of humane killing was covered at a meeting in St. John's attended by all sealers from large vessels (Rowsell, 1979a). In 1980, fisheries officers gave training symposia at each Newfoundland sealing community (Canada, DFO, 1985).

To supplement this instruction, the federal government has also produced publications and pamphlets on humane killing of seals. The 1978 and 1979 pamphlets (as reproduced in Rowsell, 1978 and CVMA, 1979) emphasize the need to strike at least three blows with a club or hakapik, and the importance of ensuring that the seal is unconscious by checking its blinking reflexes. They say nothing about the need for rapid exsanguination, but this topic was included in the 1981 sealer's manual (Canada, DFO, 1985, Appendix XX) and in a more recent brochure on humane killing (Canada, DFO, 1985, Appendix XV).

Observations of Clubbing at the Seal Hunt

Early Observations

Inhumane practices in the seal hunt were apparently common prior to the 1965 hunt, when the first government regulations to prevent such practices were put into force. England (1924) described his experiences on a large vessel in the Newfoundland seal hunt during 1922. As Watson (1985) has pointed out, England made a number of references to cruel and inhumane practices such as flensing a seal that had been clubbed and was not dead (p. 84) and hauling live seals in on gaffs (p. 87); he recorded that the captain had told a sealer to kill his seal and not to skin it alive (p. 87); he also mentioned that a very small whitecoat was stabbed and left dying, but not utilized (p. 91), that a sealer had kicked a seal in the head to stun it and then hauled it back to the ship (p. 184), and that hooded seals were wounded by inaccurate shooting (p. 230–231); he recorded, too, the loss of many seals that were shot (p. 230–231). Lillie (1955) visited the Front in 1949 and commented on particular instances of inhumane clubbing and shooting of seals, although in general he found the clubbing of seals to be humane.

Hunt in the Gulf, 1966–1968

Although public concern about inhumane killing practices grew considerably during the 1950s and early 1960s, few observations of the actual killing process date from that period. From 1965 to the present, at least 44 veterinarians, animal-welfare officers and biologists have made a minimum of 86 visits to the seal hunt to observe the clubbing of seals and to comment on its humaneness. The reports of these observers have been deposited with the DFO headquarters library in Ottawa and the Pinniped Bibliography at the University of Guelph.

Eight observers visited the harp seal hunt in the Gulf in 1966. They examined hundreds of skulls, most of which had been crushed, though some were undamaged. The observers could not judge whether the seals whose skulls remained intact had been struck unconscious prior to skinning (Hughes, 1966). Some blatant acts of cruelty were observed. In particular, nine seals were found which had been struck, but left bleeding and conscious, and 50 seals were found which had been slashed with a knife and had struggled for varying distances before they died (Hughes, 1966).

In spite of the observations of cruelty, all of the 1966 observers except Simpson (1966) were of the opinion that if the sealers were properly trained, and if the regulations were enforced more strongly and some changes made in them, the seal hunt could be made acceptably humane. Simpson held that although the club, if used properly, would produce instantaneous death with one blow, the conditions of the hunt and the inexperience of the sealers prevented them from making proper use of the club. She reported a number of instances of cruelty and concluded that she could not "envisage any way in which the commercial seal hunt in the Gulf of St. Lawrence could be made humane" and that "the seal hunt in the Gulf should be stopped."

In 1967, some observers reported a definite improvement in killing methods over those observed in 1966 (Hughes, 1967; Walsh, 1967). They did not observe any deliberate cruelty, and they recorded that the level of enforcement of the regulations had risen greatly. Walsh (1967) reported checking 512 skulls; 18 of these did not appear to have been fractured, three appeared to have been fractured only on the nose, and the rest evidently appeared to have been properly fractured.

In 1967, Simpson (1967a) noted some improvements in humane killing techniques, but she did not change her negative opinion of the overall acceptability of the hunt. She conducted post mortem examinations of 154 skulls, of which 98 had fractured crania (Simpson, 1967b). She concluded that "a large percentage of the hunted animals die in a manner which is of doubtful humanity."

Hughes (1968) reported a great improvement in the humaneness of the 1968 hunt over that of 1967. He found that seals killed by sealers from ships had uniformly been properly clubbed, and that the skulls found without massive damage were mainly in areas where airborne sealers had been working. He stated that:

> *As far as the killing of* young seals *is concerned, and in Area 2 of the Gulf... I am satisfied that we have now reached a standard of humane killing, acceptable to any reasonable person. (Emphasis in original.)*

Jones (1968) considered that "the methods of killing compared favourably with those of many slaughterhouses." Schiefer (1968a, 1968b) published the results of 695 autopsies of whitecoats performed by four veterinarians in 1968; 651 (93.7%) had skull fractures and/or brain hemorrhages and were probably dead or unconscious before skinning, and another 1.7% were probably unconscious. It could not be determined whether the other 4.7% were unconscious at the time of skinning.

After observing the hunt, both Karstad (1970) and Ronald (1969) recommended that animals should be skinned or exsanguinated immediately after clubbing, but this recommendation was not made a requirement until 1979.

Overall, it appears that the humaneness of the killing procedures in the Gulf increased greatly between 1966 and 1968.

Hunt in the Gulf, post-1968

The Royal Commission has reviewed reports written by the observers of the post-1968 seal hunts in the Gulf of St. Lawrence that were conducted by sealers from large sealing vessels. The reports showed that with two exceptions, observers were generally satisfied with the humaneness of the clubbing they witnessed. One exception occurred in 1981, when Hughes (1981) observed a number of violations by the crew members of one large vessel, even though the crew was composed of the same sealers as in the previous year, when he had not observed any such violations.

The other exception occurred in 1978 and was reported by Jordan (1978), who visited the hunt in the Gulf in 1978 in behalf of the Royal Society for the Prevention of Cruelty to Animals (RSPCA). In one sample of 13 pups he examined, seven skulls had not been fractured. In two other samples all skulls were crushed, but some had been crushed after death. Of three pups he saw clubbed, one was still alive, with an unfractured skull, after having been clubbed, and in his report he raised a question as to whether it was unconscious when skinned. Following Jordan's report, the RSPCA strongly urged the Canadian government "to call an immediate halt to the killing of seal pups."

Sealers carried to the hunt by aircraft were not a concern in 1970 or afterward, as the use of aircraft in the hunt was prohibited in 1970 except for searching for seals.

Some of the most serious problems have arisen in hunts conducted by landsmen in the Gulf. These have occurred when ice conditions brought the whelping harp seals close to land, and there was a rush, often by inexperienced men, to take part in the hunt. Enforcement of humane killing practices by fisheries officers in such hunts has been difficult and frequently not very effective because of the unpredictability of the time and location of such hunts, the numbers of landsmen who usually participated, and their inexperience. Violations of humane killing practices by landsmen from the Magdalen Islands were noted in 1971 (Hughes, 1971), 1974 (Terhune, 1974), 1975 (Ronald, 1975) and 1980 (Hughes, 1980). Fisheries officer Dudka (1979) reported a similar problem there in 1979. In 1974, a number of pups were found that had been killed and bled, but not skinned; an adult seal was found that had been wounded (presumably blinded), and six of 57 skulls were only partially crushed (Terhune, 1974). In 1975, several hundred landsmen "acted as if they had never been trained or instructed in killing techniques", and the chief fisheries officer threatened to recommend that the hunt be closed unless the inhumane and wasteful methods of killing were stopped (Ronald, 1975).

The most notorious problem with a hunt by landsmen occurred in 1981, when the seals whelped close to Prince Edward Island, a very infrequent occurrence. Because the landsmen had little sealing experience, several animal-welfare organizations recommended that the seal hunt should not be opened; nevertheless, it was allowed to commence. When the ice appeared, 240 sealers were given licences and a "crash course" on the sealing regulations (Platt, 1981). Still, Platt observed sealers clubbing seals and throwing them into a boat without exsanguinating them. CVMA (1981) reported an abandoned seal that had been killed, but not pelted; it was one-half metre from shore. Many other violations were observed, but fisheries officers were unable to control the sealers. Furthermore, much of the hunt was clearly visible to anyone on shore. The Department did react quickly, however, and after one day the hunt by landsmen was cancelled.

Canadian Hunt at the Front

Although many veterinarians, animal-welfare officers and biologists examined the seal hunt in the Gulf after 1965, no observers visited the Canadian seal hunt at the Front until 1972, when Rowsell (1972) made his first of many visits. He found that the club, as used in the Gulf, was not as effective as the hakapik for killing the larger harp seal pups on the Front or the hooded seal pups (Rowsell, 1975, 1977, 1980). He recommended that the hakapik be used (Rowsell, 1975), and its use was authorized on the Front in 1976. Rowsell (1975, 1976) also showed that hooded seal pups could be taken without shooting the female, and limits were placed on taking females in 1977.

For the most part, observers of sealers working at the Front from large vessels have been generally satisfied with the humaneness of the clubbing. Some violations of humane sealing practices were noted in 1978 (Jotham, 1978; Walsh, 1978).

The most serious problems noted at the Front occurred in 1981, when longliners were able to penetrate the ice and reach the whelping harp and hooded seals for the first time in at least nine years (Rowsell, 1981; Walsh, 1981). The vessels were poorly equipped for the hunt, and a number of the sealers apparently lacked knowledge of humane killing methods. Some sealers were clubbing seals with axe handles; some did not immediately exsanguinate and pelt their seals; and some were found to be taking hooded seals, though they did not have a quota for them.

Norwegian Hunt at the Front

In 1968 and 1970, observers were present on Norwegian sealing vessels at the Front in order to assess the humaneness of the crew's killing methods. Søgnen (1968) found that sealers used hakapiks rather than clubs, and all but one of the skulls he examined had one or more holes produced by the spike of the hakapik. Exsanguination often did not immediately follow the blows. The main reason for failure to kill seals efficiently was lack of training of young sealers; they quickly learned how to kill efficiently, but while learning they may have caused some unnecessary suffering. Søgnen concluded that the hakapik was an acceptable tool for killing, and that he could not find a better method for killing large numbers of seals under the conditions that prevailed.

Platt (1970) reported that the Norwegians had implemented most of Søgnen's recommendations. In contrast to the Canadian vessels at the Front, each of which had one or two fisheries officers aboard, the 15 Norwegian vessels carried only one fisheries officer for the entire fleet. The hunt was divided into three periods. During the first period, the Norwegians killed whitecoats with hakapiks. During the second period, beaters (seals at least four weeks old and capable of swimming) were shot or occasionally killed with hakapiks. During the last period, adults that had congregated in mating areas were shot on the ice. Platt's observations and conclusions generally paralleled Søgnen's. Although violations were observed, only a very few instances of unnecessary suffering were noted.

Rowsell observed Norwegian killing techniques in 1975 and 1980. In 1975, he examined approximately 50 harp seal skulls and found that all had multiple skull fractures (Rowsell, 1975). Some sealers were using a heavy metal hook (slagkrok) about 50 centimetres long with a heavy bar in front of the hook. They would strike a seal two or three times with the bar and then drive the hook into the brain. Rowsell did not observe any skulls on which this technique had been used, but he considered that it should be used only on newborn pups. In 1980, he examined 25 skulls of seals that had been killed by Norwegians; all showed massive skull fractures and destruction of the brain (Rowsell, 1980).

Laboratory Studies of Clubbing

Only one laboratory study of the clubbing method of killing seals has been found (Blix and Øritsland, 1970). Three hooded seal pups were each given a single blow on the head with a Norwegian slagkrok. The single blow produced immediate irreversible disappearance of brain activity as recorded on an electroencephalogram (EEG). This result demonstrated that, at least under ideal conditions, such clubbing constituted a satisfactorily humane method of killing.

How Humane Is the Actual Killing?

None of the observers whose reports the Royal Commission has seen has disputed the fact that under good conditions, a sealer following the prescribed procedures can instantaneously kill a whitecoat harp seal or render it instantaneously unconscious with a proper blow of a club or hakapik. The requirement that the seal be exsanguinated immediately after clubbing ensures that the seal does not recover consciousness before death intervenes. The difficulties arise from the actual conditions under which the seal hunt is conducted.

The killing process that the regulations require and that if properly carried out will produce a death that is as humane as possible, consists of three steps: clubbing, testing the blink reflex, and exsanguination. Each of these steps, however, is subject to abuse.

Clubbing is a physical act, and the clubber must strike every blow with precision to ensure humane clubbing. It is probably impossible to invariably achieve this precision, given the cold and slippery conditions on the ice, the long hours, the pressure to work fast, and the possibility of a moving target. Some observers noted that sealers tend to become tired or to develop tendonitis; they concluded that these factors influenced the sealers' clubbing (e.g., Jordan, 1978). Abuse of the club has been most common under the "gold rush" conditions of hunts carried out by inexperienced landsmen on those occasions when seals have come close to shore.

The testing of the blink reflex as a check on unconsciousness is probably often omitted. In 1978, several observers stated that they had not seen sealers checking the blink reflex (Jotham, 1978; Rowsell, 1978; Jordan, 1985). It is easy to imagine that the sealers would neglect this check when they were tired or in a hurry, as they usually are, or even when they felt sure that a seal was dead and that no one was watching them.

Observers have noted, too, that sealers have often clubbed several seals before returning to bleed the first seal (e.g., Walsh, 1978), rather than bleeding the first seal immediately after the kill. It should be noted that most of the reported failures to follow in full the specified humane sealing techniques (especially those failures that occurred in later years, when the requirements have become more stringent) do not necessarily imply that those killings were inhumane or cruel. What they indicate was that those killings *might* have been inhumane, and they pointed to the need for improved killing practices, enforcement of the regulations, and effective training.

The most critical question is whether seals are skinned while still conscious. This issue is more significant than the question of whether the seals are skinned while alive, since an animal may be alive by some standards – for example, its heart may still be beating – but if it is in a state of deep irreversible unconsciousness, it is totally unaware of any further experience. The blows to the skull usually produce "brain death", that is, a zero EEG (Blix and Øritsland, 1970), but the seal heart will continue to beat for up to 56 minutes after brain death occurs (Blix and Øritsland, 1970). Death under these circumstances is very hard to define in a way that is suitable for testing by a sealer or a fisheries officer. Many observers have recommended that the regulations should require that a seal be unconscious (i.e., insensitive to pain) before it is skinned, rather than that it be dead (e.g., Jones, 1968; Schiefer, 1968b; Karstad, 1970). In 1978, for the purposes of the Seal Protection Regulations, the Government of Canada adopted a definition of seal death which is essentially a definition of unconsciousness.

There have been numerous accusations that seals have been skinned while still alive, and they have been given wide publicity. A few such accusations based on events seen by qualified observers such as Simpson (1966) have probably been true, but others were probably based on a misconception and put forward by people who had seen and misunderstood the reflex muscular movements that may occur after the seal is dead. Many observers have noticed these involuntary reflex movements, particularly of the hind flippers, and have cautioned against misinterpreting them as indications that the seal was alive (e.g., Jones, 1968). Søgnen (1968) reported "normal agonal reflex actions", some of which were seen "in fully exsanguinated animals with totally fractured skulls and destroyed brain tissues." Scott (1977) reported a seal that swam vigorously on the surface for 9–12 metres after being shot in the head: "The post mortem showed that most of the seal's head had been destroyed, suggesting that the swimming could be attributed to reflex action."

The possibility does exist, however, that a seal might be conscious at the time skinning is started, although it does not make any obvious movement. The reason is that many harp seal pups "freeze" when approached. Simpson (1966) reported that when seals reacted in this manner, they remained immobile, and that "practically anything could be done with such an animal without it moving." Karstad (1970) suggested that a seal which regained consciousness after clubbing might immediately go into a freezing reaction and be conscious when skinning began. Johansson (1967), too, acknowledged the possibility that a seal in the freezing (or "opossum") reaction might be conscious when skinning began. He pointed out, however, that "because of the very rapid and massive surgical shock and hemorrhage, it is certain that consciousness would be quickly lost." It is impossible to be sure by direct observation what proportion of seals suffer in this way, but the data on the proportion of skulls properly crushed indicate that the proportion is extremely small under most circumstances. Further, it was in order to obviate this risk that the requirement for the sealer to check the blink reflex was introduced, and if this procedure is followed, it should be impossible for any seal to be bled or skinned while still conscious.

The state of consciousness or unconsciousness at the time of killing is often difficult to determine after the fact. A crushed skull before death has usually been accepted as evidence that the seal was unconscious at the time of death. Even if the skull is not crushed, unconsciousness might result from brain hemorrhages, depending on the degree and location of the hemorrhages. Veterinarians who have done post mortem examinations of uncrushed skulls have usually been able to state that some of the seals were likely to have been unconscious as a result of brain hemorrhages when killed; but after examining some other skulls, they have been unable to state whether or not the seal was unconscious when death occurred (e.g., Simpson, 1967b; Schiefer, 1968b; Karstad, 1970).

The crushed skull has served a practical purpose in terms of enforcement of sealing regulations, as it was a definite indication that fisheries officers could check in the attempt to ensure that seals had been humanely killed. In 1968 (Costello, 1968) and 1978 (Scott, 1978), fisheries officers were observed to have required sealers to club until the seal's skull was crushed, even though the regulations did not make the practice of crushing the skull before skinning mandatory until 1984. In practice, however, the crushed-skull practice was subject to possible abuse. Sealers have been observed to crush skulls with their boots after seals had been killed and pelted (Hughes, 1968; Jordan, 1978; Rowsell, 1979a). Only close examination by a veterinarian could have established that the skulls had been crushed after death.

A substantial majority of the veterinarians, humane society officers and biologists who have visited the seal hunt for the purpose of assessing its humaneness have expressed the opinion that clubbing of the young seals is a sufficiently humane method of killing for the practice to be accepted. They have noted many instances of cruelty and many areas where improvements were needed, and they have made many recommendations for achieving the changes needed to eliminate the cruelty. On the assumption that the various improvements recommended would be implemented, most observers have considered that clubbing could be done humanely, even though some were opposed on principle to this method of killing, and many have found it to be as humane as, or more humane than, slaughterhouse operations. On the other hand, a few observers (Simpson, 1966, 1967a; Jordan, 1978) have judged clubbing to be unacceptably inhumane and incapable of being rendered humane, and have consequently called for its abolition.

The Royal Commission believes, from the evidence put before it, that under the present regulations, given the existing enforcement and educational programs of the Department of Fisheries and Oceans, the very great majority of harp seal pups are killed in a manner which meets a high standard of humane killing. If the requirements for checking the blink reflex and for immediate exsanguination were invariably observed, virtually no animals would be killed in other than an extremely humane way. It is essential, therefore, that if further clubbing of harp seal or hooded seal pups does take place, the Department should maintain, and if possible improve, the level of its enforcement and educational programs.

It appears to the Royal Commission that the principal danger which would threaten the maintenance of a consistently high standard of humaneness in a hunt if it were allowed in future is that of the local development of special conditions in circumstances where adequate supervision is impossible, or when inadequately trained men are engaged in the hunt. That it was possible for such a circumstance to arise in 1981, after the regulations and supervisory organization had been in place and functioning fairly effectively for some 13 years, emphasizes the reality of the threat and the dangers of complacency. If there is any risk of such a situation developing in the future, the Department should ensure that all sealing in the area is effectively prohibited before the hunt can commence.

Pre-Kill Stress

A major concern relating to humane killing is the stress that the animal undergoes prior to the actual killing (e.g., UFAW, 1967). This is a particular concern in operations where the killing occurs at a centralized point to which the animals must be brought, as it does, for example, in slaughterhouse operations and at the Pribilof fur seal hunt.

Most observers of the Canadian hunt agree that the seal pup experiences little stress before it is killed (e.g., Hughes, 1978b). The killing does not occur at a central location, and the pups need not be moved, or even touched, prior to killing. Seal pups appear to be unaware of what is happening to other nearby seal pups (e.g., Johansson, 1967; Ronald, 1970; Scott, 1971). They show little apprehension of humans if they are approached cautiously, but may attempt to escape if alarmed (Platt, 1970). When escape is not possible, they may threaten to bite, though they rarely actually do so, or they may defecate (Simpson, 1966; Helmboldt, 1968). Other alarmed seals may react by freezing (Simpson, 1966). Although seal pups may be alarmed at the approach of a sealer, the distance within which they show this alarm was estimated to be only three to four metres (CVMA, 1979). Thus the seal pup would feel stress for only a very short period of time, if at all, prior to the kill.

Impact on the Mother Seal

Another important concern in the question of humane killing is the impact of the killing on other animals that may observe the killing or otherwise suffer as a consequence of the kill. Since, when harp seal pups are clubbed, other pups are apparently unaware of what is happening, the only issue of concern is the impact on the females.

Many of the observers of the harp seal hunt have commented on the reaction of the mother seals as the pup was approached and after the pup was killed. Highly variable reactions have been reported, a result, at least in part, of wide individual variation among the seals, as well as of variation related to the time during the short nursing periods when the kill occurred.

The proportion of female seals reported to have left their young and entered the water when a sealer approached has varied from very low to 95%. There is similar variability in the reports of interest shown by females in the carcasses of their young. Some observers believe that there is a strong pair bond between mother and young while others consider that this bond is weak. Harp seals produce milk only under the stimulus of suckling, and females which lose their young quickly cease to produce milk. The harp seal has a very short nursing period compared to that of other large mammals; the suckling period is only eight to 12 days (Lavigne, 1979; Stewart and Lavigne, 1980).

Even less is known about the mother-pup relationship of hooded seals, although Greendale (1985) concluded from his observations that it was stronger than that of harp seals. For hooded seals, the nursing period is even shorter than it is for harp seals, lasting only four days (Bowen et al., 1985).

Measures suggested to minimize distress to females include not taking pups whose mothers try to defend them and delaying the hunt until most pups have been weaned. In practice, both these measures would encounter some problems. This question is discussed further in Appendix 20.3.

Effects of Sealing Vessels on the Seal Pups

An issue occasionally raised is the effect on the seal pups produced by the ice-breaking activity of the sealing vessels. Simpson (1966, 1967a) reported that she observed several whitecoats crushed between the ship and the ice or between pans of ice; other seals that were knocked into the water attempted to swim to other ice pans, and some were able to haul out onto them. Watson (1985) reported that he had witnessed 43 seals killed by three Canadian Coast Guard vessels and numerous seals "run down" by sealing ships. No other observers have reported seals being crushed by ships. Bourne (1966) stated that "after much questioning and observation in similar areas I have no evidence of whitecoats being crushed between ships and the ice." Pimlott (1967) observed 15 seal pups that appeared to have been in the path of a vessel. All but one were unharmed, and those that were dumped into the water were able to get back on the ice. (The fifteenth was not injured, but was lost from sight behind a cake of ice.) Walsh (1967) observed seven pups that fell into the water; all were able to climb back onto floating ice or to swim to it, aided by the presumed mother.

The weight of evidence appears to the Royal Commission to suggest that few seal pups are killed by sealing or other vessels passing through the ice on which they are lying. This situation should not be compared with that in the Arctic, where passage of large ice-breakers through heavy ice may cause the deaths of some ringed seals. This question is discussed further in Chapter 23.

Other Issues

Adult and pup harp seals both shed tears copiously on the ice. It has been suggested that this tearing occurs in reaction to distress prior to being killed or to grief at the death of a pup. There is, however, no biological evidence to support this suggestion (Appendix 20.4).

Johansson (1967) stated that natural enemies or low-flying aircraft could frighten females into the water "apparently even if they are in active labor" and that "pups born in the water will drown." He did not indicate that he had observed this happening, nor did he provide any supporting evidence or reference for his claim. Both Sergeant (1985) and Lavigne (1985) indicated that they knew of no evidence to support the claim of a seal in labour being frightened into the water and giving birth under water to a pup that consequently drowned.

Other Canadian Clubbing

Clubbing has been used in eastern Canada as a method of culling grey seals. Adults are shot, and pups are shot or clubbed at the whelping areas in mid-winter (Hoek, 1985). While this clubbing has not been observed independently with a view to evaluating its humaneness, Webb (1984a) did observe a demonstration clubbing of six grey seal pups. The skulls were smashed and the seals were unconscious, but after five to eight minutes three pups began shallow breathing that continued for some time before they died.

Northern Fur Seals

Northern fur seals are harvested by means of clubbing on the Pribilof Islands in the United States and on the Commander Islands and Robben Island in the U.S.S.R. (NPFSC, 1983). The 1982 harvest totalled 33,079 fur seals (NPFSC,1983).

Northern fur seals are highly gregarious on land (Lander, 1979), and the method of harvesting them in the Pribilofs takes advantage of their gregariousness. The seals taken are bachelor bulls, generally three or four years old, which have not yet begun to breed (Lander, 1979). These bulls haul out in herds in areas near to, but separate from, the areas used as harems and rookeries (Walsh, 1968). Driving them to the killing areas does not disturb the harems or rookeries (Denney, 1971).

When seals are to be killed, groups of about 100 are driven inland to killing areas, where they are formed into a larger herd and held in check (Simpson, 1968). Small groups are cut out from the larger group, and the seals are clubbed with one or more blows of a hardwood club 155 centimetres long that resembles an elongated baseball bat (Simpson, 1968; U.S., Veterinary Panel, 1971). Seals that do not conform to the size criteria or that have damaged fur are released. Once a small group has been clubbed, the seals are bled by opening the thorax and severing the arteries and/or puncturing the heart (U.S., Veterinary Panel, 1971). They are then skinned.

In the late 1960s and the early 1970s, a number of animal-welfare officers and veterinarians visited the fur seal hunt in the Pribilof Islands in order to assess the humaneness of the hunt and to attempt to devise better methods of harvesting seals. Pfeiffer (1981) observed the hunt in 1980 to see how it might have changed from the early 1970s.

Driving of the Seals

One of the major issues raised by this hunt is the effect on the seals of the drive from the hauling grounds to the killing areas. Although fur seals travel well over land, they are highly susceptible to overheating and exhaustion (Walsh, 1968; Keyes, 1980) and may suffer if they are pushed too hard, or if the temperature is too high. The drives were begun in the early morning in order to have them completed before the ambient temperature became too warm (Denney, 1971). The seals were driven slowly (Simpson, 1968) and were given rest periods "where distance, ambient temperatures or terrain seemed to dictate" (U.S., Veterinary Panel, 1971). However, the seals were sometimes driven over obstacles such as boulders or driftwood when they could have been driven around them (Walsh, 1968).

Fur seals do suffer during the drives. Some seals have died in warm weather (Walsh, 1968), and one died on a drive during the week when Pfeiffer (1981) was present. Davies (1967) reported that many seals collapsed in apparent exhaustion. Wooldridge (1967) discovered vesicular emphysema in the lungs of some seals, but Simpson (1968) found that similar lesions had occurred at the time of death and not on the drive.

Later observers did not record the same degree of exhaustion. Denney (1971) reported that "in a few instances some individuals would get tired and drop out of the pod, but would usually follow and rejoin the herd after resting." Pfeiffer (1981) reported that a few of the smaller seals became fatigued easily, but that most of the seals arrived in good condition.

Observers reported that the length of drives was reduced from a distance, in 1968, of 150–1,200 metres with an average of 485 metres (U.S., Dept. of Interior 1968), to a distance, in 1980, of 120–1,000 metres with an average of 345 metres (Pfeiffer, 1981). The terrain had prevented removal of obstacles, however, and the seals had to be driven over them.

Killing Procedure

On the killing grounds the herds are allowed to rest for about half an hour. They are then separated into pods, generally composed of about six to 10 seals. During the drive and the separation into pods, some of the females and larger males are released, but others remain in the pods (Walsh, 1968; U.S., Veterinary Panel, 1971; Pfeiffer, 1981). When clubbing of the pod has been completed, the remaining females and larger males are released and driven from the area (U.S., Veterinary Panel, 1971). The presence of these unwanted animals complicates the clubbing: pods may be larger because of the presence of the unwanted animals, blows may be less accurate, and the larger males may be dangerous to the clubbers (Walsh, 1968; U.S., Veterinary Panel, 1971).

The U.S., Dept. of Interior (1968) reported that when a pod is being clubbed, the time from the first to the last blow ranged from five to 48 seconds, and that the killing of each seal required an average of two to three seconds. The U.S. Veterinary Panel (1971) reported that no more than 20 seconds usually elapsed from the start to the end of the stunning, but that the process occasionally took longer. The seals in the killing pods are present in the immediate vicinity of other seals being killed and are aware of this activity. The killing period presumably creates a high degree of stress that lasts until the seal is stunned or is released as unwanted.

The sealers who do the clubbing are experts who have worked their way up through the ranks and are among the highest-paid members of the crew (U.S., Dept. of Interior, 1968; Denney, 1971). They work continuously, under close supervision, killing pod after pod until breaks are called, about every two hours (Simpson, 1968; U.S., Veterinary Panel, 1971). The processes of bleeding and skinning are each done by separate groups of the crew.

The fur seals are stunned (or killed) with a blow to the cranium. Davies (1967) stated that:

> *There is no doubt, but that a blow to the head of a fur seal of the age group killed on St. Paul Island, will, if accurately delivered, shatter the skull of the animal concerned. Unfortunately, under present conditions, with the animals milling around in front of the hunters, accuracy is not always achieved.*

When the first blow was inaccurate, clubbers would give the seal a second or third blow (Simpson, 1968; U.S., Dept. of Interior, 1968). The proportion of seals receiving more than one blow has been recorded variously as 12% (Davies, 1967; Wooldridge, 1967), 13.6% (Simpson, 1968), and 8% (Pfeiffer, 1981).

When a seal was struck accurately, it would immediately collapse (U.S., Veterinary Panel, 1971). Body movements ceased and could not be elicited, but respiration sometimes continued. Of 3,200 seals that the Veterinary Panel observed being stunned, none regained consciousness prior to exsanguination.

Exsanguination followed stunning by 2–3 minutes (Wooldridge, 1967) or by 30–60 seconds (U.S., Veterinary Panel, 1971) and quickly produced death. There was no evidence that any seal suffered during skinning or that any seal had been skinned alive (Davies, 1967; Wooldridge, 1967; Simpson, 1968; U.S., Veterinary Panel, 1971).

With one exception, observers of the killing of fur seals appear to have been generally satisfied with the humaneness and efficiency they observed in the process. In particular, Simpson (1968), Denney (1971), the U.S. Veterinary Panel (1971), and Pfeiffer (1981) stated that the kill was reasonably humane, although they did recommend some improvements. Davies (1967), on the other hand, could not accept that clubbing of fur seals was humane.

Russian Harvest of Northern Fur Seals

There is little information available on the killing methods used on the Russian Islands. In a paper presented to the 23rd Session of the North Pacific Fur Seal Commission (U.S.S.R., 1980), a method is briefly described. The fur seals on the Commander Islands are driven from the hauling ground and are then stunned by a blow to the nose with a bat that is about two metres long and thicker at the striking end. The unconscious seals are next stabbed in the heart for quick exsanguination and then skinned. Bruises are sometimes seen in the blubber, caused by inaccurate blows, and some seals outside the commercial size range are occasionally taken by accident. The method is considered the most rapid and effective harvesting procedure in that it produces instantaneous unconsciousness and death very soon afterward (U.S.S.R., 1980).

Cape Fur Seals

Cape fur seals are harvested by clubbing in South Africa and Namibia. The seals, aged seven to nine months, are harvested by similar methods at a number of colonies along the coasts of the two countries (Shaughnessy, 1976; David, 1985). These seals are driven from the beach and clubbed in a manner similar to that practised on the Pribilof Islands. The harvest in 1975 amounted to approximately 75,000 seals (Shaughnessy, 1976), but the number has been greatly reduced since then (Dixon, 1984).

Two American veterinarians inspected the hunt at two sites in 1974 and 1975 (Shaughnessy, 1976). In 1974, the killing techniques were not of sufficiently high standard and were judged to have been inhumane, but in 1975 the harvest satisfied the veterinarians' criteria of humaneness (Shaughnessy, 1976). The two veterinarians concluded that clubbing and bleeding, if properly practised, was the most efficient way of killing the Cape fur seal pups.

Platt (1983) observed the Cape fur seal harvest in 1977 at a different site from the two sites visited by the American veterinarians. The site he visited had a reputation as the best and most efficient commercial sealing operation in Namibia. He cautioned that the conditions at other sealing operations were not as good as those he had observed. Provided that the standards at the other operations have been upgraded, the harvest of Cape fur seals in South Africa and Namibia appears comparable in humaneness to that of the harvest of fur seals in the Pribilofs. The clubbing and bleeding are performed under controlled conditions, but the seals experience stress during the drive to the killing area and during the actual killing, which occurs in the presence of other seals.

Other Seals

South American fur seals are killed in Uruguay (Vaz-Ferreira, 1979b). The harvest totalled 10,496 in 1979, but only 1,375 in 1982 (FAO, 1984). Groups of 1,000 or more seals are driven inland to concrete corrals, where they may be held for two to five days before clubbing (Vaz-Ferreira, 1985). South American sea lions are also clubbed in Uruguay. The annual harvest amounts to approximately 3,000 pups (Vaz-Ferreira, 1979a, 1985). Vaz-Ferreira (1985) stated that the same methods of killing fur seals and sea lions have been used in Uruguay for many years, and that no better or more humane method is known that could be used on the islands.

In the U.S.S.R., Caspian seals were formerly clubbed on the islands where they gathered (Badamshin, 1960). They are now killed on the ice by hunters either working from vessels or using sleds to encircle the seals with nets. Only pups are harvested, and there is an annual quota of 50,000 on these young animals (Popov, 1982). It is suspected that, as in the past, the seals are killed by clubbing.

In the U.S.S.R. White Sea, harp seals are hunted from helicopters. The animals are killed with clubs. The carcasses are then placed in a net slung from the helicopter and transported to shore for processing (Nesterov, 1973). Up to 15% of the pups may regain consciousness in transport or on shore. From this description it appears that this hunt is less humane than the recent Canadian harp seal hunt. In 1971–1972, the Russians were looking for alternative harvesting methods to eliminate disadvantages in their method (Nesterov, 1973; Ponomarev, 1973). Nevertheless, the method is still in use (Barzdo, 1980).

Harbour seals and grey seals are clubbed in Iceland (Einarsson, 1978).

Clubbing was used to kill harbour seal pups in the United Kingdom in 1967 (Jones et al., 1968). The Universities Federation for Animal Welfare (UFAW, 1968) considered clubbing to be an effective method of producing rapid unconsciousness and death in harbour seal pups, but believed that it was an ineffective method for grey seal pups because in the latter species the shape and thickness of the skull would require a very heavy blow. Clubbing is not specifically prohibited by the U.K. *Conservation of Seals Act, 1970*, but its use has to be specified on a sealing licence. Since 1970, most killing of seals in the United Kingdom appears to have been effected by shooting (UFAW, 1970/1971–1978/1979).

Shooting Seals

Shooting of seals is probably the most common killing method in terms of the number of species that are shot and the number of locations where seals are shot. (See Table 20.1.) Seals are generally shot at a distance, and this chapter is concerned with the humane aspects of such shooting. Shooting at close range as a substitute for clubbing is considered in the section entitled "Experimental Killing Methods".

Bonner (1970) reviewed the shooting of seals from the viewpoint of humane killing. He considered that seals should be shot in the brain, as shots in the neck or heart were not effective in producing rapid death. The seal's skull is rather fragile, and even a relatively low-powered bullet will produce a massive wound on striking the brain case. Bonner considered that under normal conditions of shooting in England (at ranges of up to 35 metres), any bullet with an energy of 474 joules (at 90 metres) was quite adequate for killing British seals, provided that the bullet struck the brain case (although he did consider it prudent to specify more powerful ammunition). Bonner's specifications would permit the use of .22-magnum ammunition, but not low-powered standard .22-calibre ammunition.

This view is not entirely applicable to Canadian conditions. Many Canadian hunts take place, or have taken place, under conditions which make it impossible to obtain an acceptably high proportion of kills with head shots. This limitation applies to all types of operations, including culling, bounty hunting, and commercial and subsistence hunts. The causes include long-range shooting, shooting from moving boats, and shooting at seals in the water. Under such circumstances, a much higher proportion of instantaneous or quick deaths may be achieved with heavier or high-powered ammunition, which makes a much larger wound and has more shocking power. Canadian regulations specify ammunition requirements only for shooting seals in the Gulf and Front areas. Centre-fire cartridges that are not made with metal-cased hard-point bullets must be used, and they must have a muzzle velocity of not less than 1,800 feet per second (550 metres per second) and a muzzle energy of not less than 1,100 foot pounds (1,490 joules).

However, heavier higher-powered ammunition often sacrifies accuracy for killing power, and is also considerably more expensive. (For example, prices in Pangnirtung, in November 1985, were $0.066 for .22-calibre short, $0.23 for .22-magnum, $0.652 for .222-calibre, and $0.975 for .303 soft-nosed). Furthermore, differences in size and thickness of skull among species of seals mean that ammunition suitable for killing one species may be inadequate for killing another. The Royal Commission believes that serious consideration should be given to prohibiting the shooting of seals with low-powered .22 ammunition and that additional specific restrictions might be required for some hunts, depending on the species of seal hunted and the normal conditions of such hunting, especially the normal range at which the shooting takes place. Because such restrictions could cause hardship to sealers, they should be discussed with the sealing communities that would be affected prior to their enactment.

Shooting is clearly a humane way of killing if the animal is killed outright, but in any large-scale operation some proportion of seals will merely be wounded. These animals may recover or may die some time later; in either event the shooting inflicts a serious degree of suffering. The critical question in assessing the humaneness of shooting operations is what proportion of the animals hit are only wounded. When considering seals that have been recovered, most studies of hunting efficiency have not distinguished between seals that were wounded first and later killed and those that were killed by the first shot. Furthermore, many seals that are shot and killed in the water sink before they can be recovered (e.g., McLaren, 1958), and wounded seals that escape to die (or survive) usually cannot be counted separately from seals that are killed, but sink before they can be recovered. Consequently, the rates of wounding are unknown for most shooting operations.

The use of shotguns in hunting seals is also likely to lead to the painful wounding of a number of animals unless the guns are loaded with a solid projectile (Walsh, 1978). Since 1966, the regulations have prohibited the use of shotguns unless rifled or "Poly-Kor" slug shells are used, and then only if the shotgun is 20 gauge or more. There seems to be a need to examine the meaning of these regulations and their practical application, to ensure effective prohibition of the use of these weapons in ways which could lead to a significant level of wounding of seals.

Harp and Hooded Seals

Harp seals have been shot by landsmen using longliners or small motorboats in the Gulf, by landsmen and sealers in large Canadian and Norwegian vessels at the Front, and by Inuit in the eastern Canadian Arctic and in Greenland (Reeves, 1977). Hooded seals have been shot in similar conditions at the Front and in Greenland (Kapel, 1975; Rowsell, 1975). Both species may be shot in the water or on the ice. Shooting is probably practised by the Norwegians in their hunt for harp and hooded seals off Jan Mayen, and in their hunt for harp seals in the Barents Sea, though there is little information available on these hunts. Shooting of these seals in the Arctic is considered in the next section.

In contrast to the large number of veterinarians, animal-welfare officers and biologists who have assessed the humaneness of clubbing of seals, only seven observers making 10 visits have observed the shooting of harp and/or hooded seals to assess its humaneness. Early observers of the shooting of harp and hooded seals at the Front and in the Gulf noted a number of instances of wounding of seals or of the killing of seals that could not be recovered (England, 1924; Lillie, 1949, 1955; Davies, 1965).

More recently Søgnen (1968) and Platt (1970) observed the Norwegian shooting at the Front. The shooters were generally expert marksmen, although Platt observed some indifferent shooting. They used expanding bullets. Seals were usually killed by a shot to the head or neck. Søgnen observed a few seals that were not killed by the shot; these surviving seals were usually clubbed with a hakapik. He considered the methods used in the hunt humane "when compared with accepted methods employed in hunting and slaughterhouses" and stated that he could not find a better killing method, given the conditions of the hunt.

Platt (1970) was of the opinion that some conditions for shooting beaters from the ship were not good - it often required three to five shots to kill a seal - and that the marksmen should have waited to fire until the ship slowed down. He also observed the shooting of adult harp seals in moulting patches on the ice; he examined hundreds of carcasses and found only one seal that had been left wounded. "By far the majority of seals I saw killed", he stated, "died in a manner comparable to that of food animals slaughtered on land."

Rowsell (1975) observed the shooting of hooded seals and beater harp seals from a large Canadian sealing vessel at the Front. Both the male and the female (mother) hooded seal were shot, and the pup was then clubbed. The seals were next winched aboard to be bled and skinned. Because some seals were conscious when winched aboard, Rowsell recommended that all hooded seals be struck with the hakapik before being taken on board. This recommendation was made a government requirement in 1977.

In 1981, Rowsell and Walsh observed the shooting of hooded seals from large vessels at the Front (Rowsell, 1981; Walsh, 1981). Rowsell noted that males were shot and pups were clubbed, but that females were left alone, except for one that was mistaken for a male and shot. After males were shot, they were struck with a hakapik. Walsh recorded that some seals were bled before they were winched aboard, but that most were winched before being bled. Rowsell remarked that a sealer checked the corneal reflex of seals brought aboard. The marksmanship was excellent on two vessels, and any seal that showed any movement was shot a second time. On a third vessel, however, the marksmanship and general attitude of the sealers were of considerably lower quality (Walsh, 1981).

Four observers who were present at the Front in 1977 assessed the shooting of harp seals by landsmen operating from longliners or from small motorboats (Hughes, 1977; Rowsell, 1977; Scott, 1977). Marksmanship was good on the longliner from which Rowsell and Scott were observing. Rowsell examined 76 carcasses of seals - one of them a hooded seal - that had been shot in the longliner operation; 10 of the seals (13%) would not have been rendered unconscious instantly. Rowsell compared this observation with his 1975 observations that unconsciousness would not have been instantaneous in 8% of hooded seals that were shot, but cautioned that shooting conditions were more difficult in the longliner operation.

Hughes (1977) observed 31 carcasses of seals that had been shot from another longliner; he considered that these seals had been killed cleanly. Of 41 seals shot from small motorboats which he examined, 39 had been killed with shotguns loaded with either slugs or shot, and two had been shot with rifles. The use of shotguns may only wound seals or may seriously damage the pelt (Walsh, 1978).

Arctic Seals

The principal species hunted throughout the Arctic is the ringed seal; smaller numbers of bearded seals are also hunted. In the eastern Canadian Arctic, some harp seals and a very few hooded and harbour seals are also taken. The great majority of these seals are killed by shooting. When seals are shot in the water in the Arctic, their loss through sinking is high. This loss varies not only among the species of seals, but also seasonally.

In general, the loss rate diminishes during the summer, for the animals become more buoyant as the thickness of their blubber increases. For harp seals, Haller et al. (1967) reported a decline in the loss rate from 65% at break-up to 50% in July, 37% in August and 0% in October. For ringed seals, the loss rate dropped from 28%–52% in June–July to 4%–16% in August–September (Davis et al., 1980). Bearded seals are less buoyant than ringed seals and may sink at any time of the year (McLaren, 1958); Burns (1967) reported a loss of at least 50% of bearded seals killed in Alaska.

Although the proportion of animals not retrieved after shooting is high in the Arctic, it cannot be taken as a measure of the proportion of animals wounded but not killed outright. No useful data seem to be available on this point.

A number of observers (Haller et al., 1967; McLaren, 1958; Smith and Taylor, 1977; Davis et al., 1980) have described hunting techniques in which the seal in the water is deliberately wounded by a shot so that the hunter can approach it and be in a position to retrieve the carcass after killing the animal with another shot. This practice must cause a degree of suffering. The Royal Commission has no data on the number of animals treated in this way and no information on the length of time which elapses between the deliberate wounding of an animal and the final kill. Its members believe, however, that in general it is probably short compared to the period of suffering which would be experienced by an animal which is accidentally wounded and not recovered.

Seals are also shot in winter and in spring before break-up, at breathing holes and when hauled out on the ice. Seals killed at breathing holes are shot at very close range, but even so, some seals may be wounded and escape (Haller et al., 1967). In the Thule area of Greenland, a harpoon is sent down the hole immediately after the shot is fired, to retrieve the seal (K'ujaukitsoq. 1985). Shooting on the ice is reported to be generally accurate, and few seals are missed, although with the increasing use of snowmobiles it appears that more shots are now fired per seal killed (Wenzel, 1981). This observation may imply less careful shooting and an increased rate of wounding.

Further information on the arctic seal hunt is given in Appendix 20.5.

Grey Seals

Grey seals have been killed in Canada, chiefly in efforts to control their numbers in order to benefit fisheries. Both culling by government employees and bounty schemes have been used. Culls were carried out from 1967 to 1984, at sites on the Gulf of St. Lawrence and on the Atlantic coast of Nova Scotia (Canada, DFO, 1985). The annual kill ranged from 152 (1968) to 2,385 (1983) and included an average of 81% pups. Adults were shot on land, on the ice, or in the water; pups were shot or clubbed on land. To obviate the risk of death by starvation if the mother is shot, the attempt has been made to kill all pups at a site.

Webb (1984a, 1984b) observed the cull in 1982 and 1984. He was concerned that more effective ammunition be used, although Bonner (1970) found that similar ammunition (30.06 soft-nosed) was considered satisfactory for humane killing in the United Kingdom.

Bounties have been applied to grey seals since 1976; the number paid has ranged from 496 to 952 (Canada, DFO, 1985, Appendix LX). Most seals on which bounties are claimed have probably been shot, but some have been taken incidentally in nets. Sinking rates for shot seals are high, ranging from 50% to 76% (Mansfield and Beck, 1977), but no estimate of the proportion wounded is available. Licence to kill for a bounty is limited to bona fide fishermen, but the Department of Fisheries and Oceans (DFO) considers that the loss and wounded rates for seals are higher than in the culling operations because participants in the latter process use high-powered rifles and are under direction. Bounty hunting is prohibited in the whelping season, apparently to prevent pups being orphaned, but at least one breach of this regulation has been recorded (Dudka, 1978).

Grey seals have been hunted extensively in the United Kingdom, mainly for the benefit of fisheries. The adults have generally been shot on land or in the water with high-powered ammunition, and the pups have been shot at close range with lighter weapons. Most reports record the operations as satisfactorily humane (e.g., UFAW, 1967/1968), though some problems with orphaned pups have been noted.

There have been conflicting reports of the effect on the surviving seals of shooting in a colony. Scott (1972) describes the animals as stampeding and says that the effect on them "could not be described as humane". Brown (1972), on the other hand, was surprised at the small amount of disturbance that the shooting caused.

Harbour Seals

Bounties were paid on harbour seals until 1964 on Canada's west coast and until 1976 in the Atlantic provinces (Canada, DFO, 1985). Of the sub-adult and adult harbour seals that were reported shot in a survey taken in the Maritime provinces, 65% were retrieved (Boulva, 1973). Almost all the pups were retrieved either because they were taken on land or because they floated when shot (Boulva, 1973). In British Columbia, harbour seals were generally shot in the water by hunters on land, and because they represented a very small target, the result was usually either a kill or a clean miss (Bigg, 1985a).

In the United Kingdom, harbour seals were harvested commercially in the Wash until 1974. Hunters in high-speed boats approached hauled-out seals and shot or clubbed whatever pups they could on land (Jones et al., 1968). They then shot pups that had escaped into the water. As the pups grew larger, most were shot in the water. Most pups shot in the water by experienced marksmen within a range of 25 metres were killed outright. At greater ranges, or when the shooter fired from a boat, some pups were only wounded and had to be clubbed when they were recovered. Some sealers were highly competent marksmen, but others made many misses. In 1972, four of 10 harbour seals that were shot in the water at close quarters were only wounded (UFAW, 1971/1972).

Sea Lions

Steller sea lions were subject to control programs in British Columbia during the period 1912–1968, in an attempt to reduce their interference with commercial fisheries (Bigg, 1984; Canada, DFO, 1985). The control programs operated through bounties and organized kills by both fisheries officers and commercial users of the carcasses. In the last period of hunting, between 1958 and 1968, about 19,000 animals were killed in departmental and commercial operations combined (Bigg, 1985b). In the operations carried out by fisheries officers, both pups and adults were killed at the rookeries. Pups were killed ashore, but adults were killed both in the water and where they were hauled out. The majority of adults were shot from boats while the sea lions were on the shore (Bigg, 1984, 1985a).

Sea lions are difficult to kill; high-powered rifles are needed for this purpose, and even when they have been used, many animals have merely been wounded. Bigg (1985a) believed that the most humane method of culling sea lions was to shoot the pups on land. During the Second World War, quite large numbers of sea lions were killed by the Canadian navy and air force, but little information is available about the numbers involved. Steller sea lions were protected on the B.C. coast in 1970 (Canada, DFO, 1985).

Humaneness of Shooting

A bullet that strikes the brain case of a seal with sufficient energy will produce an instantaneous and humane death (Bonner, 1970), but any shooting at a distance or under difficult conditions will produce a certain proportion of inaccurate shots. In such circumstances, a much higher level of humane kills will be obtained with high-powered ammunition than with low-powered .22 loads.

Shooting is most accurate when the seal is on land or on ice and the shooter is on solid footing: land, ice, or a large ship that is proceeding slowly in calm waters. Under these circumstances, accuracy is high, and few seals are wounded or lost (Haller et al., 1967; Søgnen, 1968; Davis et al., 1980). The replacement of harpoons by rifles in the Arctic has considerably improved the humaneness of hunting seals when the seals are on the ice. Shooting is less accurate when the seal is in the water, even if the shooter is on solid footing. In these circumstances, the seal presents a much smaller target, and there are likely to be many more misses than wounding shots unless the shooter has deliberately tried to wound the seal to prevent its sinking.

There is less certainty in shooting seals on land or on the ice, but especially in the water, from an unstable platform such as a small motorboat or a large vessel in rough seas. Greater numbers of seals are probably wounded under such circumstances. Hunting methods that deliberately wound or harass a seal so that it can be killed at close range are sometimes used to avoid sinking losses (McLaren, 1958; Haller et al., 1967; Wenzel, 1981), and these cannot be considered satisfactorily humane. Nevertheless, some of the non-shooting killing methods that have been proposed in the Arctic to avoid sinking losses, such as the use of harpoons and nets (McLaren, 1958; Burns, 1967), are probably more inhumane than is shooting in open water.

Netting Seals

Harp seals are taken in nets along the Labrador coast, the lower north shore of the Gulf of St. Lawrence, and the northeastern coast of Newfoundland (Sergeant, 1965, undated; Boles et al., 1983). The seals are taken primarily during December and January on their southward migration, but small numbers may also be taken on their northward migration once the ice has gone in spring. Although the numbers taken have varied considerably from year to year, they have sometimes reached 6,000 harp seals on the lower north shore (Sergeant, undated). Nets may be set out in many configurations to catch harp seals (Beck, 1965; Baril and Breton, undated). More details are given in Appendix 20.6.

Nets are occasionally used in the Canadian Arctic, both in summer and in winter, to take ringed seals (Haller et al., 1967; Davis et al., 1980). They have also been used to take harp seals on the south shore of Hudson Strait, including Port Burwell (McLaren, 1958; Sergeant, 1965).

Netting is also practised in Greenland (Christiansen, 1968; Kapel, 1975), Iceland (Einarsson, 1978), the U.S.S.R. (Sdobnikov, 1933; Mineev, 1971; IFTF, 1977) and Japan (Naito, 1971).

Humaneness

Ronald (1982) conducted a study that involved using divers to investigate how harp seals became trapped in the nets, and how they died. In simple net systems such as those across passages, seals were caught by swimming directly into the mesh or by entrapment in the "hook" where two nets converged. In complex net designs, they were caught in the specially designed trap areas. They generally became more or less entangled in the meshes (Appendix 20.6).

The form in which the death of seals in nets occurs is generally the result of the elaborate set of physiological adaptations which enable seals to stay under water for lengthy periods (Ronald, 1982). Among these adaptations are the following:

- The seal can voluntarily reduce its heart rate for diving and can reduce it even more under stress.
- The seal has a peripheral shunt that, when it is diving, supplies blood, and thus oxygen, only to the heart and brain.
- The seal's muscles are rich in myoglobin, which stores oxygen, and seals can function for some time after the peripheral shunt comes into effect.
- The seal can convert carbon dioxide to a non-toxic form, store the converted form and then release it when it surfaces.
- When the oxygen in the seal's blood and tissues is exhausted, the tissues, including the brain tissues, can undergo an anaerobic period of activity.

These adaptations all play important parts in determining the behaviour of the seal in the net and the way it dies.

Seals that become trapped in nets probably do not realize their danger at first (Ronald, 1982). In laboratory tests, seals tried to push through nets, but did not at first show stress. At some point the seal would struggle violently, probably becoming badly entangled in the net, but possibly escaping. At this point it slowed its heart rate to the minimum and would be fully adapted physiologically for a long dive.

The phase of violent struggle might be followed by a period in which the seal was immobilized as a result of oxygen exhaustion in the myoglobin of the muscles. This inactive phase might be psychologically stressful, as the brain would function to the end, first because of the peripheral shunt and secondly by passing into an anaerobic phase. Because the carbon dioxide in the seal's system would be detoxified and stored, it would not build up and could not cause quick narcosis and unconsciousness.

The seal would thus be conscious until the final onset of death. It would remain in the dive reflex with reduced heart rate and would not attempt to breathe. The lungs of the seals that died in the nets did not contain water

(Ronald, 1982). Instead the animals were considered to have "dry drowned"; this condition, in which a diving mammal will not attempt to breathe underwater, even though it is dying from lack of oxygen, is also seen in beaver.

Most of the female harp seals taken in the early winter net fishery were pregnant. On the basis of studies of other species, Ronald (1982) suggested that the seal fetus might be more resistant to oxygen deprivation than the mother seal, and might therefore survive longer under similar conditions of stress.

Because of the long time it took seals to die underwater, and because the seals were conscious throughout this period, Ronald (1982) concluded that "there is little evidence that the seals are being killed [in the net fishery] in any way as humanely as the club, hakapik or gun methods." This conclusion seems to the Royal Commission to represent an understatement of the degree of inhumaneness involved in killing seals with nets as compared either to clubbing or shooting.

Other Killing Methods

Traditional Arctic Methods

Harpoons were formerly the primary Inuit device for taking seals, but they have now been replaced in many areas by rifles, although they may serve as auxiliary weapons during rifle hunting (e.g., Christiansen, 1968). Harpoons are still used in upper Lake Melville for hunting seals at breathing holes (Boles et al., 1983), as well as in the Thule area of Greenland (K'ujaukitsoq, 1985). Fairly recently, seals were still occasionally harpooned at a breathing hole in the Igloolik area of the Canadian Arctic (Bradley, 1970), and harpoons tied to floats were used occasionally from kayaks in Greenland (Kapel, 1975; Haller, 1978). Smith and Taylor (1977) reported that deliberate wounding of bearded seals to prevent loss by sinking still caused higher losses than the use of harpoons.

Another traditional method of capturing seals that is still used occasionally is to trap the seals at breathing holes, using either seal hooks or harpoon guns (McLaren, 1958; Davis et al., 1980). McLaren reported that seal hooks, which trap the seal in its breathing hole, were used with great success in the central Arctic. Harpoon guns were more expensive, but probably did not frighten the other seals as much as some other weapons.

These traditional methods all depend on catching and holding the seal until the hunter can kill it. For this reason, they probably inflict considerable pain before the seals are finally killed.

Hooks and Lines

Seals were formerly taken on hooks and lines in the Magdalen Islands (Sergeant, 1965), but this practice was banned in 1964, under the Seal Protection Regulations.

Military Action

When efforts were being made to control the numbers of Steller sea lions on the B.C. coast, the Department of Fisheries arranged for military aircraft and vessels to bomb and strafe haul-out sites in remote areas (Bigg, 1984). This action was taken during the Second World War and in 1958. Such indiscriminate action, which must lead to extensive wounding, and which does not provide reliable information about the numbers of seals destroyed, is obviously highly undesirable.

Poisoning

The only poisoning of seals in Canada of which the Royal Commission is aware was an experiment made in 1950 to test strychnine as a means of protecting salmon nets from grey seal predation (Fisher, 1985). Although the experiment was successful in killing seals, the method was not used further because it involved potentially serious problems created by releasing strychnine into the marine system.

Some Scottish salmon fishermen used poison to destroy seals that were raiding their nets (Bonner, 1970). The strychnine, which causes great suffering prior to death, was placed inside a salmon that was then tied into the net. The method was effective but inhumane; it was banned in 1970. It is understood that cyanide was also tried, but its use was probably discontinued when the use of gill nets to take salmon was banned in 1975 (UFAW, 1974/1975).

Drugs

Harp seal pups are taken to the shore from the ice in the White Sea area of the U.S.S.R.; they are held in enclosures until they have moulted and are then killed. Some of the initial experimental work was described by Ponomarev (1973) and Nesterov (1973), but there are some discrepancies in the accounts. It appears likely that the pups were immobilized with muscle-relaxant drugs such as ditilin (succinylcholine). It also seems probable that the animals were killed with drugs, again probably with ditilin (Nesterov, 1973). At one time a quota of 24,000 fur seals was taken in this way (Barzdo, 1980).

The method may have some advantages from the point of view of centralization and quality control, but it is open to serious criticism for its inhumaneness in at least two aspects. First, the collection of the animals and the subsequent packing into containers for the helicopter journey to the shore would be traumatic, although the trauma would be mitigated for the second stage if the seals were effectively anaesthetized.

Secondly, the drug ditilin is not an anaesthetic, but a muscle relaxant which only immobilizes the animals. The paralysed animals die from suffocation. In humans its use is reported to cause intense anxiety, and its use in euthanasia is not recommended (AVMA, 1978). Its use, as in the U.S.S.R., for transport and subsequent killing, seems highly undesirable.

Experimental Killing Methods

A number of attempts have been made to develop acceptable methods of killing seals, principally as an alternative to clubbing. The chief aim has been to find methods which would be satisfactorily humane on virtually every occasion. There has also been some concern to find a method which would overcome the "brutal" visual image of clubbing.

Most of the effort to find better methods has been focused, in Canada, on the clubbing of harp seal pups, and in the United States, on the clubbing of northern fur seals.

The Royal Commission was not informed of any work aimed at improving the humaneness of operations in which seals are shot.

Shooting

Harp Seal Pups

A long series of experiments by Hughes (1980, 1982, 1983, 1985a) which tested the effects of different types of pistols seems to represent the only case in which a practicable alternative to the established killing methods may have been developed. Any such method must not only be satisfactorily humane, but also capable of effective use under the particular physical conditions of the hunt. Hughes (1980, 1982) laid down the following criteria for the pistol he proposed, and these criteria seem to be realistic:

- The weapon must kill the seal pup instantly without physical or mental pain or distress.
- The weapon must be safe for the sealers to use. For this reason, weapons that fired bullets were not acceptable, and the shotgun ammunition chosen was of a calibre and power to be lethal only over a short distance.
- The weapon must be light and easy to carry, and must not interfere with the sealer's activities. For this reason a pistol was developed.
- The pistol must be easy to load and operate, and capable of being easily serviced and repaired.
- The pistol must be rugged enough to withstand conditions on the ice.
- The pistol should be relatively inexpensive.
- The pistol should cause minimal damage to the pelts.

After a number of experiments, the Canadian Veterinary Medical Association Humane Practices Committee stated that "the .38 calibre single shot pistol is capable of producing humane death, i.e. immediate and terminal unconsciousness in Grey Seal pups" (CVMA, 1984). Hughes (1985a) has stated that he is now satisfied that further trials are unnecessary, and that "the Accles & Shelvoke .38 shot pistol will undoubtedly kill any seal pup of any age humanely at short range." Accordingly, he believes "that use of clubs and other instruments of manual killing should be abolished and that, in future, the use of an approved gun and ammunition should be made mandatory." He has suggested (Hughes, 1985a) that these pistols be issued to master sealers by the Department of Fisheries and Oceans at the start of the sealing season and collected at its end. He has further suggested that the barrel could be modified to ensure that the pistol fire shot only and not bullets.

Although Hughes' report (1985a) of his latest tests appears promising, the device he recommends does not seem to have been widely tested by regular sealers under the actual conditions of the hunt. Several additional improvements have been suggested (CVMA, 1984; Webb, 1984a). The Royal Commission cannot, therefore, concur at this stage with the suggestion that the proposed pistol be immediately substituted for the club if the harp seal hunt continues. The Royal Commission does consider that if this hunt continues, the government should support further experiments to ascertain whether this pistol, modified if necessary, can actually be used on a large scale to kill seals humanely and with safety to other people in the vicinity. If the results of these experiments are positive, serious consideration should be given to regulatory action to introduce the pistol in place of the club. In this case the authorities should examine Hughes' proposals (1985a) that the actual killing be restricted to trained master sealers using weapons supplied by the government, and that skinning and other support activities be done by assistants. Experiments should also be undertaken to test the suitability of this pistol for killing seal pups of other species, whose destruction may be proposed as a population-control measure.

Northern Fur Seals

Shooting was tested as an alternative to clubbing of northern fur seals in the Pribilof Islands (U.S., Dept. of Interior, 1968). Standard .22-calibre rifles firing pulverizing cartridges were used to shoot two seals in the head. Although the animals were judged to have been rendered unconscious immediately, heavy gasping continued for several minutes. The bullets passed completely through the skulls and thus could have wounded personnel or other seals.

The U.S.S.R. also tested the shooting of northern fur seals with small-bore guns and pistols (Popov, 1968; U.S.S.R., 1980). The method was not adopted because of the likelihood of wounding non-target animals or of damaging the fur of other target animals (U.S.S.R., 1980).

Other Methods

A wide variety of experiments has been conducted, particularly on northern fur seals, to try to find more acceptable methods of killing. None of those methods of which the Royal Commission has found records showed any promise of success, and nearly all were discarded after limited preliminary experiments. They included:

- mechanical stunning devices, including captive-bolt pistols and others driven by compressed air;
- electric shock;
- gases (carbon dioxide and nitrogen); and
- drugs, particularly succinylcholine, to immobilize prior to mechanical stunning.

The characteristic of the harp seal hunt that makes most of these experimental methods unsuitable is the fact that the seal pups are scattered over a wide expanse of sea ice at low temperatures, rather than concentrated at one killing site. The sealer must travel to the seals, carrying with him the killing device. For this reason the device must be light, uncomplicated and easy to operate. Most of the experimental methods have required either devices that are not readily portable or, at best, heavy and awkward equipment, a means of restraining the seals, equipment dangerous to use on the ice (e.g., electrical devices), or complicated devices (e.g., drug-injection equipment). These methods have been generally tested on northern fur seals and found unsuitable for use on these animals (Keyes, 1980; U.S.S.R., 1980). All would be even less suitable for the harp seal hunt.

Comparative Humaneness of Methods of Killing Seals

The methods of killing seals described above can be evaluated in terms of the following criteria:

- the pre-kill stress suffered by a seal;
- the humaneness of the kill when it is done properly;

- the frequency with which the killing is not done properly;
- the consequences to the seal when the killing is not done properly; and
- the stress to any other seals caused by observing the killing of a seal.

Pre-Kill Stress

Pre-kill stress is primarily an issue in the clubbing of fur seals and the taking of harp seals ashore to keep them in enclosures. On the ice the harp seal pup does not appear to be distressed by the killing activities going on around it (Ronald, 1970), and would undergo stress only very briefly when the sealer moved to club it or shoot it at close range.

Fur seals experience stress during the drive to the killing grounds and the period during which they are held there prior to killing. Harp seal pups would suffer from several forms of stress in the Russian shore-based method of kill.

Pre-kill stress is not an issue in shooting at a distance, but it may be an issue when animals in a group are shot at close range as in some culling operations.

Killing Method When Properly Practised

When performed properly, a single blow of a club or hakapik will crush the skull of a harp or fur seal and render it instantly unconscious (e.g., Davies, 1967; Rowsell, 1973). Prompt exsanguination will ensure that a clubbed seal does not regain consciousness prior to death. When a seal is shot in the brain case at long range with a sufficiently powerful bullet or at short range with a shot pistol, it will instantly be rendered unconscious or killed outright (Bonner, 1970; CVMA, 1984). All of these methods of killing are humane when properly carried out.

Two methods of killing, netting and succinylcholine injection, cannot be considered humane. When seals are netted, they remain conscious until death occurs (Ronald, 1982). Because of the adaptation of a seal to diving, the seal will struggle violently against the net for some time and may undergo considerable stress. Succinylcholine produces paralysis and death by respiratory collapse, but the seal remains conscious until death occurs (AVMA, 1978).

Frequency of Improper Killing

The frequency of improper killing is not at issue with the methods of netting and drug injection. The issue does arise, however, when clubbing is the method of kill.

When seals are clubbed, some are not struck properly with the first blow. These seals may be given additional blows, but even so their skulls may not be fractured. The percentage of seal carcasses with unfractured skulls is often taken as a measure of the degree of improper clubbing because it can readily be checked; but the percentage of seals that are not rendered unconscious will be smaller, as some animals may be unconscious as a result of brain hemorrhages, even though their skulls are not fractured (e.g., Taylor, 1979). Simpson (1967b) recorded that 36% of the 154 harp seal skulls she examined were unfractured, but more recent observers working with large sample sizes have recorded lower percentages with unfractured skulls: 1%–2% for ship-borne sealers and 5%–6% for airborne sealers in a sample of approximately 400 (Jones, 1968); 0.20% of 509 (Ronald, 1969); 0% of more than 400 (Ronald, 1977). Many of the problems relating to improper clubbing of harp seals have arisen when inexperienced landsmen have participated in the harp seal hunt. If the proposed sealing pistol (Hughes, 1985a) is found to be satisfactory, its employment in place of the club and restriction of its use to a select group of professional sealers might reduce the number of harp seal pups that are killed improperly.

The numbers of seals that are shot and wounded are usually not separable from the numbers that are killed more or less instantaneously, but are not recovered. Recorded percentages of seals not recovered have ranged from 0% to 76%, depending on the species of seal, the time of year, whether the seal is on the ice or in the water, and whether the shooter is in a boat or on solid footing. In a sample of 75 harp seals and one hooded seal that were shot and recovered from a longliner, 13% would not have become unconscious instantaneously (Rowsell, 1977).

Consequences of Improper Killing

When a harp seal pup or a fur seal is clubbed improperly, it can be clubbed again very quickly. It is thus usually rendered unconscious with one or more blows, and its skull is probably fractured. If a seal were not rendered unconscious, it would rapidly lose consciousness when exsanguinated (Karstad, 1970), and for this reason exsanguination has been clearly identified as a step in the killing method to be performed immediately after clubbing and to be completed before skinning is begun.

The consequences of shooting and wounding a seal at a distance will depend on the severity of the wound and the time elapsing before the animal dies, is killed or ultimately recovers. When shooting occurs on land or on the ice, the opportunity will usually exist to kill any wounded animals. Such killing will be carried out whenever possible, when the purpose is to recover the carcass for subsistence, for commercial use or for a bounty. In the large-vessel hunt for harp seals, the preferred procedure is to kill any wounded animals with a club or hakapik as soon as possible, but this procedure has not always been followed. In open-water hunts, it may be possible to kill the wounded animal later, but when shooting occurs in heavy or broken ice, it is probably much less common to kill (and recover) a wounded seal.

Stress to Other Seals

The mother harp seal may suffer distress from being present when her pup is killed or on returning after it has been killed. The extent and importance of such distress is not known. The mother does not suffer distress, however, if the pup is killed after it has been weaned.

Northern fur seals suffer stress if they are present in a small group of which some members are being clubbed. Some northern fur seals which have experienced stress are released after the others in the group have been clubbed (Pfeiffer, 1981).

Stress to other seals does not appear to occur either in the shooting of seals at a distance or in the netting of seals. Shooting a seal may cause nearby seals to dive into the water, but this act may be no more than a normal escape reaction.

Slaughterhouses

Because there appear to be no absolutes in terms of the humaneness of killing animals, the Royal Commission believes that it is appropriate to compare the information about seals with the information available on two other activities in which large numbers of animals are killed in Canada: slaughtering domestic animals in abattoirs and hunting. Consideration is given here only to the larger mammals killed in abattoirs, that is, to cattle, pigs and sheep, and in big game hunting. In addition, very large numbers of domestic chickens are killed, and large numbers of rabbits and other small mammals, game birds and waterfowl are shot. The number of larger animals killed for human food in Canadian slaughterhouses each year - 3,718,319 cows and calves, 288,243 sheep and lambs, and 13,254,165 hogs in 1984 (Willsher, 1985) - is many times greater than the number of seals killed annually.

Canadian Humane Slaughter Laws

The *Humane Slaughter of Food Animals Act,* which was passed in 1959, applies to food animals that are to be exported from Canada, or that are to be shipped from one province to another. This legislation does not apply to many small slaughtering operations that market their meat within their own province. These operations are subject to provincial jurisdiction, but some provinces have enacted no provincial humane slaughter regulations.

Under the Humane Slaughter Regulations, food animals must, with one exception, be rendered unconscious immediately before slaughter or immediately before they are hung to be slaughtered forthwith. The methods prescribed for rendering the animal unconscious are:

- a blow to the head by means of an approved mechanical penetrating or non-penetrating device;
- a blow to the head applied by manual means for lambs and young calves;
- exposure to carbon dioxide in such a manner as to produce rapid unconsciousness by an approved procedure; and
- application of an electric current to the head of the animal by means of an approved device in such a way as to produce immediate unconsciousness.

The Regulations do not specify the method of slaughter to be used once the animal is unconscious. They do state, however, that in preparing an animal for slaughter and in slaughtering it, the animal is not to be subjected to any unnecessary pain.

The exception to the requirement of unconsciousness prior to slaughter is the method of kill prescribed under Jewish dietary laws. According to this method, the food animal cannot be hung, but must be restrained in an approved device and then slaughtered by means of a rapid cut that simultaneously and completely severs the jugular veins and carotid arteries, causing immediate unconsciousness. Slaughter under Islamic religious laws is performed somewhat similarly.

The requirements for the killing methods set out in the Humane Slaughter Regulations are considerably less specific than are the requirements for clubbing laid down in the Seal Protection Regulations.

Mechanical Stunning

Mechanical stunning may be carried out by means of a penetrating captive-bolt stunner, a non-penetrating captive-bolt stunner, or a gun shot (Grandin, 1980a). The captive-bolt devices may be fired by means of an explosive cartridge or by means of air pressure. They must be held firmly against the skulls of the animals in order to jolt the brain sufficiently to produce immediate unconsciousness (Grandin, 1980a). Regular pistols or rifles may be used to produce unconsciousness by shooting into the brain from a few inches away.

Penetrating captive bolts were considered by Lambooy et al. (1983) and Grandin (1980a) to be sufficiently powerful to stun effectively all slaughter animals, provided that the correct charge and bolt length for the particular animal were used. Non-penetrating concussion stunners have been found effective for cattle, but they are not recommended for calves or sheep.

The major problem in captive-bolt stunning occurs when animals move their heads and deflect the impact of the captive bolt (Grandin, 1980a). Restraining the animal's head in a yoke is practicable only in some plants. Because even the most skilled operators will sometimes miss the mark and fail to stun an animal properly, observers have recommended that a second captive-bolt device should be loaded and kept ready for an immediate second shot (Grandin, 1980a).

Von Mickwitz and Leach (1977) examined the operations of a number of slaughterhouses in the European Community (EC). Captive-bolt stunning of calves in four slaughter plants was judged to have been unsatisfactory, rating 5.0 on a scale where 1 was rated as very good and 6 was rated as poor. Stunning of cattle by penetrating captive bolt (in 19 plants) was considered to have been adequate, rating 3.9 on the scale just mentioned, but concussion stunning (in three plants) was held to be considerably better, rating 2.4. Corneal reflexes were still present in some animals after captive-bolt stunning. Stunning of sheep with the penetrating captive bolt (in six plants) was considered to have been satisfactory, rating 3.0, but concussion stunning (in one plant) was poor, rating 6.

Essentially, these operations provided no objective methods of testing that determined when an animal was improperly stunned. Instead, a slaughterman would rely on his professional experience to determine when an animal should be stunned a second time.

Rowsell (1979b) reported on mechanical stunning of beef animals at three Canadian slaughterhouses. He found that the operations met the requirements for humane slaughter, although he expressed some concern about them. Grandin (1982) visited 14 Canadian abattoirs where cattle were stunned with penetrating captive bolts. She considered eight unsatisfactory because their stunning pens held more than one animal at the time of stunning.

Manual Stunning

Under the *Humane Slaughter of Food Animals Act*, lambs and young calves may be rendered unconscious by a blow to the head applied by manual means. Many other small animals are killed by manual clubbing in small Canadian slaughterhouses (Hughes, 1985a). Rowsell (1979b) reported on the clubbing of lambs with a steel bar at a Canadian packing plant. Several lambs were confined together in a small pen, and there was little room to swing the club. The lambs moved and shifted their heads; consequently, one was hit on the neck, and another required two blows to stun it. Blink reflexes were still present in some of the lambs that had been struck.

Electrical Stunning

Electrical stunning is used especially for pigs, but also for sheep (Von Mickwitz and Leach, 1977; Grandin, 1980a). Instantaneous unconsciousness is obtained in this method by passing an electric current through the brain of the animal. The animal must then be bled before it recovers consciousness. Unconsciousness lasts at least 30 seconds in pigs (Hoenderken, 1978), but may be as short as 12–15 seconds in sheep (Leach, 1978). The application of incorrect voltages may produce paralysis without unconsciousness. If this occured, the animal would have to experience the electric shock for its duration and then the pain of being hung and bled (Hoenderken, 1978).

An alternative means of applying the current is to send it through the head and body. Current applied in this way will not only cause unconsciousness, but will also stop the heart function and thereby lead to the death of the animal (Von Mickwitz and Leach, 1977).

Von Mickwitz and Leach (1977) found that electrical stunning of pigs was, on average, satisfactory/adequate, rating 3.4 on the scale mentioned earlier, in 17 slaughter plants in the EC. Electrical stunning of sheep (in three plants) was given a less satisfactory rating of 4.6.

Rowsell (1979b) reported on the electrical stunning of pigs at a Canadian slaughterhouse. Unconsciousness was difficult to ascertain, as the blink reflex was obscured by muscular contractions. Although the time from stunning to bleeding was reported generally to have been about 15 seconds, it was over two minutes in some instances, and some of these pigs had regained consciousness before being bled.

Grandin (1982) visited 11 Canadian slaughterhouses where packer hogs were being slaughtered after the use of either electrical or carbon dioxide stunning. All of the plants using an electrical stunning apparatus did a good job of stunning, but three plants took too long (more than 30 seconds) between the times of stunning and bleeding.

Carbon Dioxide Stunning

Carbon dioxide stunning is used primarily on pigs (Von Mickwitz and Leach, 1977; Grandin, 1980a). Inhalation of carbon dioxide at a concentration greater than 7.5% has a rapid anaesthetic effect (AVMA, 1978), but it does not produce instantaneous unconsciousness. Pigs may remain fairly quiet for the first 10 to 15 seconds, but they then show stress and excitement and experience some violent movements before they become unconscious after an average delay of 26 seconds (Hoenderken, 1978, 1983; Leach, 1978).

Von Mickwitz and Leach (1977) considered that the carbon dioxide stunning of pigs at four EC slaughterhouses was adequate. They ranked the process at 4.0.

Rowsell (1979b) visited one Canadian slaughterhouse where pigs were being stunned with carbon dioxide. Most, but not all, of the pigs were rendered unconscious, with loss of the blinking reflex. For a few pigs, the time from stunning to bleeding was more than 30 seconds. Rowsell commented, however, that the method was uniform and could not be abused in the manner possible with electrical stunners.

Religious Slaughter

In slaughter carried out under Jewish or Islamic law, the question of humaneness is tied to the questions of how painful the cutting of the animal's throat may be, and how quickly the animal loses consciousness. Proponents contend that the cut is painless when made properly (e.g., Homa, 1971), and Grandin (1980b) concluded that the Jewish and Islamic methods "are probably the least painful techniques of throat-cutting for conscious animals, provided a humane restraining device is used."

Animals remain conscious for several seconds after their throats have been cut. This time varies from 3 to 10 seconds for sheep to up to 100 seconds for calves. Hormone studies show that the procedure induces severe stress (Grandin, 1980b). Various observers have also pointed to the stress induced by the way the animals are restrained prior to killing.

Pre-Kill Treatment

The treatment of animals prior to stunning and bleeding is a major area of concern in slaughterhouse operations. Animals are taken from their familiar surroundings, forced to climb ramps into trucks, mixed with unfamiliar animals in the trucks or later, shipped by truck, unloaded by ramp, confined in holding pens, and then walked to crowding pens and into the stunning pen. Furthermore, several animals may be in the stunning pen at the same time. (This practice may be an advantage in the case of sheep, which may be less stressfully handled in a group; Kilgour, 1976, cited in Grandin, 1980c; Kilgour, 1978.) That all of these events may be stressful to the animal has been shown by the increased levels of stress hormones that have been measured in the blood. (See Grandin, 1980d.)

Comparison with Harp Seal Hunt

The slaughterhouse methods can be compared in detail with the clubbing of harp seal pups on the basis of the same considerations on which the various seal hunts were compared.

Pre-Kill Stress

Harp seal pups on the ice experience little or no pre-kill stress but considerable stress occurs in all slaughter operations in moving the animals to the slaughterhouse, holding them and then moving them to the stunning pens.

Killing Method When Properly Practised

Clubbing a harp seal pup, when carried out properly with proper equipment, will produce instantaneous unconsciousness, as will mechanical, manual and electrical stunning of animals to be slaughtered. Carbon dioxide stunning and the Jewish slaughter method do not produce instantaneous unconsciousness, and the animal may endure stress or pain prior to lapsing into unconsciousness.

Frequency of Improper Killing

The frequency of improper killing of harp seal pups was reviewed in the section entitled "Comparative Humaneness of Methods of Killing Seals." Since 1968, the frequency of unfractured skulls has usually beeen recorded as less than 10%, but problems have arisen, most notably during hunts by landsmen.

The frequency of improper killing at slaughterhouses varies greatly among establishments according to such features as slaughterhouse design, equipment maintenance and employee attitudes. Many of the Canadian and EC slaughterhouses inspected by Von Mickwitz and Leach (1977), Rowsell (1979b), and Grandin (1982) appear to have been responsible for improper killing of numerous animals. In particular, in a number of plants using electrical or carbon dioxide stunning, the interval from stunning to bleeding was too long, and most or all of the animals would have regained consciousness prior to bleeding. In the Jewish slaughter method practised in the United

States, approximately 30% of the animals are not killed properly according to the religious tenets (Grandin, 1980b).

Consequences of Improper Killing

When a harp seal pup is not rendered unconscious by the sealer's first blow, it can be quickly clubbed again. The skull is usually fractured or crushed with one or more blows, thus rendering the seal unconscious. If the seal were not unconscious as a result of the blow or blows, it would rapidly lose consciousness when exsanguinated (Karstad, 1970).

All the slaughterhouse methods of stunning (mechanical, manual, electrical and carbon dioxide) can be repeated quickly if necessary. Slaughter animals that are improperly stunned manually can quickly be clubbed again in the same way. Improper mechanical stunning can be quickly remedied if a second captive-bolt pistol is kept ready for use. Electrical stunning can be quickly repeated if the condition is recognized, although in some cases of improper electrical stunning, the animal may be paralyzed while remaining conscious and will retain consciousness until it is bled if the condition is not recognized. Animals that are not properly stunned with carbon dioxide can be rerouted through the stunning chamber. All slaughter animals that are not properly stunned prior to bleeding will quickly lose consciousness when they are bled; unconsciousness will probably occur in less than one to three minutes.

Stress to Other Animals

The female harp seal may suffer distress from being present when her pup is killed or on returning to find that it has been killed. The extent and importance of such stress is not known.

Slaughter animals will experience stress if there are more than one in the stunning pen at the same time. This reaction applies particularly with cattle and pigs. The stress will probably be increased further if the animals are not restrained within the stunning pen. Stunning pens that hold several animals have been commonly reported in the inspection reports of Von Mickwitz and Leach (1977), Rowsell (1979b) and Grandin (1982). The stress caused an animal by seeing another animal stunned would not last long, however, as the observing animal would presumably soon be stunned also.

Summary

Clubbing of harp seals is as humane as, or more humane than, the methods used in slaughterhouses when both methods are carried out properly. The frequency of improper killing appears to be generally lower for harp seals than for the majority of animals in the slaughterhouses inspected.

The pre-kill stress of harp seal pups is very much less than that of slaughtered animals. The only other animals affected are the female harp seals. Any distress to these animals may be compared to the distress caused to female farm animals when their offspring are removed for later slaughter. It seems that in farm animals, which have a much longer period before weaning than harp seals, the parent-offspring bond may be stronger and the stress correspondingly greater.

Overall, the clubbing of harp seals by sealers from the large vessels appears to be as humane as, or more humane than, the killing methods practised in most slaughterhouses. The situation is less certain when hunts have been conducted by landsmen, and the incidents of improper killing have been more common.

Some observers, familiar with slaughterhouse operations, who have assessed the humaneness of the harp seal hunt, have similarly considered it to be as humane as, or more humane than, the killing of food animals in slaughterhouses (Hughes, 1967; MacLeod, 1967; Jones, 1968; Platt, 1970; Jotham, 1978; Taylor, 1979). MacLeod, for example, stated that:

> *There is no doubt that the killing of whitecoat harp seals in the Gulf of St. Lawrence by Canadians is as humane as the average slaughtering operation, and more humane than many, particularly those where there are no provincial humane slaughter laws.*

Even though this comparison may imply that the degree of humaneness in the harp seal hunt is about the same as that in most of the slaughterhouse operations which are implicitly accepted by the public, it should not be taken to mean that all is entirely well in this whole matter. Rowsell (1985) makes a telling point: "There is not a single area where animals are killed where problems in producing instant unconsciousness do not exist." As long as seal hunting continues, therefore, there should be no relaxation of efforts to maintain and improve on standards of humaneness.

Big Game Hunting

Large numbers of big game animals are shot each year in North America. Hunters took 2,143,210 deer in the United States in 1976 (Langenau and Aho, undated). Further inquiries suggest that the annual sport harvest in the United States and Canada during the period 1980–1985 was at least of the order of 65,000 elk, 65,000 moose, 35,000 antelope, 35,000 bears, 30,000 caribou, and 5,000 mountain goats and sheep.

Most of these animals are shot with modern rifles, but there is a significant harvest of deer that are shot with bow and arrows. Some states and provinces also permit hunting with shotguns, pistols, muzzle-loading rifles, muzzle-loading pistols, crossbows, and/or hand-thrown spears.

Humaneness of Big Game Hunting

The questions concerning the humaneness of big game hunting centre mainly on how many big game animals are not killed instantly, and how long such animals suffer. There is little information available on these questions for big game animals other than deer. Calculations of the numbers of deer that are shot but not recovered have ranged widely from 3% to 64% of the total numbers of deer legally shot, whether recovered or not, with an average of about 24% (Losch and Samuel, 1976; Wegner, 1981, 1985). These percentages of unrecovered deer are different from the percentages of deer that are wounded. They include deer that are wounded and survive; deer that are wounded and die at that time or later, but cannot be found; and deer that are killed and are found, but then abandoned for some reason.

The Royal Commission has been unable to find any useful information on the proportion of unrecovered deer that ultimately die of wounds from rifle fire, but one worker concluded that 26% of deer wounded by arrows died, possibly months later (Herron, 1984, cited in Wegner, 1985). In another study 11%–15% of the deer population was estimated to be recovering, or to have recovered, from wounds (Langenau, in press, cited in Wegner, 1985).

Comparison with Shooting of Seals

The rates for unrecovered deer seem generally to be comparable with those for open-water seal hunts, but higher than those for hunts on the ice. A lower rate of unrecovered seals might be expected on the ice, since there the hunter would more often have a clear view of the seal and frequently a chance of a second shot if a seal were wounded. In the water, on the other hand, the seal may be seen only briefly when it comes up to breathe, and when hit it often sinks and is unrecoverable.

While there are no good data, it also seems likely that for several reasons, the proportion of lost seals which are wounded rather than killed is lower than it is for deer. Wounded seals must surface to breathe and so may provide a chance for a second shot, while a wounded deer, if not too badly hit, may rapidly leave the place where it was shot. Seals killed outright will often sink, while a dead deer may be relatively easily found. Moreover, since seal hunters generally depend on their kill for subsistence or cash income, they are likely to have a higher standard of expertise and exercise a higher standard of care than deer hunters.

These reasons seem to suggest that in shooting seals, both on ice and in open water, the proportion of animals hit which are wounded and escape rather than being killed is lower than it is in most deer hunting. Since it is the incidence of wounding which is the critical factor in assessing the humaneness of any hunting with long-range shooting, it can be tentatively concluded that most hunting of seals by shooting is more humane than is the widely accepted hunting with firearms of other large mammals on land. While this conclusion seems consistent with what is known of the various hunts, it is based on limited and indirect observations.

Summary

Criteria of Humane Killing

1. The main requirements for killing humanely are:

    - The animal should be rendered unconscious as nearly instantaneously as possible.
    - Death should intervene rapidly thereafter, without the animal regaining consciousness.
    - The animal should undergo as little stress, pain or panic as possible before being killed.

- Other animals in the vicinity should be caused as little stress or panic as possible.

Clubbing of Harp and Hooded Seal Pups

2. Until 1966, when the seal hunt was first widely examined, the standard of killing methods seems to have been poor, and much cruelty was probably inflicted. Over the next few years the standard rose rapidly, and there has been some further improvement since then. This improvement has resulted from a tightening of the regulations, more thorough enforcement, and programs of sealer education. These administrative developments have taken place largely in response to recommendations of observers and their sponsoring bodies.

3. The key stipulations of the current regulations require that:

   - the animal be struck with an approved club so that the skull is crushed;

   - the sealer check that the animal is unconscious; and

   - the animal be exsanguinated (bled) immediately after clubbing and before skinning.

   These procedures, if properly carried out, will ensure that the animal is killed humanely.

4. Most qualified observers appear to be satisfied that in general, all but a very few pups are killed in a humane manner. The precise proportion of pups not properly killed cannot be determined, since such killings occur patchily. A few observers consider that the hunt can never become acceptably humane.

5. In recent times the most serious incident of unsatisfactory killing took place in 1981, when the ice brought seals very close to Prince Edward Island. Large numbers of untrained, ill-disciplined and poorly equipped men took part in a hunt in which many seals were undoubtedly killed in a cruel manner.

6. It is generally accepted that the pups undergo little or no stress of any kind prior to being killed.

7. The evidence relating to stress to mother harp seals is conflicting, but probably only a small proportion are distressed when the pup is killed; many retreat to the sea when the sealer approaches. Further regulatory changes, such as prohibiting the killing of pups if the mother is actively defensive, may be desirable. For the hooded seal the bond is much stronger, but it appears to exist only during the nursing period, and nursing lasts only a few days.

8. Very few seal pups are killed by being thrown into the water or crushed by vessels going through the ice.

Clubbing of Northern Fur Seals

9. Driving the animals to the killing grounds on the Pribilof Islands causes them some degree of stress, and in this respect this hunt is inferior to the Canadian hunt for whitecoats. When properly carried out, the method of killing itself is as humane as that used in the Canadian harp seal hunt.

Shooting

10. Provided that sufficiently powerful ammunition is used, or that the animal is hit in the head, death will be virtually instantaneous. In many shooting operations a large proportion of the animals are instantly killed.

11. Use of small-calibre low-powered ammunition causes a high incidence of wounding unless shooting is very accurate, but prohibiting the use of this type of ammunition could create economic difficulties in some aboriginal communities.

12. Use of shotguns to hunt seals must lead to many animals being wounded, unless the gun is loaded with a solid projectile, and is at least 20 gauge.

13. Where animals are shot in the water, about 10%–50% are not recovered. What proportion of these animals are killed outright, and what proportion are wounded and either die later or recover is not known. It does not necessarily follow that the proportion of animals wounded is greater when the loss rate is greater.

14. Harp and hooded seals are shot both in the water and on the ice from small vessels (longliners) and large vessels. Prior to 1966, a high proportion of wounded animals was observed, but conditions have improved more recently. The present practice of placing a fisheries officer on each large vessel is to be commended.

15. The arctic hunt, mainly by Inuit, for ringed and some bearded and harp seals, is conducted principally by shooting. When seals are shot on the ice, the rate of accuracy, and therefore of instantaneous killing, seems high, although the recent use of snowmobiles may have reduced it somewhat. When seals are shot in the water in summer, the loss rate may be high, but the wounding rate cannot be assessed.

16. In general, the standard of humaneness in the arctic hunt seems quite high. Much official supervision is probably not possible, but the traditions of the people seem to tend to promote satisfactory standards.

17. In some communities seals are deliberately wounded to facilitate their recovery. This practice must lead to much suffering and should be prevented as far as possible.

18. Grey seals have been hunted and killed, mainly by shooting, to control numbers for the benefit of the fishery; this practice has been carried out both by government hunters on the breeding grounds and by fishermen operating under a bounty scheme. On land the wounding rate is low; in the water the loss rate is high (up to 76%), although there are no comparative data on wounding rates.

19. Harbour seals have been subject to both bounty hunting and culling. Loss rates of adults are quoted at 35%–50%, but pups were generally retrieved.

20. Until 1968, Steller sea lions were hunted to control numbers. Adults were shot both in the water and on land. They are said to be hard to kill, and the wounding rate was high. It was suggested that the most humane way of culling sea lions would be by shooting pups on land.

Netting

21. Netting is used to take harp seals along the lower north shore of the Gulf of St. Lawrence, and on the Labrador and eastern Newfoundland

coasts. The numbers taken in this way are small compared to the kills by clubbing and shooting. Some ringed and harp seals are also netted in the Arctic.

22. Netting is a very inhumane way of taking seals. Seals do not drown in the nets, but continue to struggle until the oxygen in their blood is used up. This process may take a considerable time, and the animals remain conscious until the end.

Other Methods of Killing

23. Traditional killing methods used in the Arctic, probably now obsolescent in many places, make use of harpoons and seal hooks in breathing holes. Both devices probably cause considerably more suffering than the practice of shooting or clubbing.

24. Use of the navy and air force to kill sea lions, as has occurred on the coast of British Columbia, is clearly objectionable, and the Royal Commission assumes that such arrangements would not be contemplated in the future.

25. Poisoning seals has been tried only experimentally in Canada. It should not be considered further.

Experimental Methods of Killing

26. The shot pistol designed by Hughes for killing harp seal pups appears to be humane and less repugnant than clubbing. It is probably safe to use, but it requires further testing under field conditions. If it is found to be satisfactory in the field, its use should be considered in the event that seal pups of any species are to be killed in future.

27. None of the other methods tested gives promise of meriting further examination.

Killing in Slaughterhouses

28. Very large numbers of animals are killed in slaughterhouses for human food. Methods used are:

- mechanical and manual stunning;
- electrical stunning;
- carbon dioxide stunning;
- religious slaughtering.

Clubbing of seals is about as humane as mechanical, manual or electrical stunning, when all methods are properly used. The average incidence of errors in slaughterhouses seems to be similar to, or greater than, that which occurs in the clubbing of harp seals under good conditions.

29. In general, the level of both pre-kill stress and stress on other animals present is considerably higher in slaughterhouse operations than in most Canadian seal hunts.

30. Shooting of seals may often be less humane than slaughterhouse operations because of the relatively high proportion of animals wounded.

Big Game Hunting

31. Large numbers of deer and other big game animals are killed annually in North America. The chief problem relating to humaneness in this type of hunting is the proportion of animals wounded.

32. The most relevant comparison to seal hunting is that of the shooting of deer. The proportion of seals not recovered on the ice appears to be lower than the usual proportion of deer shot and lost, and there is likely to be a similar or greater difference in the proportion of animals wounded. In open water the loss rate seems about the same as in deer hunting, but the proportion of animals wounded is lower in the seal hunt.

33. The Royal Commission therefore tentatively concludes that deer hunting and possibly other forms of big game hunting are less humane, as judged by the proportion of animals wounded, than the seal hunts carried out by long-range shooting.

Conclusions

1. Judged by the criteria of rapidity of unconsciousness and particularly the absence of pre-slaughter stress, the clubbing of seal pups is, when properly performed, at least as humane as, and often more humane than, the killing methods used in commercial slaughterhouses, which are accepted by a majority of the public.

2. The most serious recent failures to meet satisfactory standards of humaneness in the clubbing of seal pups have occurred when ice carried seals unusually close to shore, where they were accessible to inexperienced and ill-disciplined landsmen.

3. If killing of seal pups of any species is ever deemed necessary, the special pistol developed by Hughes may prove to be more humane and less repugnant than clubbing. It is probably safe to use, but requires further testing under field conditions.

4. Shooting seals in Canada for subsistence or commercial purposes is generally more humane than the shooting of animals for sport, except that

   - the practice of deliberately wounding seals in order to facilitate recovery must lead to considerable suffering; and

   - the use of small-calibre low-power ammunition can cause a high incidence of wounding unless shooting is very accurate.

5. Catching seals in nets unavoidably causes slow and probably painful death.

6. No methods of killing which have come to the notice of the Royal Commission, other than clubbing and shooting, achieve acceptable standards of humaneness.

Recommendations

Killing of Seal Pups

1. Given that taking of harp seal pups continues (but see the Royal Commission's recommendations in this matter, Chapter 12), the Department of Fisheries and Oceans should make every effort to ensure that if the seals are likely to be easily accessible from the shore, all sealing in the area is effectively prohibited.

2. Consideration should be given to requiring by regulation that a sealer shall not attempt to kill a pup if its mother shows aggressive actions or attempts to defend the pup.

3. If seal pups of any species are to be killed in the future on the breeding grounds (e.g., as a measure of population control), further tests of the Hughes pistol to provide an alternative to clubbing should be undertaken under operational conditions.

Shooting of Seals

4. Discussions should be held with sealing communities with a view to gaining acceptance of the use of those types of rifle ammunition that ensure a high proportion of instantaneous kills under the conditions normally encountered in hunting each species of seal.

5. Discussions should be held with sealing communities with the aim of making clear that the practice of deliberately wounding seals to facilitate recovery is not condoned, and of finding ways to reduce the practice as far as possible.

Netting of Seals

6. The government should take action with a view to phasing out the netting of seals, as rapidly as possible, in those communities which now rely largely on this method to take harp seals both for subsistence and to provide a substantial part of their income. Netting of seals in other areas should be prohibited immediately.

Other Killing Methods

7. No new methods of killing seals for purposes of either harvesting or population control should be used in Canada unless they are clearly demonstrated to be acceptably humane.

Culling Operations

8. Reduction in numbers of Steller sea lions, if it proves necessary, should be achieved as far as possible by shooting pups on land rather than by shooting adults.

General

9. There should be no relaxation of the efforts to maintain and improve the standards of humaneness in all aspects of the various seal hunts. The conclusion that clubbing and shooting, when practised efficiently, are at least as humane as the general levels of slaughterhouse killing and big game hunting respectively should not be allowed to promote any sense of complacency.

Appendices

Appendix 20.1. Canadian Government Regulations re Methods of Killing

In 1966, the weapons that could be used to kill seals were restricted to clubs, gaffs or rifles, with the exception that nets could be used by local residents in the northern Gulf and at a portion of the Front. (Sealing with longlines had been prohibited in 1964.) Gaffs were prohibited as killing weapons in 1967, but shotguns firing slugs were permitted. Hakapiks, when used by sealers from large vessels, were permitted at the Front in 1976, and in the Gulf in 1979. Specifications for clubs were established or amended in 1964, 1966, 1967 and 1982; those for gaffs in 1966; those for hakapiks in 1976 and 1977; those for rifles in 1966 and 1967; and those for shotguns in 1967.

In 1967, the regulation was introduced that seals could be struck only with a club – though hakapiks were later permitted – and then only on the forehead. It was required in 1977 that all hooded seals shot must be struck with a hakapik, and in 1978 it was required that all sealing vessels must carry a club or hakapik. In 1980, seals killed with a club or hakapik were required to be struck three times or until the skull was crushed. In 1984, it was required that when a seal was clubbed, its skull must be crushed prior to skinning.

Skinning of a seal before it was dead was prohibited in 1964. In 1967, a new regulation was introduced to the effect that "No person shall hook, commence to skin, bleed, slash or make any incision on a seal with a knife or any implement until the seal is, without doubt, dead." The phrase "without doubt" was removed in 1976. In 1978, a seal was considered to be dead (and hence permitted to be bled, skinned, and so forth) if it "(a) is glassy eyed; (b) has a staring appearance; (c) has no blinking reflex when the eye is touched; and (d) is in a relaxed condition." The regulation that once a seal was dead, it must immediately be bled by cutting the blood vessel to the fore-flippers was introduced in 1979. Amendments enacted in 1980 prohibited any sealing group from stockpiling more than 10 seals that had not been pelted.

The use of aircraft in the seal hunt for any purpose except locating seals was prohibited in 1964, for all areas except the main part of the Gulf. The exemption relating to the Gulf was removed in 1970. Night sealing was prohibited in 1967, and adjustments to sealing hours were made several times thereafter. Out-of-season taking of seals by landsmen was restricted to local residents in 1971; and in 1977, all sealers operating from shore or in small boats (landsmen) were restricted to taking seals in the waters off the part of the province in which they resided.

In order to enforce the regulations and to control the sealers on the ice, regulations were introduced requiring licences for sealing vessels (1961), aircraft (1964), vessels over 30 feet (9 metres) in length (1964), sealers from vessels requiring licences or from aircraft (1964), and all individual sealers (1966). Modifications and restrictions to the licence requirements were introduced from time to time thereafter. Fisheries officers were given the power, in 1967, to suspend a sealer's licence immediately for up to 30 days, and sealers were required to wear visible means of identification. Masters of ships and pilots of aircraft were made responsible, in 1967, for the killing methods used by their crew members or passengers. In 1976, criteria were established for experienced sealers and assistant sealers, and assistant sealers were restricted to working under the supervision of an experienced sealer and to killing only under his direct supervision.

Appendix 20.2. Norwegian Regulations, 1968–1970

The Norwegian sealing regulations that were in effect in 1968 (as reported in Søgnen, 1968) required the sealers to use humane methods of kill and to strive to prevent unnecessary suffering. Seals could not be taken by line, net or trap; they could be killed only with a hakapik, a club or a rifle. Seals were to be struck with the hakapik or club only on the head. The fastening of hooks to live seals was forbidden, as was the skinning of a seal before it was certainly dead. In 1970, as reported in Platt (1970), seals could be clubbed with a heavy iron hook, but not with a club. When a seal was shot, the skull was to be crushed immediately with a hakapik. Seals had to be dead before they could be hauled aboard ship. In 1964, when the Canadian fishing zone was extended to 12 nautical miles offshore, and in 1977, when Canadian jurisdiction was extended to 200 nautical miles offshore (including the waters of the Front), the activities of Norwegian sealers within those respective areas became subject to the Canadian Seal Protection Regulations.

Appendix 20.3. Reactions of Female Seals to Loss of Young

Observations of harp seal mothers and pups have been made at various times during the short nursing period of eight to 12 days (Lavigne, 1979; Stewart and Lavigne, 1980). The point of time within the nursing period at which the observations were made appears to have affected the reactions of the females observed (Quine, 1985).

Some females leave their young and enter the water when a sealer approaches. Estimates of the numbers that do so have varied from the high proportions of 90%–95% (Fischberg, 1969) and 85% (Taylor, 1979) to the low numbers of Jotham (1978) who reported that most females that were on the ice when the pup was approached remained to defend it. Some of the females that remained to defend their pups soon left them or were easily chased away (Jordan, 1978); but some seals showed strong aggression in protecting their pups. Johansson (1967) reported that 1% or fewer were strongly aggressive; Rowsell (1980) reported aggression by females for 24% of 106 pups that were checked. Most aggressive females have been first-time breeders (Johansson, 1967), but on at least one occasion an older female was observed to have been quite aggressive (Walsh, 1978). Females in an unhunted whelping patch were more aggressive toward humans than those in hunted patches (Ronald, 1975).

The reactions of females towards the carcasses of their pups have also been quite variable. Rowsell (1979a) noted a number of females in the vicinity of carcasses; the females seemed to be oblivious to the presence of the carcasses. Some seals returned to sniff carcasses and then left quite quickly (Johansson, 1967); one seal that had been very aggressive in defending her pup when it was clubbed but not pelted paid little attention to the carcass after it had been pelted (Rowsell, 1978). Another female was observed to sniff a carcass that was not that of her pup (Hughes, 1978a; Scott, 1978). Other females have been aggressive in defence of the carcasses of their pups (Simpson, 1966, 1967a) or have remained with them for a considerable time (CVMA, 1980). Quine (1985) estimated that 4%–5% of the females would defend their pups against a sealer or would return and lie over the skinned carcass.

The strength of the pair bond during the short nursing period and the distress that the female may feel on the loss of her pup are not known. Some observers have been of the opinion that the females may indeed suffer (e.g., Fischberg, 1969; Taylor, 1979), whereas others have believed that the females were not much affected (Maton, 1969).

Seals produce milk only under the stimulation of suckling (Ronald, 1970), and females that lose their pups before weaning will quickly cease to lactate. Cessation of milk production will probably be quickly followed by mating (Lavigne, 1979; Ronald and Dougan, 1982).

One suggestion for eliminating any stress that the female harp seal may suffer when her pup is killed is to prohibit the taking of any seal pup when the female actively defends it (e.g., Walsh, 1966; CVMA, 1980). Although sealers sometimes refrained from taking the pups of aggressive females (e.g., Maton, 1969), this recommendation was never required by the regulations. Females that leave their pups when a sealer approaches, or that were absent when he approached might still suffer distress if this suggestion were to be implemented.

A second possible method of ensuring that females do not suffer distress at the killing of their pup would be to delay the hunt until most of the pups have been weaned and the mothers have left them. Hughes (1985b) suggested that the ideal time to kill harp seal pups was immediately after weaning. Because of differences in timing of the pups' births, this practice would probably involve taking many older seals that had moulted (beaters) and were more vigorous and active than newborns (Hughes, 1985a). In consequence, it would alter the nature of the seal hunt to some extent. The practicality of making such a change would have to be evaluated.

The distress that may be suffered by the female hooded seal on the loss of her pup has received much less consideration than has that of the harp seal. Rowsell (1975) noted a female that did not make any frantic search for the pup, but instead chased the male into the water. Until 1977, it was customary to shoot the female prior to taking the pup. Since that time none of the observers have commented on the reactions of female hooded seals to the loss of their pups. Greendale (1985) stated that in his experience female hooded seals have shown more attachment to their young (after they have been either killed or removed during the course of tagging) than have female harp seals. Hooded seals have a very short nursing period which averages four days (Bowen et al., 1985) after which the seal pup is left alone. A possible means of avoiding distress to the female hooded seals on the taking of their pups would be to delay the start of the taking of hooded seal pups until most have been weaned (e.g., Reeves, 1977). Again, the practicality of making such a change in timing would have to be evaluated.

Appendix 20.4. Tear Production in Seals

Mammals (and all terrestrial vertebrates) possess a number of glands that provide secretions to moisten the eyeball and, to some extent, to keep it aseptic. These glands are hidden in the eye socket in various positions depending on the species. The most important glands are the lachrymal glands, the secretions of which are called "tears" in humans, and the Harderian glands. The Harderian glands provide a somewhat more viscous lubricating fluid and are often considered to function so as to cushion the eyeball (Eglitis, 1964; McEwen and Goodner, 1974).

Because the surface of the eyeball, particularly the transparent area of the cornea, cannot be allowed to dry without risking serious problems, both glands constantly secrete fluid. In terrestrial species this applies especially to the lachrymal gland. In terrestrial mammals (including humans) each eye possesses a nasolachrymal duct or tear duct in the lower lid, normally in the inner or medial corner. This duct drains the constantly secreted fluids into the nasal cavity (McEwen and Goodner, 1974).

If, for any reason, there is cause for an abnormal increase in tear production, such as a breeze in the face or some foreign irritant in the eye, the tear ducts are unable to handle the drainage of the extra fluid that is produced mainly by the lachrymal glands, and the excess tears dribble or flow down the face. If there is an abnormal blockage of one or both tear ducts, even the normal secretions cannot be drained away, and the result will be tears dribbling out of the eyes.

Seals possess no nasolachrymal ducts. The Harderian glands are particularly large, whereas the lachrymal glands are relatively small (King, 1983). When seals are in the water, where they spend most of their lives, the Harderian glands probably play the more important role, and the viscous fluid they produce would minimize the frictional effect of the flow of water against the cornea.

When seals are on land or on ice and their fur has dried out, tears can always be seen dribbling from their eyes, since even the normal lubricatory secretions, which in seals almost certainly come mainly from the lachrymal glands, cannot be drained away. This is true of both hunted and undisturbed seals. When there is a wind blowing, the tears that would normally dribble down the front of the face not only increase in volume to protect against drying damage to the cornea, but are also blown back around the eye area and the side of the head so that large patches of wetness constitute a normal phenomenon around the eyes.

Whitecoat harp seal pups readily display normal dribbling of tears from the eyes, but their long white fur usually prevents the large wet patches from forming around the eye area. (These patches are typical of adult harp seals with their short flat hair.) The pups' tears dribble in large droplets down the front of the face. When there is no wind and the flow of secretions is minimal, pups often shut their eyes momentarily. They may do this involuntarily or voluntarily if, for example, they are touched by a person. This reaction squeezes tears out of the eyes, as the tears cannot go down a non-existent tear duct. This response does not mean, however, that there is a sudden increase in tear production.

Humans are unique among mammals in producing emotional or psychic tears (McEwen and Goodner, 1974). Crying, laughter, and emotions such as anger, fear, sadness or joy cause the lachrymal glands to respond with increased secretions, and the effect is similar to that caused by wind or an irritant: the ducts cannot drain all the flow, and tears result.

No evidence has been found that any mammal other than man weeps emotional tears, and in particular there is no evidence that seals do so. The "crying" of a lonely puppy, for example, is not accompanied by tear production. Walls (1942) stated that bears weep "psychic tears", but he did not elaborate or provide any reference, and the Royal Commission is unaware of any substantiation of his statement.

In a large whelping patch of harp seals or any seal species breeding in large gatherings, there is a constant cacophony of sound, mainly from vocalizing pups, but also from answering parent seals. Much of the ability to locate and recognize in mother-pup relations is based on the uniqueness of the individual calls of the mothers and pups (Evans and Bastian, 1969; Petrinovich, 1974). Once physical contact has been made, final recognition is olfactory, based on the uniqueness of the odour of the amniotic fluid on the pup's fur (Bartholomew, 1959).

There is no basis for labelling these normal vocalizations weeping, with accompanying tears of fear, in the presence of a hunter. The cries of the pups among a patch being slaughtered are no different from their normal sounds, although there is sometimes a snarling response as a person approaches closely. Nor is there any change in the normal secretion rate of the tears (Fisher, 1985).

Appendix 20.5. Shooting of Arctic Seals

When harp seals first arrive in the Arctic in June, after migrating from the south, the thickness of their blubber is at a minimum, and most will sink when shot (Haller et al., 1967). As they feed through the summer, there is a decrease in sinking loss. During break-up there was a 65% loss of 46 seals shot; during the open-water period in July there was a 50% loss of 34 seals shot; and during the open-water period in August there was a 37% loss of 38 seals shot (Haller et al., 1967). By October harp seals were reported to float when killed.

Davis et al. (1980) have reviewed the losses of ringed seals by sinking. Losses depend on the type of hunt and on the time of year. Ringed seals have less blubber thickness and less buoyancy in May and June during the moult and are most likely to sink at this time (McLaren, 1958). The water salinity and water density are reduced during break-up in June and July, and this factor also leads to increased sinking (McLaren, 1958). Losses of ringed seals in hunts on ice, at the floe edge or at break-up (February–July) ranged from 7.5% to 23.1%, with one high value of 47.4% (Davis et al., 1980). Losses of ringed seals in open-water hunts ranged from 27.9% to 52.4% in June and July, and from 3.6% to 15.9% in August and September (Davis et al., 1980).

The high losses from sinking considerably influence the methods used to shoot seals and the humaneness of these methods. Hunting techniques in the eastern Canadian Arctic vary with the time of year and the ice conditions. In winter ringed seals are taken at their breathing holes (Haller et al., 1967; Wenzel, 1981). The seal is shot from point-blank range and is unlikely to be missed, although some wounded seals may escape (Haller et al., 1967).

In spring ringed and bearded seals begin to haul out on the ice, and two techniques are used to hunt them. Using the first technique, the hunter stalks a seal on foot until he is within 90 metres of the seal (Haller et al., 1967). He then supports the rifle for a careful shot and shoots the seal in the head. Accuracy is high, and the killing shot prevents the seal from escaping to the water. Loss of bearded seals can, however, be high at this time (Davis et al., 1980). A second method that has become more common in recent years is to stretch a white screen across the front of a snowmobile and drive the snowmobile toward a seal that is hauled out (Wenzel, 1981). The seal is usually slow to locate the source of the sound, and the hunter can frequently approach close enough to shoot the animal. With the snowmobile technique, almost twice as many shots were fired per seal killed as were fired with the technique of stalking on foot (Wenzel, 1981), and possibly more seals were wounded.

At break-up, seals may be shot in the water by hunters on the ice, who then launch a small boat to retrieve the carcass (Haller et al., 1967). There is a higher percentage of hits during early break-up, when shooting is at closer range. Some ringed seals may sink at this time, and most harp seals will sink. Hunters in the Cumberland Sound area have been reported to shoot to wound the harp seals in the nose or throat (Haller et al., 1967). In this way the seal is weakened from loss of blood and is less able to dive, and the hunter can get sufficiently close to shoot it fatally and to retrieve it before it sinks.

During the open-water period seals are shot in the water by hunters in boats (Haller et al., 1967; Wenzel, 1981). Haller et al. (1967) describe a technique of hunting ringed seals in which hunters shoot at them as soon as they surface in order to force them to dive and to resurface more rapidly than is normal. The hunter will try to anticipate where the seal may surface and will turn off the motor for a more accurate shot. In northern Labrador, where the water is very clear and hunters can see the bottom, seals that sink are retrieved with a cod jigger (Andersen, 1985).

Because harp seals sink so quickly, they are hunted in Cumberland Sound during the early open-water period only if they are close to the boat (Haller et al., 1967). Later in the summer, hunters more frequently chase harp seals and shoot them from a moving boat. Smith and Taylor (1977) have noted the characteristic "porpoising" of harp seal groups when they are chased in open water; this behaviour would make them difficult targets, and in consequence, the authors have suggested that wounding rates must be high.

Bearded seals are also hunted during the open-water period, but they sink very quickly. They may be intentionally wounded with a shot to the back or belly so that hunters can approach close enough to harpoon and then kill them (McLaren, 1958; Smith and Taylor, 1977; Davis et al., 1980). Wenzel (1981) described an open-water method of hunting bearded seals in which at least two boats formed a wide circle to prevent the seal from getting beyond them. Each time the seal surfaced, the hunters immediately fired at it to force it to dive. When it was exhausted and could not dive, the boats closed in and the seal was killed. Bearded seals were also shot when they hauled out onto ice pans during the open-water period (Wenzel, 1981).

At Lake Melville, Labrador, hunters shoot ringed seals on the ice during the haul-out period (Boles et al., 1983). Seals must be stalked sufficiently closely to ensure a killing shot. Hunters aim for the head to ensure a clean kill and to prevent damage to the pelt. Many hunters prefer small-calibre rifles because of the less expensive ammunition, and because the bullet is less likely to damage the pelt. Ringed seals are also shot in open water on a year-round basis, in tidal channels near the mouth of Lake Melville (Boles et al., 1983).

Similar hunts (breathing hole, haul-out, ice edge and open water) are practised in Greenland, although snowmobiles and, in some areas, motorboats are not used (Kapel, 1975).

On the basis of the few statistics available and of the descriptions of the hunting techniques used, Miller et al. (1982) have suggested that loss rates were lower in Greenland. The custom followed in the Thule area during the breathing-hole hunt is to shoot the seal and immediately to launch a harpoon down the breathing hole to retrieve it (K'ujaukitsoq, 1985). In the Upernavik area, harp seals were intentionally wounded with shotguns so that they could be retrieved before they sank, and ringed seals were shot at repeatedly as soon as they surfaced to exhaust them and make their final kill and retrieval easier (Haller, 1978).

Appendix 20.6. Netting of Harp Seals

On the lower north shore of the Gulf of St. Lawrence, seal nets are set out in various configurations (Beck, 1965; Baril and Breton, undated). In many places they are set across passages either between islands and the mainland or between islands. In some places a series of nets is extended out from shore to form a trap that is difficult to escape from. At La Tabatière a very complex set of nets with several small inner traps is set up; the same pattern of nets has been in use there for more than 100 years (Ronald, 1982). The nets are usually hung so that the top rope is at a depth of two metres (to avoid ice) and the bottom of the net is on the sea floor (Beck, 1965). The head rope is brightly coloured. Harp seals are also caught in smaller-mesh fish traps. In this instance the seal swimming inside the trap is probably shot (COSS, 1984). The net fishery on the lower north shore has been greatly reduced in very recent years with the collapse of the market for sealskins (Sergeant, undated).

Migrating seals would try to dive under the head rope of the net (Ronald, 1982). They would then push against the mesh until they became entangled. Alternatively, they might attempt to push under the net at the bottom, only to have it cover and trap them. Few seals apparently swam over the head rope. Seals pushing against a net would cause the slack of the net to engulf them. Some would push forward against the mesh until they had a flipper through the mesh and were entrapped. Others would turn and spin, and thereby become completely entangled. Most seals were taken at night; those caught during the day were mainly seals that had been forced to dive by the harassment of being chased by boats and shot at.

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Chapter 21

The Status of Stocks of Atlantic and Arctic Seals

The myth of seals as endangered species must be dispelled (Cournoyea, 1985).

Harp Seals

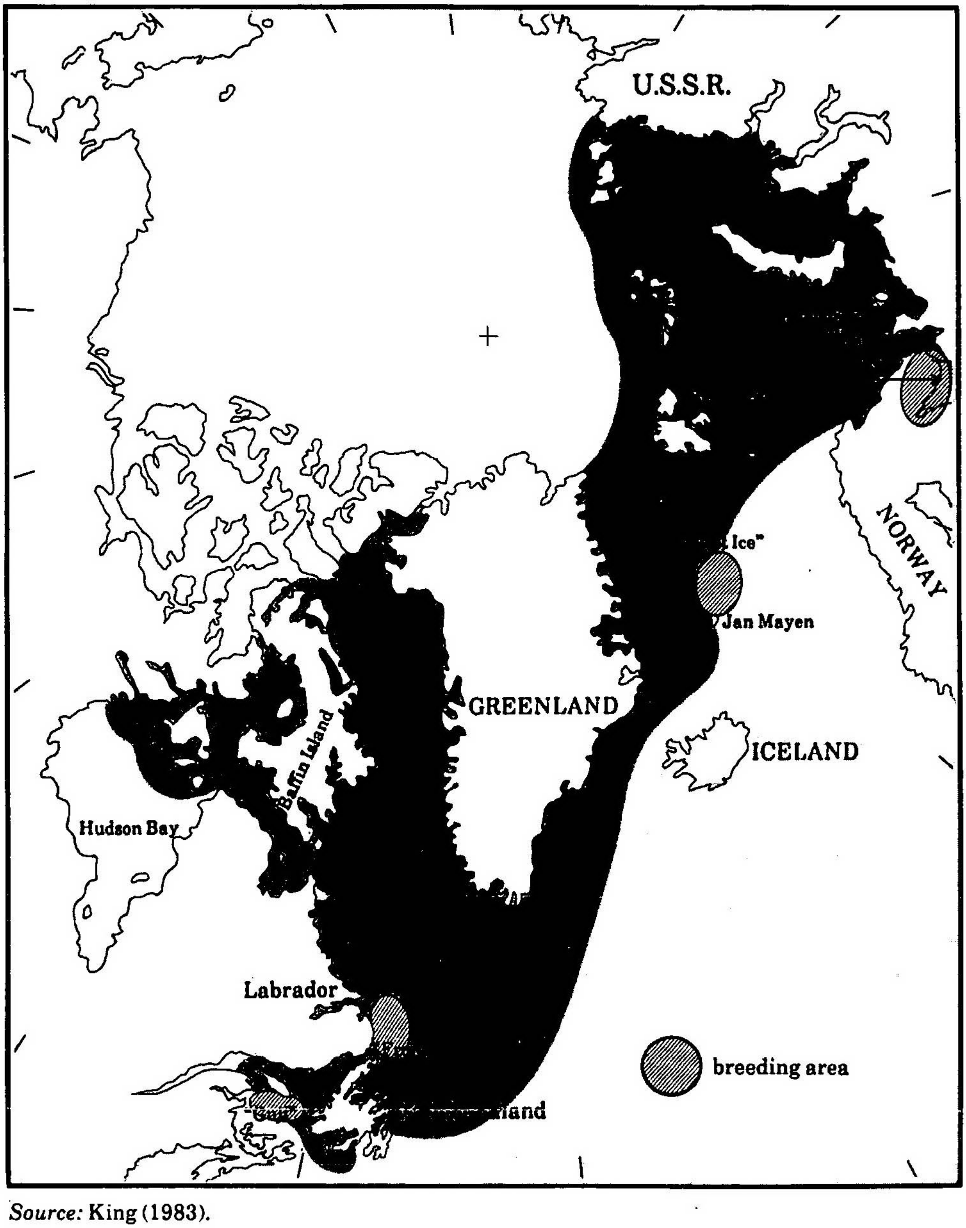
Summary

Harp seals are found across the northern part of the North Atlantic; they breed in three main areas: off eastern Canada, around Jan Mayen Island, and in the White Sea off northern Russia (Figure 21.1). The Canadian herd breeds in two distinct concentrations: in the Gulf of St. Lawrence, and on the Front area to the northeast of Newfoundland. The young are born in the early spring, and the seals migrate north and northeast to spend the summer feeding in northern Canada as far as Lancaster Sound, and off west Greenland (Figure 21.2).

In the northern areas, for centuries they have been subject to a traditional hunt by aboriginal peoples, but the main commercial harvest has been of pups and some adults on the breeding grounds. Catches during the present century have been high, comprising some hundreds of thousands of animals and reaching a peak of about 450,000 in 1951. Since 1971, catches have been controlled by quotas and have fallen to 150,000–200,000 annually. In 1983, the market collapsed, and in the last three years catches have been much smaller.

A number of methods have been used to estimate the total population of seals, which is usually measured as the number of pups produced in one year; these methods include direct surveys of the breeding population from the air, tag-recapture studies, and analyses of the age composition of the catches (including survival index and similar methods). Despite the very different assumptions involved in each method, the different data sets used

Figure 21.1
Distribution of Harp Seals



Source: King (1983).

in applying the methods, and the general difficulties inherent in studying an animal that lives in a harsh and remote environment, and can only be easily observed while on the breeding ice patches for a few weeks each year, there is good agreement among the different estimates. With a few exceptions, such as those obtained from tagging results in a particular year, most estimates of pup production in recent years are in the range 200,000–600,000. When allowance is made for the bias that may arise in applying some methods, it appears that the pup production in the years close to 1978, the most recent period for which several estimates are available, was some 300,000–350,000, equivalent to a total population of animals of all ages of about 1.5–1.75 million. Allowing for a probable increase in the harp seal population since 1978, the total number of these animals at the end of 1985 was about two million.

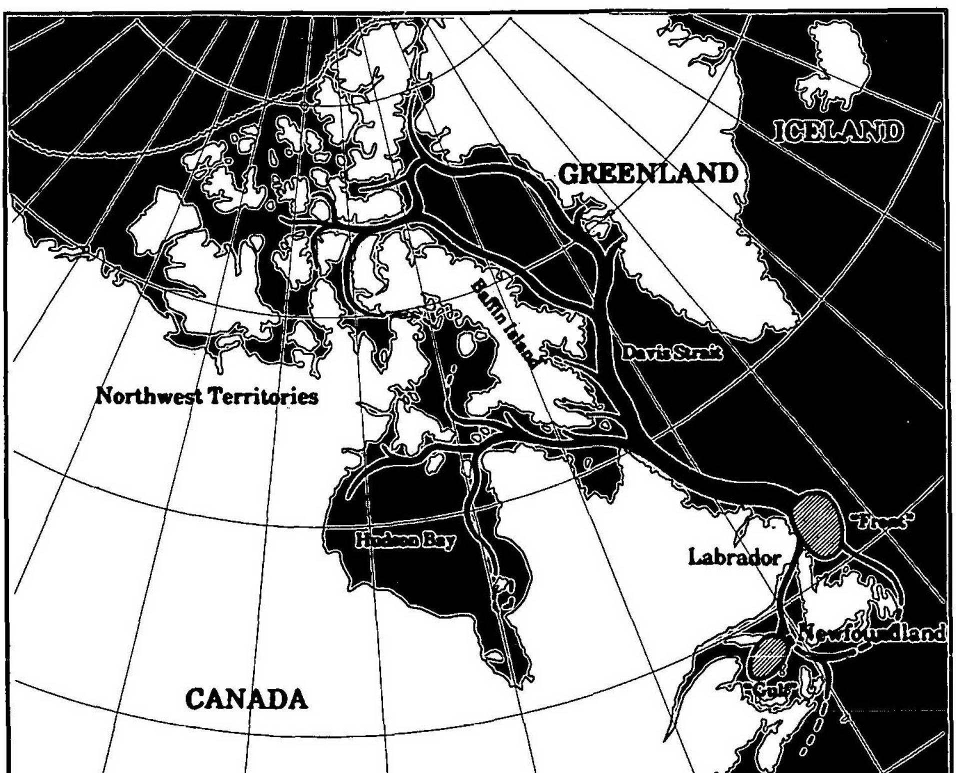
Though this number is large, it is well below the initial number of harp seals. The harp seal stock has been seriously reduced from its size when commercial sealing began. Presumably in response to this reduction the natural population parameters are now such that the number of births exceeds the number of natural deaths, and in the absence of any hunting the population would increase. The response appears to have occurred largely through density-dependent changes in the age at which seals mature and possibly, also, in the pregnancy rate. If there were no more hunting, these parameters would presumably, as the population recovers, return in due course to their original values, and the population would stabilize at some level greater than the present one. This stable level might not be exactly the pre-exploitation level, because of possible natural changes in the carrying capacity and also because of the effect of human exploitation of fish stocks on which the seals feed. It is not known what this stable level is, but it is probably well above the present level.

The sustainable yield, that is, the difference between the numbers of births and natural deaths, will depend on the population parameters, particularly the natural mortality and age at maturity. For the more likely sets of parameters, it is believed to be about half of the number of pups born each year. If some older animals are killed, the total numbers taken will have to be reduced from the allowable catch if the harvest were taken entirely as pups. The sustainable yield for any combination of old and young seals can be calculated by taking one adult seal as being equivalent to about two pups.

Since catch quotas were introduced in 1971, catches usually have been at or below the quota levels. Quotas have probably been set at less than the sustainable yield so that between 1972 and 1983, the total seal population has probably increased; the possibility that it has decreased cannot, however, be ruled out. If there was a decrease, the rate of decrease was low. Since 1983, the population has certainly increased. Since catches are likely to remain small, this increase, which may be about 5% per year, will almost certainly continue for some time to come.

The population figure which corresponds to the maximum sustainable yield (MSY) is not known, though it is more likely than not to be greater than the present population figure. In the context of the harp seals, however, and in view of the different objectives to be considered (few of which are primarily concerned with achieving the greatest possible yield), the MSY

Figure 21.2
Migration of Harp Seals in the Northwest Atlantic



Source: Mansfield (1967a).

level is not very significant. The critical level at which the population is so small that there is real risk of its declining to extinction, even in the absence of any more hunting, is probably only a few hundreds or fewer, and is certainly very much lower than the present level.

Though the uncertainties about the dynamics of the harp seal population are not significant in terms of assessing the species' present status, their effect increases when one attempts to project the effect of different policies into the future. It is probable that catches of about the size taken in the late 1970s would allow the harp seal population to increase, but there is a chance that they would cause a decrease, and if this decrease were allowed to continue uncorrected for a period of as long as 10–20 years, it might occasion a serious threat to the stock. It is therefore important that any future harvesting of harp seals, other than at the most trivial level, should be accompanied by a regular program of monitoring the stock and adjusting the allowable catches accordingly; the same conclusion applies also to other species of seals. If there can be significant variation in the year-to-year catches of young seals, the survival-index approach would be a suitable method of monitoring. Otherwise direct surveys would be needed. Even in the absence of large-scale harvesting, monitoring of stock abundance will be required if there is any question of an increasing abundance of seals having a serious effect on commercial fisheries.

Under the present circumstances, these discussions about future management are somewhat hypothetical. With the collapse of the markets for seal products, recent catches have been small, and there is little immediate prospect of economic conditions changing. Elsewhere in this Report (Chapter 12) the Royal Commission recommends that the commercial hunting of pups (whitecoats) should not be permitted. If this recommendation is acted on, it is difficult to see large-scale hunting of harp seals recommencing in the foreseeable future.

The stocks will therefore increase. How fast they will increase and how long this increase will continue depends on how much hunting of older seals occurs, and the dynamics of the stocks, especially the density-dependent effects. If no hunting is done outside Greenland and the Canadian Arctic, catches may be no more than perhaps 20,000–30,000, compared with a current sustainable yield, in pup units, of perhaps 170,000. The net increase is therefore likely to be the equivalent of 100,000 pups or more. Without some estimate of the ages of any seals killed, and without examining the details of the present age structure of the population, it is not possible to express this increase exactly as a percentage increase. Given a current (end of 1985) population abundance of about two million, the increase is likely to be about 5% per year.

The current population is certainly well below the initial population abundance, and although the carrying capacity may have been reduced by the exploitation of some of the fish species on which harp seals feed, it, too, is likely to be well above the present level. It would be realistic to expect the increase to continue until the abundance is at least twice the present level, and perhaps well beyond. The information is not good enough to make useful predictions of the actual abundance in future years, since small changes in the population parameters can make a great difference. Thus, if the rate of increase is, in fact, 5%, then in 15 years the population will have slightly more than doubled (to 208% of the present number). However, if the true rate was 3% or 7%, the changes would be only 156%, or nearly trebling (to 276% of the present number). In these circumstances, and if there were any concern about the possible impact of increasing numbers of seals on the fishery, regular monitoring of the stocks would be very important.

Background

The harp seal is found throughout sub-arctic waters of the North Atlantic where it has three main breeding areas: in the White Sea, around Jan Mayen Island and off the coast of Canada. The last group is separated into two main concentrations of breeding animals which are found in the Gulf of St. Lawrence, and in the Front area to the northeast of Newfoundland. There is apparently no mixing between harp seals of the eastern and western Atlantic, but considerable mixing between animals of the Gulf and the Front.

Harp seals are gregarious animals and breed in huge concentrations. Their mating takes place shortly after pupping, and they are apparently monogamous or promiscuous, but there is no evidence of any organized social system. The young are born on the ice in late February to mid-March. In the summer the seals from the Canadian breeding grounds move north through Davis Strait, and they are found along the west coast of Greenland, and on the Canadian coast, from Hudson Bay to Baffin Island and Lancaster Sound (Lavigne, 1979).

After they are weaned, the young seals feed largely on zooplankton (mysids and euphausiids), while the older animals also eat a variety of fish (polar cod, herring and capelin, and occasionally groundfish), as well as squid. The adults apparently eat little or nothing during the breeding season (Mansfield, 1967a). The food of harp seals is dealt with in more detail in Chapter 24.

Harp seals mature at about five years of age. They live up to 30 years or more, with a natural mortality rate of about 10% per year. Not much is known about the causes of natural mortality. Predation by polar bears, Greenland sharks *(Somniosus microcephalus)* and killer whales is believed to be low; parasitism and disease are also believed to be factors of little significance (Lavigne, 1979).

History of Exploitation

The "seal hunt" as commonly imagined by the public is the harvest of whitecoat harp seal pups in the first couple of weeks of life, on the ice fields of the Front and the Gulf of St. Lawrence. This hunt, particularly by crews of large vessels from St. John's, Newfoundland, Halifax, Nova Scotia and Norway, has accounted for the greater part of the kill in historical times, but is not the only harp seal hunt. There are similar hunts in the White Sea conducted by the U.S.S.R. and near Jan Mayen Island, conducted by Norway and the U.S.S.R. Immature and adult harp seals are also taken commercially by a variety of small-boat fisheries. In addition, subsistence hunting is important in both Greenland and northern Canada. The details of the harvest, the numbers taken, and the products (oil, fur, leather and meat) are treated in Chapter 14.

In the Canadian region, catches at the beginning of the century amounted to about 250,000 animals per year. These numbers declined during the First World War and stood at about 150,000 per year between the wars. Virtually no commercial sealing was done during the Second World War, but after 1945, Canadian sealers were joined by Norwegians. Catches on the breeding ice reached a peak of some 450,000 animals in 1951, and averaged about 300,000 a year up to 1966. In 1965, a quota of 50,000 harp seals was set for the Gulf, but a quota for the whole hunt, including the Front (then outside Canadian waters), was not set until 1971. Since then, catches have been limited by quota; subsequent to the ban imposed by the European Community (EC) and the collapse of the market, catches have been low. In 1984, only 31,000 animals were taken. Most of these were beaters, that is, animals that have moulted out of their original white fur, but are still in their first year of life; some older animals were also taken.

Estimation of Abundance

All the main methods for making a census of marine mammals, as described by Eberhardt et al. (1979), have found some application to harp seals. The abundance of the harp seal population has been estimated by four methods: direct surveys of part or the whole of the population; mark-recapture methods; the "survival index" method; and sequential analysis of the history of the population. A fifth method, analysis of catch and effort data, has not proved useful because of the nature of operations in the main season, though data from the summer season in Greenland may be useful in following changes in relative abundance. The next sections describe three methods of estimating abundance: in a single year (surveys), or over a short period (mark-recapture and survival index). The method of sequential analysis will be considered after the reasons for changes in population size.

Surveys

Harp seals can be surveyed directly when they are on the ice during the breeding season and shortly afterward, when they are moulting. The entire population is not available to be counted, but counts can be made of either breeding females or the newborn pups. The latter are not easily seen against the ice, but they show up well on photographs taken with ultraviolet light (Lavigne and Øritsland, 1974).

The basic principle of conducting a survey is simple and sound, but in practice the survey must be carried out carefully if it is to provide useful results. Given good weather (which cannot be guaranteed during the short period available for counting), the method is reliable and free from some of the errors and uncertainties inherent in other methods.

The chief problems are:

- The survey may not cover the entire breeding population. It may not be possible to survey both the Gulf and Front areas, and it is not easy to be sure that all the whelping patches in an area have been detected and surveyed.
- The females may not all be on the ice at the time of the survey.
- Some males may be present and may be counted as females.

- The survey may take place before all the pups are born or after some have died or left the ice.

All these possibilities of error, except for the third mentioned, which is likely to be small, lead to underestimates of the total population of breeding females or of pups, but the degree of underestimation is unknown and could be large if, for example, a large patch is missed. The method is therefore not attractive when an attempt is being made to obtain a single best estimate, and it has been neglected recently in favour of other methods. For other purposes, such as deciding whether the removal of 1,000 pups is likely to threaten the stock, a lower bound to the abundance is useful. The method is also the only one that does not depend on a significant harvest, and it could therefore be invaluable for future monitoring.

The published estimates of the production of pups obtained from surveys are given in Table 21.1. Confidence limits are available for only some of these estimates, and the quoted figures suggest big differences in the precision achieved by various procedures. The 95% confidence limit of ± 30% achieved by Lavigne et al. (1980) for the 1977 Front total by stratified random sampling is probably typical of most figures.

Table 21.1
Estimates of Pup Production (000s) by Different Survey Methods

Year	Gulf	Front	Total	Source
1950	215	430	645	Sergeant (1975)
1959–60[a]	150	215	365	Sergeant (1975)
1964	100 [b]			Sergeant (1975)
1967	over 30[c]			Sergeant (1975)
1970	75	150	225	Sergeant (1975)
1972	125	100	225	Sergeant (1975)
1975	46	no estimate	250	Lavigne et al. (1980)
1977	no estimate	200(+)		Sergeant (1975)

Note: A variety of different methods was used for analysis of the data, resulting in a range of different estimates. Stratified random sampling was believed to give the best estimates, which are given here.

a. Pooled data.
b. South Gulf only.
c. North Gulf only.

Mark-Recapture

The basic principle of the "mark-recapture" method is simple. (See Eberhardt et al., 1979.) Suppose that 2,000 animals are marked or tagged and well mixed with the rest of the population. Later, a second sample of the population is examined and 1% of the animals are found to be tagged. It may then be presumed that the population consists of 200,000 animals. There are several factors, however, that can make the method unreliable. It may be, for instance, that:

- the population is not closed; animals may enter the population between the two samples;
- the animals tagged are not a random sample of the population;
- the second sample (which will normally be part of the commercial catch) is not a random sample of the population;
- the presence of a tag may change the probability of the animal appearing in the second sample;
- tags may be lost from the animal before the time of the second sample; and
- some tags in the second sample may not be recognized or not reported.

These factors have been considered by scientists of the Department of Fisheries and Oceans, and the last three can be adequately dealt with (Bowen and Sergeant, 1983, 1984). It seems unlikely that the presence of a tag affects the behaviour of the animal, or its chances of being caught. Tags do wear off, but the rate of loss has been estimated by attaching two tags to the same animal. One method of analysing the results is to note the frequency of later returns from animals with only one tag, the other having become detached. Alternatively, the overall return rate from seals with two tags can be compared with that from seals originally tagged with only one tag. The return rate from seals with two tags will be greater because the loss of one tag will not prevent recovery , and the difference can also be used to estimate a rate of loss of tags. This estimate exceeds that obtained from observing the return of single tags from seals that were originally double-tagged. The reason for the discrepancy is not clear, but it will not make a big difference to the correction needed to allow for tag loss.

Few, if any, tags escape notice, but not all tags are returned. The frequency of non-return has been estimated by detailed inquiries among the sealing communities. Corrections for tag loss and non-return of tags can readily be made. The corrections actually made do not take into account double-tagged animals that lose both their tags in the same incident, or of non-returns that were not detected even in the follow-up. Thus corrections may be too small, and this error may lead to overestimates of population size, but the effect is probably very small.

The first three factors are more troublesome. The only period when it is practicable to mark large numbers of animals is in the breeding season, when large numbers of pups can be marked in the breeding patches. Even if efforts are made to spread the tags evenly, there will almost inevitably be some degree of clumping; in particular, there is likely to be a discrepancy between the numbers tagged in the Gulf and Front herds. Animals may be recaptured as whitecoats or beaters in the same year or as older animals in subsequent years. There will have been little mixing of animals in their first few months of life, and the rate of return will depend greatly on the degree of overlap of the positions of tagging and hunting. Whitecoat returns are of limited value for total population estimates, but they can be used to estimate production in individual patches if tagging can be well spread throughout the patch.

Beaters will be better mixed, and there seems to be good, but not complete, mixing within the Front or Gulf herds. Returns from the catches of beaters can therefore be used with caution to estimate the pup production in one herd or the other. Estimates for the total production can best be obtained by summing independent estimates for the two herds.

Better mixing will be obtained after at least a year, by looking at the occurrence of animals tagged as pups in 1978 among the catches of one-year-old animals in 1979, two-year-olds in 1980, and so on. This introduces the problem of knowing just how many one-year-old animals were caught in 1979, as well as various problems of adequate sampling and of possible errors in age determination.

Confidence limits on the estimates can be calculated to take account of some of the known sources of variation, particularly the relatively small numbers of animals tagged. These, typically, give coefficients of variation of some 10%–20%; that is to say, differences between pairs of estimates of less than about 30% cannot be considered statistically significant. These calculations cannot take account of all the sources of variation, especially when the basic assumptions of the method are not entirely satisfied. These assumptions are likely to be particularly important when analysts are comparing results from tagging with those from surveys or other methods.

Sufficient pups have been tagged in eight years to give usable results. These results are summarized in Table 21.2. These figures are reasonably consistent; they will be compared later with those from other sources.

Table 21.2
Estimates of Pup Production (000s) from Mark-Recapture Experiments

Year of Tagging	From First Year Returns			From Later Returns
	Gulf	Front	Total	Total
1964	127–154[a]			
1966	120[b]	189[d]–200[b]	320[b]	
1968	120[b]–127[a]			
1970	68[a]–74[b]			
1977				318 (222–414)[c]
1978			2,245[c]	497 (429–565)[d]
1979			698[c]	478 (408–548)[d]
1980			309[c]	475 (381–565)[d]
1983			534[d]	136[d]

Note: The estimates distinguish between returns within a year of tagging and later returns. Confidence limits, when given, appear in parentheses.

Source:
a. Sergeant (1975, Table 50).
b. Sergeant (1975, Table 52).
c. Bowen and Sergeant (1983, Tables 13 and 16).
d. Bowen and Sergeant (1984). These differ very slightly from the figures in Bowen and Sergeant (1983, Table 16), by the inclusion of data from returns in 1982.

The very high figure from first-year returns in 1978 (and to a lesser extent in 1979) is probably the result of incomplete mixing and, as noted by Bowen and Sergeant (1983), is less reliable than other estimates. The low estimate from later returns of animals tagged in 1983 is less easily explained. Bowen and Sergeant (1984) suggest that it may have occurred because most of the catch was taken close to shore, though there may also have been difficulties in estimating the number of one-year- old animals caught. In contrast, they suggest that the absence of a large whitecoat hunt in 1983 allowed a better spread of tags on the breeding patches so that the first-year returns might have been more reliable than those of previous years.

Survival Index

The principle of this method, first developed by Sergeant (1971), is straightforward. If unusually large numbers of pups are killed, fewer survivors will recruit to the stock of older animals, and there will be a relative scarcity of that year-class in the age composition of samples taken from the stock in later years. The relative abundance, or "survival index", of a year-class can thus be quantitatively related to the harvest of pups, to produce an estimate of the number born. This estimate will be the point on the line that relates survival index to pup kills at which the survival index falls to zero, that is, all the pups are harvested.

The practical application of the method faces two problems: births are not constant from year to year so that the number of survivors is not uniquely determined by the numbers harvested; and it is not easy to attain a "survival index" that is truly proportional to the numbers surviving. These problems have been examined in a number of published papers which have progressively refined the methods used (Sergeant, 1975; Benjaminsen and Øritsland, 1975; Ricker, 1975; Winters, 1978; Beddington and Williams, 1980; Roff and Bowen, 1983). The most recent study was recorded in a Ph.D. thesis presented in 1983 at the University of York, U.K. by J. Cooke; its main points are given in Cooke (1985), from which many of the present conclusions are derived. Although the later studies have detected and removed several weaknesses in the original form of the method, the changes in the estimates are not large, generally amounting to a few tens of thousands in estimates of some hundreds of thousands. These differences would be significant if management were concerned with determining the maximum possible allowable catch which would still permit some small increase in population. For other management objectives, the differences are not important.

There is little information on random year-to-year changes in pup production, as a result of environmental factors, for example, but the impression from the findings is that the proportion of adult females breeding each year is high and does not change much. Such minor changes as do occur probably affect the estimates little, but a trend in population, such as the probable downward trend in the two decades leading up to the early 1970s, could cause a bias. Simulation studies suggest that the pup production will be overestimated, though probably not by much; that is, the estimate is equivalent to the population numbers near the beginning of the period under review, and not to the true average. It seems probable, though, that this conclusion only holds if there is a similar trend in the numbers of pups killed. In that case, high kills are associated with high initial numbers of seals, so that the effect of the harvest is underestimated, and the pup production is overestimated. If, on the other hand, there are opposite trends in harvest and pup production, then high kills will be associated with small numbers of seals and the impact will be overestimated and the estimate of production biased downwards.

The essential conclusions are that the "survival index" method should be used with care when there are trends in population numbers, and that it should be used only for relatively short periods (say, five to 10 years) during which population changes are likely to be relatively small.

The chief difficulty lies in obtaining a valid index of survival. Any sample from commercial or research catches will be selective according to the time and place of sampling, so that the proportion of a year-class in a sample will not be a true representation of the proportion of that year-class in the stock, that is, the survival rate. This problem can be dealt with by suitable processing of the sampling data, assuming that the density pattern of a given sampling method (such as that in the commercial catch at a given time and place) is the same from one year to the next, and that year classes suffer the same rates of natural mortality after the first few months of life. These are reasonable assumptions, except possibly for selections for one-year-old animals, which are variable.

For the older animals, in particular, uncertainties in age determination are another source of bias. Any errors will tend to reduce the apparent differences in survival rate and hence lead to underestimates of the impact of harvesting and overestimates of population abundance. Cooke (1985) has developed a method of correction that can be applied by using the known differences among determinations of the same animals by different observers as the only source of error. The correction given by this method must provide a minimum estimate of the error, since there will presumably be some, but an unknown number of occasions when two observers agree on an interpretation which differs from the true age of the animal. With this qualification, Cooke's estimates based on samples of animals from two to eight years old, with a correction for the known extent of aging errors, are probably the best to be obtained from this approach.

Averaging the estimates given by the maximum likelihood and the least squares methods of statistical fitting gives, for the average annual pup production in 1958–1967, an estimate of 445,000 and an estimate of 324,000 for the period 1968–1977.

Sustainable Yield and Changes in Population Abundance

The estimates recorded in the preceding section mostly fall in the range of 200,000–600,000 pups born annually. Because they have been made by different methods and refer to different years, they are not immediately comparable. Before attempting a detailed comparison and an estimation of the changes in population abundance during the period, it is helpful to consider the factors that will cause the abundance to change. These factors are the births of young animals, the harvest by man, and deaths from natural causes. Given these factors, the changes in the population abundance can be determined by simple accounting. The natural mortality rate (*M*) among adult seals is not known directly, but can be inferred with reasonable precision from the observed age composition of the seal population. It must be fairly low to allow 20- to 25-year-old seals to be common, and it is probably close to 0.10 (i.e., 10% per year). A range of feasible values of 0.08–0.11 has been given by the working group of the International Council for the Exploration of the Sea (ICES, 1983). Except for some values that have later been shown to be based on erroneous methods, most other published values fall in this range. Since underestimation of the true mortality rate will have more serious consequences on the projections of future population trends, extreme values of 0.08–0.12 will be used here, although the true value more probably lies in the range of 0.09–0.11. It is likely that the mortality rate for young and very old seals (those over 25 years of age) is higher. A higher value for old animals makes little difference because the numbers in this age group are small.

A higher value would also be expected for younger animals; the difference in this age group would be expected to be greatest in the first few months of life, and it would decline until that for three- or four-year-olds becomes very close to the adult mortality rate. The only direct evidence on mortality rates comes from counts of dead, dying or sickly pups on the ice. These rates are low, suggesting that early mortality rates for harp seals are much lower than those for some other seals, such as grey seals in the United Kingdom or fur seals in the Pribilofs. It may be that higher rates do occur when the harp seal pups first enter the water and have to feed themselves, but there is no evidence of significant occurrence of dying juveniles or of high predation. Most attempts to estimate mortality in the first few years of life have used cohort analysis or similar methods of extrapolating back from a known population of older animals which depend on an assumed value of natural mortality. Though these methods are of some use in tending to confirm that natural mortality is low, they are of little value in providing a direct estimate of M. For the purpose of calculating sustainable yields, upper limits of M that are three times that of the adult animals have been used for the first year of life, and corresponding limits that are 50% higher have been used for the rest of the juvenile stage. (See Appendix 21.1.)

The natural mortality rate is notoriously difficult to estimate in any natural population, but the long life of harp seals makes it relatively easy to estimate total mortality. Given estimates of total population, the fishing mortality (exploitation rate) can be estimated directly from the numbers of seals caught, and the natural mortality follows by subtraction.

Since the fishing mortality on adults is only a small part of the total (unlike the situation in many fish stocks), the resulting estimate is reasonably good, and can be further improved by additional analysis. The limits set out above are therefore generous.

Sustainable Yield and Replacement Yield

Given the natural mortality rates for harp seals at each stage of life, the average age at which females will produce young for the first time, the fertility rate and the sex ratio, it is possible to determine how many young a batch of, say, 100 pups would produce in their life, in the absence of any hunting. If this number exceeds 100, then the surplus can be taken, and will be equal to the sustainable yield. The details, which follow similar calculations in a number of reports, are set out in Appendix 21.1.

Alternative calculations are given in Appendix 21.1 for a range of feasible values for the different population parameters. The average age at first whelping can be reasonably well determined; the most recent (1978 and 1979) data set it at a little less than five years (Roff and Bowen, 1983, Table 3). Higher values of up to eight years have been observed in the past, and these are included. The fertility rate seems to be close to 0.94 at present, but again, different (lower) figures have been observed in the past, and these are examined in Appendix 21.1. The changes in age at maturity and fertility are almost certainly related to the abundance or density of the stock and have important implications for the long-term dynamics of the stock. These will be considered in the section entitled "Future Management and Monitoring" (below).

From Table 21.8 in Appendix 21.1, it can be seen that the only combinations of conditions for which there is no sustainable yield (i.e., under which 100 pups will, in the absence of any hunting, produce fewer than 100 young during their lives) are those of high mortality, low fertility and high age at first whelping; these conditions do not apply at present. That is to say, under present conditions, in the absence of hunting, 100 pups would produce more than 100 young, and the stock would increase. The only report which is in apparent contradiction to this statement is that presented by the Nature Conservancy Council of the United Kingdom (NCC, 1982) for the Commission of the European Communities, and it states: "It cannot be said with certainty that the stock will recover, even if all hunting ceases." This statement was made in the context of changes in food supply, which would alter the carrying capacity for harp seals. Thus, while the stock will increase, it is by no means certain that it will recover in the sense of returning precisely to its pre-exploitation abundance.

By looking at Table 21.8, it can be seen that for the more likely values of the parameters (M = 0.09–0.11; age at first pregnancy of five to six years) the sustainable yield, taken as pups, is some 30%–60% of pup production. The value is particularly sensitive to differences in M and less sensitive to the total mortality between birth and first pregnancy. The effect of different pregnancy rates (given in Table 21.9, Appendix 21.1) is rather small.

Table 21.8 also shows that the sustainable yield, if harp seals are taken as pups, is about twice the sustainable yield if they are taken as adults. The difference increases with an increasing natural mortality rate and increasing age at first pregnancy. It is, as might be expected, about equivalent to the total mortality between birth and first pregnancy.

The sustainable yield is therefore not a single number, but depends on how the harvest is taken. This fact has been recognized by most recent assessments, which generally give a sustainable yield on the assumption that this figure is taken as consisting of 80% animals in their first year (i.e., pups or beaters) and 20% older animals. This formula, however, while correct as far as it goes, does not express explicitly the range of options open to the manager, and the extent to which taking the harvest as a larger or smaller proportion of old animals reduces the total number of seals that can be taken, compared with a harvest consisting wholly of pups. It seems preferable to express the sustainable yield as, say, the number of pups, or "pup equivalent", together with an indication of the number of pups equivalent to a given harvest of adults or older immatures.

The calculations of sustainable yield presented here are strictly correct only for an equilibrium situation, in which the population has reached equilibrium and the population parameters remain constant for some time. In practice, the population in any given year will differ in its structure from an equilibrium population to an extent depending on its recent history. Thus the population in 1971 had, because of the high pup harvest in the preceding years, fewer young animals than an equilibrium population of the same total numbers. There would therefore be relatively more births and fewer deaths. A harvest equal to the sustainable yield for an equilibrium population with the same total number of all animals would have allowed an increase in number. Conversely, at present, because of the regulations applied since 1971, there are relatively more young animals so that taking the sustainable yield for an equivalent equilibrium population would cause the stock to decrease.

For tactical year-to-year management, it may therefore be necessary to consider the *replacement yield,* that is, that yield which, if taken during a single year, will leave the numbers in the population at the end of the year the same as those at the beginning. Since there may well be changes in the composition of the stock, with the relative numbers in each age group coming closer to that of the equilibrium condition, the replacement yield at the end of the year may not be the same as that at the beginning of the year.

Recent Changes in Population Abundance

Some of the most controversial scientific arguments about the seal hunt concern the recent changes in abundance of harp seals. There are two independent approaches to this topic: to compare estimates of abundance at the beginning and at the end of the period concerned, or to compare the catches made during the period with the average sustainable yield, using estimated values of the population parameters. A mixed approach is also possible, using sets of the population parameters to simulate the changes in population numbers, taking into account the catches, and finding which set best matches the direct data (e.g., from tagging) on population abundance.

The first method is perhaps the most convincing, particularly when the same technique is used throughout the period. However, it is useful only when the changes are greater than the statistical variation in the estimates. Thus the survey data (Table 21.1) show fairly conclusively that the pup production decreased between 1950 (estimate of 645,000) and the 1970s (estimates of 225,000–250,000).

The problems in later years can be illustrated by reference to the data below, presented by the ICES working party (ICES, 1983) in its report.

Year	Method	Pup Population (000s)
Late 1960s	Modified survival index	320–420
1977–78	Tagging	380–500

On the face of it, these data suggest an increase. However, the two ranges overlap so that the population could have declined, for example, from 410,000 to 400,000. More serious is the fact that the methods are different and subject to different sources of bias. There are several reasons, including loss of tags and failure to return tags, why the tagging estimates could be biased upwards. Even if the degree of bias is small so that the estimates are still useful measures of the abundance, the biases could still be big enough to invalidate the estimates as evidence of a population increase during the 1970s. In brief, the various estimates, including those not mentioned in the tabulation above, are not good enough to demonstrate an increase, though they are more consistent with an increase than a decrease. A similar conclusion may be reached from the index of relative abundance provided by the catch-per-unit effort made in Greenland, which shows some increase since 1970 (Kapel, 1985).

After 1971, as a result of regulations, there was a sharp fall in the number of pups killed. In terms of pup equivalents, and taking one seal aged one year or older as equivalent to two pups, the harvest dropped from over 400,000 in most years up to 1967, to an average of 190,000 in 1972–1976 and 230,000 in 1977–1982, and to 106,000 and 77,000 in 1983 and 1984, respectively (Table 21.3). In the 1970s, the number of pups born was, to take a convenient round figure for the purposes of illustration, about 350,000. That is, the harvest was equivalent to taking about 54% and 66% of the pups in 1972–1976 and 1977–1982, respectively. Reference to Appendix 21.1, Table 21.8 shows that both these rates are below the sustainable rate for several combinations of parameters, and the 54% rate, at least, would allow the population to increase for many of the more probable values.

Table 21.3
Catches and Quotas of Harp Seals in the Northwest Atlantic, 1970–1985

	Landsmen[a] Canada		Total Commercial[b] Canada and Norway		West Greenland	Total of All	Pup Equivalent[c]
Year	Quota	Catch	Quota	Catch	Catch	Catches	(000s)
1970[d]	-	47,078	-	257,495	5,747	263,242	310
1971	45,000	47,197	245,000	230,966	5,001	235,967	262
1972	30,000	24,128	150,000	129,883	5,591	135,474	155
1973	30,000	45,382	150,000	123,832	8,700	132,532	166
1974	30,000	40,420	150,000	147,635	6,422	154,057	193
1975	30,000	53,539	150,000	174,363	5,000	179,363	220
1976	30,000	66,487	127,000	165,002	4,904	169,906	212
1977	63,000	60,191	160,000	155,143	6,257	161,400	199
1978	73,000	94,531	170,000	161,723	7,662	169,385	233
1979	73,000	63,166	170,000	160,541	12,774	173,315	217
1980	73,000	76,386	168,200	169,526	12,270	181,796	240
1981	70,800	107,572	168,200	197,832	13,605	211,437	256
1982	75,500	64,516	175,000	166,739	17,244	183,983	230
1983	75,500	47,339	175,000	57,889	18,739	176,628	106
1984	75,500	30,273	175,000	30,900	17,061	47,961	77
1985	75,500	17,723 [e]	175,000	17,723 [e]	-	-	-

Source: Quota and catch data
1970–1978: ICNAF (1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1985)
1979–1982: NAFO (1981, 1982, 1983, 1984)
1983–1984: Moulton (1986); Cooke et al. (1986, Appendix, Table D)
1985: Canda, DFO (undated, 1986).

a. Landsmen includes longliners, small vessels, and shore fishermen.
b. Total commercial includes landsmen and large vessels.
c. Calculated as: one animal age 1(+) = 2 pups, from data in Cooke et al. (1986, Appendix, Table A).
d. Quotas were not set for 1970.
e. Preliminary data for Newfoundland and Quebec only.

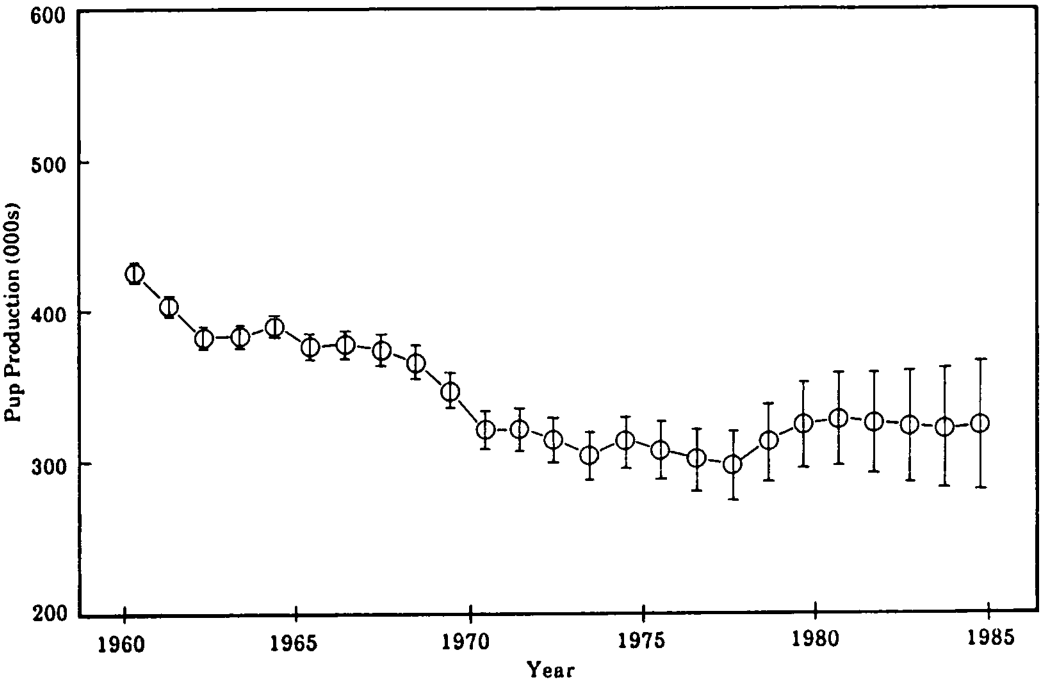
Too much should not be read into this analysis. Apart from the rough figure used for the pup production, the population was almost certainly not in equilibrium, so that the replacement yield was probably different from the sustainable yield. The ICES working group did calculate replacement yield and came to similar conclusions: that is, for three out of five sets of alternative parameter values, the replacement yield was greater than recent catches. For the other two sets, in the worst case the catches were 22,000 in excess of the replacement yield, which is to say that the population would have decreased by 22,000 in that year. It should be noted that the ICES calculation used an 80:20 ratio in the harvest of pups and older animals. In all recent years, except 1981, the proportion of older animals has been higher, which would slightly reduce the replacement yield.

A convenient way of examining how numbers of seals changed in recent years is by sequential analysis or simulations of the year-to-year changes in numbers under various combinations of population parameters. The most up-to-date simulation of the recent history of the harp seal has been carried out at the University of British Columbia (UBC) under contract to the Royal Commission (Cooke et al., 1986). A typical result of this simulation, using age samples of seals taken from nets during the period 1961–1984, is given in Figure 21.3.

The other fixed inputs to the simulation were the pregnancy data, but the mortality rates and age selectivity of the gear (which are confounded together and cannot be estimated separately) and the initial pup production were adjusted to fit the observed age data. This method of fitting, which essentially matches disturbances in the age data to the catches, is roughly similar to the survival-index method. Different results were obtained with different sets of age data. These simulation results, giving the estimated pup production in 1978, are given in Table 21.4, which also includes some reanalysis of the tagging data carried out by the UBC study (Cooke et al., 1986).

The first conclusion about this table is that there is a reasonable degree of consistency, especially considering that the figures are derived from three entirely different methods with independent sets of data and different sets of assumptions. The data sets, but not the assumptions, are also independent for three estimates from tagging. This range of methods and the degree of agreement between them are unusual in the study of wild animals and give considerable assurance of the reliability of the results.

Figure 21.3
Estimates of Annual Pup Production (I)[a]



Source: Cooke et al. (1986).

a. From age samples of seals aged 3–11 taken in nets, 1961–1984. Vertical bars indicate standard errors.

The second conclusion is that there are consistent differences between methods, with the tag-recapture estimates higher and the census estimates lower than those derived from the age samples. These differences might be the result of a sampling error, especially for the single estimate from the aerial census, but they are in the directions that might be expected from the possible sources of bias that can occur in the methods: missing part of the breeding area in the census and incomplete returns or loss of tags. It also proved impossible in the simulation studies to find simulations that were consistent with the age data, and for which the confidence limits straddled the results obtained from tagging. The Royal Commission therefore accepts that there is some degree of positive bias in the tagging data, and possibly some negative bias in the survey data. The Royal Commission's best estimate is therefore that the pup production in 1978 was 300,000–350,000.

These figures can be used to provide estimates of the number of mature females from the pregnancy rates, and the total numbers of animals aged one year or older (the 1+ population) from mortality and maturity rates and the sex ratio. Different values of these rates will give slightly different ratios of pups to 1+ animals, though the range is not great. Roff and Bowen (1983) and ICES (1983) used a ratio of 1:4. Use of this ratio gives a 1+ population in 1978 of 1.2–1.4 million, or a total population soon after the pupping season of 1.5–1.75 million.

Table 21.4
Estimates of Recent Pup Production (000s)[a]

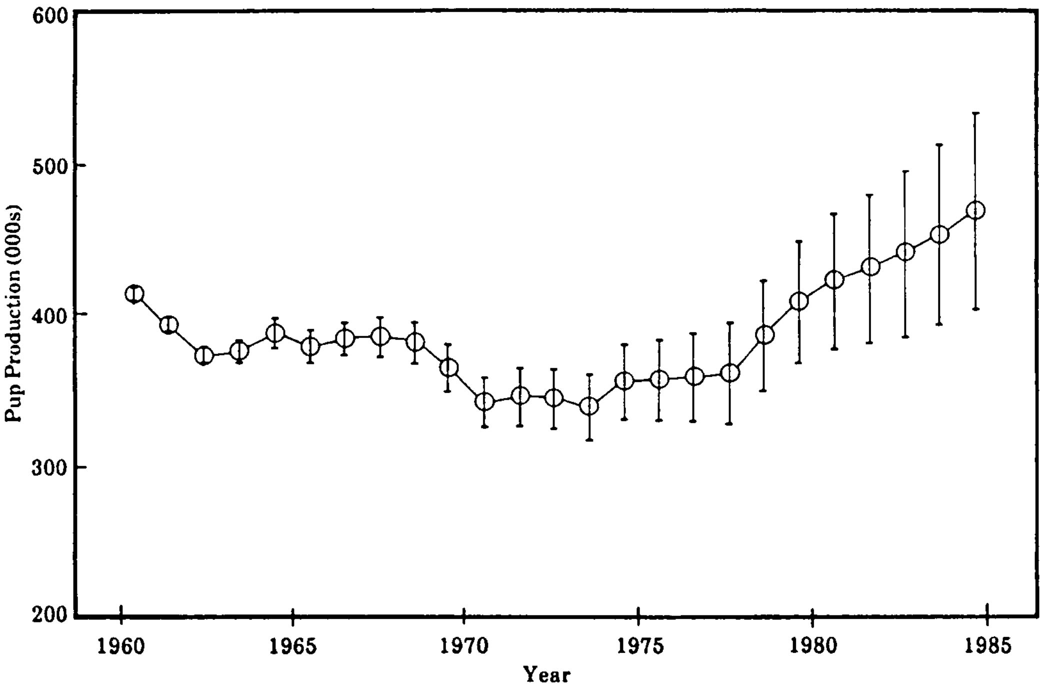
Year	Method	Source Data			Pup Production
1978	Age samples	Large vessels	1961–84	Age 3–11	358 (34)
1978	Age samples	Nets	1961–84	Age 3–11	295 (24)
1978	Age samples	Others	1961–84	Age 3–11	341 (92)
1978	Age samples	Large vessels	1961–84	Age 3–6	296 (27)
1978	Age samples	Large vessels	1973–84	Age 3–11	331 (45)
1978	Tag recoveries	Long-term returns	1979–84		536
1979	Tag recoveries	Long-term returns	1980–84		532
1980	Tag recoveries	Long-term returns	1981–84		482
1977	Aerial census	(1977 Front + 1975 Gulf)			251 (110)

Note: The figures for tag recoveries differ slightly from those in Table 21.2 because of new analysis of the data.

a. Confidence limits (±) are given in parentheses.

The simulation models allow some insight into the likely changes in population abundance over the last 20 years, the period for which some estimates are available. A comparison of Figures 21.3 and 21.4 shows that there are differences in the pictures presented by different data sets, especially for the most recent years. The changes apparent during the period covered by most estimates (such as those presented by ICES, 1983), that is, from the late 1960s to 1980, are likely to have been complex, with an initial decline, a halting of the decline, and then, possibly, a recovery. Such a pattern is unlikely to be detectable by examining a set of population estimates for a few individual years.

Figure 21.4
Estimates of Annual Pup Production (II)[a]



Source: Cooke et al. (1986).

a. From age samples of seals aged 3–11 taken by large vessels, 1961–1984. Vertical bars indicate standard errors.

If trends in population abundance are to be used to judge the effectiveness of management measures, the first year-class to have been significantly affected by the quota measure was that of 1972, most of which would not breed until 1977. It would not be until the early 1980s that more than a small proportion of the breeding stock would be made up of seals that might have benefited from the quota limits on pup kill.

Assessment of recent trends has to be made, therefore, largely from a comparison of catches with estimates of sustainable yields, increasingly so as the most recent years are approached. On this basis, taking account of the range of likely values of the parameters and the direct estimates of population abundance, the conclusion that fits the data best, and that is based on the central values of the parameters, is that the total population has increased from 1972 onwards, with the changes in pup production being delayed some four or five years. However, neither no change nor a decrease can be ruled out. If there has been a decrease, then the catches will have exceeded the replacement yield by a small amount, and the decrease will have been slow. In 1983, the catches were below any reasonable value of the replacement yield, and the stock presumably increased. The 1983 population was probably slightly above the 1978 population, amounting, that is, to slightly more than 1.50–1.75 million. The Royal Commission's estimate of the present population at the end of 1985 is, therefore, in round numbers, some two million.

Management Measures

Prior to the 1950s, management of the seal harvest, in the sense of controlling the numbers and types of seals killed in order to maintain a healthy stock, had not been very widely considered. During the 1950s, scientific studies, such as Fisher (1955), began to give warnings of the effect on the stocks of uncontrolled harvesting, and the first quantitative studies of the numbers of seals and the sustainable yield were made (Fisher, 1955; Sergeant, 1959).

At that time, the Front area was largely outside Canadian jurisdiction and international agreement was necessary for effective management there. In 1961, Canada proposed that seals and sealing should be brought within the responsibility of the International Commission for the Northwest Atlantic Fisheries (ICNAF). This suggestion was agreed to, but it was not until 1966 that the last ICNAF member country, Italy, finally ratified the agreement, and ICNAF could consider seals.

Meanwhile, in October 1964, the Canadian government set a quota of 50,000 pups for the large vessels operating in the Gulf area (inside national jurisdiction). The main management measures, however, were concerned with operational aspects aimed at reducing waste and cruelty. These included specifications for the clubs that could be used, protection of adults on the breeding patches, and a requirement to remove pelts from the ice within 24 hours.

When ICNAF did gain responsibility for seals, there was some considerable discussion over the scientific evidence, including arguments over the degree of mixing between the animals breeding in the Gulf and Front areas. It was not until 1970 that ICNAF agreed on quotas, setting the quota for 1971 at 245,000 animals, including an allowance of 45,000 for landsmen. At that time it was agreed that catches by aboriginal peoples in Greenland and northern Canada would be outside the quota system. It was recognized, as well, that catches by Canadian landsmen varied with ice conditions and could not easily be controlled. The quota therefore included an allowance for landsmen, with the expectation that the overall quota would be exceeded in some years (as it was in 1975, 1976 and 1981), but that over a period the average catches would be within the quota. The subsequent history of quotas and actual catches are given in Table 21.3.

In 1971, the Canadian government set up the Committee on Seals and Sealing (COSS). Both COSS and the scientists in ICNAF expressed considerable concern about the state of the stocks, and some studies indicated that the adult stock would decline for some years even if no more pups were harvested. COSS (1971) recommended a phasing-out of commercial sealing, starting with a quota of 150,000 (large vessels plus landsmen) for 1972, and 110,000 for 1973, 70,000 for 1974 and zero in subsequent years. Within ICNAF, the scientific advisers recommended a quota of 150,000, which was put into force. During the next few years no major new assessments of these stocks were undertaken, and the quota was kept at the same level.

In September 1975, a special meeting of scientists was held to review the information, including the first results of aerial surveys using ultraviolet light. There was agreement that the state of the stock was poor, showing a reduction in breeding stock believed to amount to about 12.5% per year, and that a moratorium on harvesting was desirable. Some scientists from other countries did not accept these results. Despite two meetings of the ICNAF scientific advisers, held in November and December 1975, it was not possible for participants to agree on a single quota, and quota recommendations ranged from 90,000 to 127,000 animals. ICNAF then implemented the higher figure.

After 1975, the balance of scientific advice became less pessimistic. There was general agreement that the stocks were below the level of the maximum sustainable yield (MSY) – which was commonly accepted as at least a reference level for guidance, if not necessarily as the definitive target – and that the stocks should be increased, but there was less concern over the possibility of a further, and possibly catastrophic decline. The ICNAF scientific advisers, meeting in October 1976, received reports that mostly indicated that the sustainable yield was in the range of 199,000–215,000 and recommended a total allowable catch (TAC) of 170,000. Against this, one analysis (Capstick et al., 1976) estimated a sustainable yield of about 103,000–130,000. ICNAF adopted a TAC of 170,000, including 10,000 for Greenland and Canadian aboriginals, leaving 160,000 harp seals for the commercial hunt.

In subsequent years the picture was much the same. No complete agreement was reached on the scientific analysis, and doubts were expressed on matters such as new methods of analysis introduced by Beddington and Williams (1980) or the precise value of the natural mortality rate.

Some scientists continued to be concerned about the state of the stock, and this concern was expressed in reports such as that prepared by the Nature Conservancy Council (NCC, 1982), of which the summary states that "There is a *risk* that the population would be *endangered* by a continuation of present rates of exploitation" (emphasis in original), though there seems to be no basis for this statement in the main text of the report. The summary states earlier that "It is uncertain whether this stock – for which the range of current estimates is 1–2 million animals – is increasing or decreasing, although any change in size can only be small." This is hardly a conclusion that implies significant risk. In the light of this uncertainty, the formal advice to ICNAF and by its successor after 1979, the Northwest Atlantic Fisheries Organization (NAFO), was to continue the TAC at the same level, except that the allowance for the aboriginal catch was in addition to, rather than part of, the 170,000 TAC.

Examination of Table 21.3 shows that the quota management did achieve its immediate objectives. Catches from 1972 onwards were sharply reduced from the 1970 level, which was fairly typical of the preceding years. Though the landsmen's catch often exceeded the planned figure, the total commercial catch only exceeded the TAC in four years: 1975, 1976, 1981 and a slight excess in 1980. Overall, the total catch from 1971 to 1982 (the last year before the market collapse affected the catches) was less than the sum of the TACs. The TACs set were also in accord with the formal scientific recommendations, though it must be recognized that these were often reached only after long discussions and were sometimes the figure that could be most widely accepted, rather than the best figure in any scientific sense or the most cautious figure.

Did the quota management achieve its long-term objective and move the stock towards its most desirable level? This is the more important question, but it is difficult to answer even if it were clear what was the most desirable stock level. Though achieving MSY had considerable support as the principal objective, it was not fully adopted, and the most commonly expressed objective was to increase the stock or, as it was sometimes expressed in later years, to allow the stock to continue to increase. Whether it did or not has been examined in the previous section, and the answer reached was probably, but not certainly. What can now be said with certainty is that after 1972, the stock did not decrease greatly, and the most pessimistic scientific views expressed in the mid-1970s – for example, that the stock was decreasing at 12.5% per year – were indeed too pessimistic.

Long-Term Effects and the Maximum Sustainable Yield

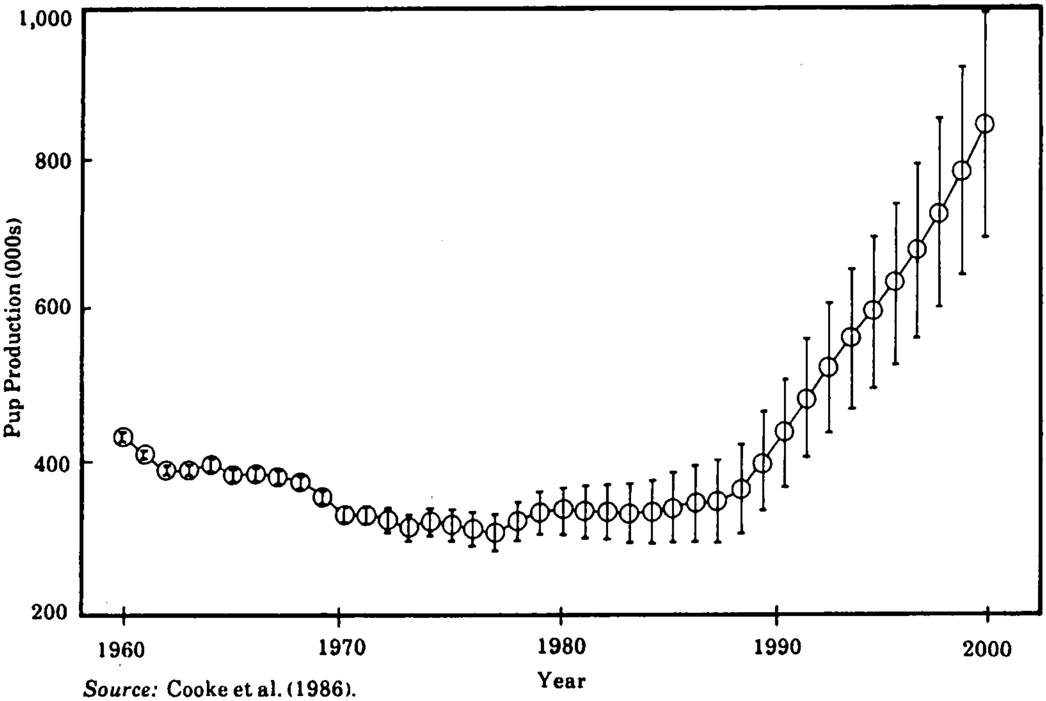
Density Dependence

From the preceding sections it is clear that in the absence of any hunting, the present harp seal population would tend to increase. The exact rate of increase is not known; it might amount to only a few percent, or it might be similar to the 13% increase annually observed for the grey seal on Sable Island. If it were only 4% per year, and if this increase were to continue indefinitely, the pup production would double in 18 years and increase 10-fold in 60 years. (See Figure 21.5.) A 10-fold increase is most unlikely. There will be changes in one or more of the population parameters related to population density, so that the population expansion slows down and stops before the north Atlantic is covered with harp seals.

Some kind of density-dependent mechanism is believed to occur in all natural populations, but the actual density-dependent mechanisms are likely to differ from population to population. Unless there are good data for a long series of years during which the population abundance has changed significantly, it is difficult to know exactly what the mechanisms are in a particular case. The harp seal provides no exception. There is reasonable evidence, however, that as the population increases, the animals mature later, and some evidence exists that the fertility rate decreases (Lett et al., 1979; Bowen et al., 1981; Bowen and Sergeant, 1981).

The quantitative interpretation of these and other data on density dependence is not straightforward. An apparently extremely useful method of observing changes in the ages at maturity of marine mammals, based on the interpretation of the same structures (ear plugs, teeth) used to determine

Figure 21.5
Example of Forward Projection of Pup Production[a]



Source: Cooke et al. (1986).

a. From estimates based on age samples assuming that no pups or seals aged 1 + are caught. Age samples from seals aged 3–11 taken in nets, 1961–1984. Vertical bars indicate standard errors.

age, has been shown to have a built-in methodological bias, and this finding has greatly changed some of the perceived ideas about the extent of this density-dependent process in marine mammals (Cooke and de la Mare, 1983). Procedurally, the least problems derive from direct observations of samples of animals to determine their age and whether they are mature. Data from such samples are presented in Table 21.5, recalculated from Bowen et al. (1981). There are big differences between the January–February samples and the March–April ones. The mean age in the latter is often more than a year less than in the January–February samples. A year is the maximum difference that might be expected if most seals reaching maturity became detectable as doing so between the January–February and the March–April samples. The big differences suggest problems in these data, such as the difficulty of sampling mature and immature animals of the same age with equal probability.

Table 21.5
Estimates of Mean Age at Maturity of Female Harp Seals

Year	Jan.–Feb. Samples		Mar.–Apr. Samples	
1951–54	6.06	(0.48)[a]	–	–
1952–54	–	–	6.05	(0.18)
1961–62	–	–	4.89	(0.27)
1964	6.03	(0.29)	–	–
1965	6.67	(0.15)	–	–
1966	7.18	(0.40)	5.51	(0.22)
1967	6.77	(0.22)	–	–
1968	6.16	(0.20)	–	–
1968–70	–	–	4.56	(0.19)
1969	7.07	(0.26)	–	–
1970	7.14	(0.41)	–	–
1976	–	–	5.30	(0.37)
1978	5.90	(0.22)	–	–
1979	5.10	(0.17)	4.58	(0.17)
1980	5.56	(0.12)	–	–
1981	6.15	(0.32)	4.65	(0.16)

Source: Recalculated from Bowen et al. (1981).

a. Standard errors are in parentheses.

The January–February samples suggest a decrease in the age at maturity between 1965–1970 and 1978–1981, consistent with the drop in population numbers. It is difficult to relate this decrease precisely to density since the age at maturity (e.g., in the 1980 samples) is presumably related to the conditions for the young seals in preceding years (i.e., to the density in 1978 rather than in 1980), so that it is not clear which year's density should be related to which year's maturity data. Also, there are doubts about the exact values of the density in each year and about how the density has changed from year to year. Other factors, such as changes in food supply other than any created by changes in the seal population, could be having as much effect as seal density. In terms of the expected density-dependent response, the early (pre-1965) January–February samples (but not the March–April 1952–1954 sample) are anomalous, but about that time there were environmental changes at west Greenland that were affecting other animals at least. The last good year-class of cod off west Greenland was that of 1963 (Cushing, 1982).

These data are far from conclusive. They are, however, entirely consistent with what one would expect of seals behaving according to ecological theory. Other things being equal, there was a considerable reduction in age at maturity as density fell, but there were difficulties in estimating the mean age at maturity, and this age was also affected by environmental factors.

It is also possible that the natural mortality changes over all or part of the life-cycle in response to changes in density. Apart from observations of dead or dying pups on the ice, however, there is no direct evidence related to natural mortality. The indirect evidence available, such as that taken from age-composition data, is sufficient to give a reasonable estimate of natural mortality as an average over the last few decades, but it is of little help in determining whether or not natural mortality among the older seals has changed. It can, however, be said with fair confidence that there is no observed occurrence in harp seals of high pup mortalities associated with high densities, similar to those occurring in northern fur seals and in grey seals in the United Kingdom, though Lett et al. (1979) present evidence of a substantial decrease of natural mortality of harp seals in the first year of life between the 1950s and the 1970s. There are reports of increased occurrence of wounded seals and seals in poor condition at high densities, but it is not possible to relate this in a quantitative manner to increases in natural mortality.

Examination of the tables in Appendix 21.1 shows that there are a number of combinations of changes in the parameters which would bring the population into equilibrium and which would be quite reasonable in the light of changes actually observed. Table 21.8 shows that a mean age of first whelping of seven, a natural mortality of 0.11 and a fertility rate of 0.94 would result in a sustainable yield of pups of only 17%, while no sustainable yield is possible with $M = 0.12$. That is, with an M between 0.11 and 0.12, the population would be in equilibrium in the absence of any killing. If the density-dependent relations for all the parameters were exactly known, it might be possible to calculate the population figure at which the net rate of increase would fall to zero, that is, the long-term equilibrium population. The information available is not sufficient to make this calculation possible with any degree of precision, but studies (such as that made by Lett et al.,

1979) give unexploited equilibrium populations in the range of 4–10 million animals, which are consistent with independent estimates of the size of the population when exploitation began, based on information on the numbers killed in the 19th and early 20th centuries.

Food and Environment

The current abundance of the harp seal population is not the only factor that can affect the population parameters. It is reasonable to expect (but unproven) that density-dependence acts, to some extent, through the association of a high density of seals with a reduced per capita food supply. The populations of the different species that harp seals feed on have not remained constant, since they are affected by environmental changes and, in some species, by human exploitation.

The effect of exploitation has been a general decrease in the abundance of fish stocks, and until the extension of the limits and jurisdiction in 1977, the management measures were not effective in reversing this decrease. Since 1977, most of the stocks have come under full Canadian control, management on the whole has been more effective, and some stocks are being rebuilt. This success has been variable, however, and many fish stocks are still at a relatively low level. The effect of these low levels on the seal stocks might be negative, though any effect is not easily detected. (See Chapter 23.)

One example of a negative effect has been suggested by Stewart and Lavigne (1984), who noticed a reduction in the condition of seals, as indicated by the thickness of the blubber of breeding seals between 1976 and 1978. This reduction occurred just after there had been very large catches of capelin from the stocks to the east and north of Newfoundland, and many believed that it was a simple case of cause and effect, showing how human overexploitation of a fish stock can affect seals. Later studies (e.g., Carscadden et al., 1984) have shown that though several capelin stocks did decrease greatly between 1975–1976 and 1978–1980, part of that decrease is probably the result of changes in year-class strength (Leggett et al., 1984) rather than of heavy fishing. Since 1980, the abundance of capelin in the northeast Newfoundland-Labrador stock has increased. It is not known how blubber thickness has changed in later years, nor what is the long-term effect of changes in condition on population parameters and on the dynamics of the harp seal population. In the short run, there seems to have been little effect. The age of first whelping in 1978–1979 was as low as in other recent years.

The absence of a demonstrable effect on population parameters would not be surprising. Though capelin are among the chief items in the harp seals' diet, the seals have a wide range of prey, and the partial loss of one item could be, to a large extent, balanced by increased attention to other items. Nevertheless, such a loss must have some cost, and the equilibrium population or the carrying capacity of the harp seals' environment cannot be considered as entirely fixed. In particular, to the extent that some of the harp seals' food (capelin, shrimp) is being increasingly exploited by man, it must be expected that one indirect effect of this increasing general level of exploitation of north Atlantic fisheries will be a reduction in the carrying capacity for harp seals and in the equilibrium population. However, because of the complex interactions between fish species, exploited or not, eaten by harp seals or not, these effects are not certain.

Two aspects of the possible effects on seal stocks of heavy exploitation of fish stocks or of environmental change need to be considered. In the first instance, if the effects are not very great, they will cause some change in population parameters, carrying capacity, and the values of sustainable yield and of the population level at which MSY occurs. Thus, heavy fishing of capelin could reduce the MSY population level, so that a population below the MSY level under the original conditions (and therefore under some criteria deserving of protection) might be above the MSY level corresponding to the new conditions (and therefore, under the same criteria, potentially exploitable). On the contrary, the sustainable yield (as a percentage of the population) under the new and less favourable conditions would presumably be lower so that quotas or other regulations would need to be adjusted to match the new conditions.

The more serious effect would be a reduction of the seals' food supply to such an extent that their existence was threatened; this would occur if the effective reproduction rate fell below the natural mortality rate. Such an eventuality would require very great changes in one or more of their parameters. Though this is a prospect that should be kept under review, it does not seem to be a serious possibility at the present time.

Many fish stocks were, in fact, seriously depleted in the 1960s and 1970s, when foreign fishery vessels had open access to the areas beyond the territorial waters of Canada. With the imposition of the 200-mile exclusive economic zone (EEZ), these waters are no longer open to foreign fisheries, and the aim of Canadian policy is to rebuild the fish stocks. Though this rebuilding will take time, the expectation is that the availability of fish will tend to increase in the future.

Consideration should also be given to possible changes in the predators on harp seals. These include polar bears, killer whales and Greenland sharks. The predation rate is stated to be low (Lavigne, 1979), but the evidence for this statement is poor and, even if the predation rate amounted to only a few percent per year, it would represent a significant part of the natural mortality rate. Although direct evidence is poor, Greenland sharks have probably been reduced by incidental catches in bottom trawls. The impact of exploitation on these predator species would act in the opposite direction to the impact on harp seals of exploitation of capelin and other food species.

Fishing has, too, a more direct impact on seals, when these animals die as a result of being caught or entangled in fishing nets. This problem is discussed in Chapters 23 and 25. It appears that in the past such entanglements have not been significant for harp seals, and it does not seem necessary to make allowance for accidental seal catches in the analysis of past population trends. Although there have been recent reports of an increasing number of seals becoming entangled in gill nets (e.g., Lien, 1985), it does not seem that the numbers of animals involved are sufficiently large to be significant in terms of total population, but the situation should be monitored. In any case, the number of seals killed incidentally should be taken into account when authorities are setting quotas on the basis of assessments of population status and sustainable yields.

Maximum Sustainable Yield (MSY)

In Appendix 21.1, calculations are made of the sustainable yield expressed as a proportion of the total numbers or the numbers of pups. The sustainable yield will depend on the values of the population parameters. As the population abundance changes, these parameters will also change, as will the sustainable yield expressed as a proportion of the population. Multiplying the proportion of seals that can be harvested by the actual production rate gives sustainable yield in actual numbers. This yield will be small both for a small population and for a large population that is close to the environment's carrying capacity. At some intermediate population level, the sustainable yield will be at a maximum. This maximum and the population level at which it occurs will probably be slightly different depending on whether the quantity maximized is expressed as number of pups or adults or immatures, or as some combinations of these groups. As the pup equivalent of an adult, given in Appendix 21.1, does not change very much, the difference in the position of MSY will probably be minimal.

When the greatest possible sustained harvest of seals is the prime management objective, the manager will probably try to maintain the population close to the level which gives the MSY, and thus an accurate knowledge of this level is of considerable concern. As explained in more detail in Chapter 27, this objective is not likely to be valid for harp seals. The manager is much more concerned with balancing the interests of those harvesting seals against both the interests of fishermen, who want a low population, and the interests of environmental or other groups, who want a very high population; these latter aims both imply populations with sustained yields well below MSY.

The significance of the MSY as a management objective is discussed in Chapter 27. There it is pointed out that although MSY has played an important role in the theory and practice of resource management, it does not have particular significance in the Canadian context. Those hunting seals, whether in Newfoundland or in the Arctic, need enough seals to satisfy their immediate needs – to bridge the gap in income before the fishing season or to feed their families – and above a certain level, increasing the volume of the catch is not a priority. Fishermen, who complain about the competition with seals or damage to nets, would rather see a low seal population. The seal population that corresponded best to the balance of interests between these groups and those with general interest in a healthy and balanced ecosystem could well be at a lower level than the MSY level, though still providing a reasonably large sustainable yield.

From the purely Canadian viewpoint, it is therefore not particularly important to know the precise level of population corresponding to MSY, or whether the population is above or below that level. However, there are other viewpoints. Under the United States *Marine Mammal Protection Act of 1972* there is a requirement to bring any population of marine mammals to the optimum sustainable population (OSP) level, which is effectively the MSY level and above. A knowledge of whether or not the harp seal population was at OSP, that is, at or above MSY, might be important in relation to the possible export of seal products into the United States.

This knowledge is difficult to obtain with any certainty. The empirical approach of observing the sustainable yield at different population levels is clearly impracticable. The standard approach is to compare the current population, as a percentage of the initial population, with the percentage at which the MSY occurs. The latter percentage depends on the form of density-dependent relationship. Since the fact of a density-dependent effect on the fertility rate, or age at maturity, is not easy to demonstrate conclusively with the available data, it is much more difficult to be confident concerning knowledge of whether the effect occurs fairly uniformly over the full range of stock abundance (which would give an MSY somewhere around 50%), or mostly at high densities, closer to the maximum population. This would give a high MSY population level (60%–70% or more of the maximum population).

Some analyses, such as Figure 10 of Lett et al. (1979), even suggest density-dependent processes that give an MSY below 50%. For the present, though, there is no evidence that validates rejecting the accepted wisdom that the MSY for marine mammals, and for harp seals in particular, occurs well above 50% of the maximum population.

Equally, there are problems in determining the maximum population. Attempts to project the present population forward, which give estimates that range from four million to ten million (Lett and Benjaminsen, 1977; Lett et al., 1979) depend on making assumptions on how the density-dependent factors operate in order to reach the equilibrium point. Too little is known about the early history of sealing – doubts surround even the crude catch statistics – and the present data base is too remote from the beginning of large-scale sealing to make anything more certain than intelligent guesses about the original populations. Considering the very large catches that were taken in the 19th century, the larger, rather than the smaller, figures in the above ranges seem more likely.

For these reasons, it is not worth attempting to make a precise estimate of MSY and the population level at which it occurs. Lett et al. (1979, Figures 9 and 10) suggest that the MSY might be about 200,000–250,000 animals (taken in the ratio of 80:20 of pups to older animals), and that it might occur at population sizes of 1.5–3.0 million animals. The proportionately much larger range of population sizes than yields indicates the flatness of the sustainable yield curve near the maximum and the difficulty of precisely estimating the population level corresponding to MSY.

The population levels for MSY are somewhat above the likely values for the present population, but the difference is not large. Slightly different values for the present population or for the nature of the density-dependent processes or for the reduction in the carrying capacity (e.g., by exploitation of the fish stocks on which harp seals feed), could bring the estimate of MSY level below the present population figure.

Critical Population Size

The lower limits of population size, at which there is risk of extinction, are of major interest. At extremely low levels, when there are only a few individuals, stochastic processes (i.e., pure chance) may result in the population becoming extinct even when, on the average, it would be expected to increase. At a slightly higher level of population, rather similar statistical considerations apply to the genetic composition. The population may contain so little genetic variability that it may not be able to accommodate small changes in conditions. Both of these considerations apply only to populations of the order of a few tens or hundreds. They are not causes for concern with respect to harp seals now, nor would they be even if the population was reduced to a figure well below the present level.

Of much greater potential concern is the possibility that the favourable changes in population parameters, which have occurred since the population has decreased from its original level, may be reversed at low population levels. Natural mortality or the age at maturity may increase, or fertility may decrease. There are no direct observations to indicate that any of these changes may happen, and there are theoretical reasons to believe that they are unlikely. The most probable cause of an increased natural mortality rate at low population levels would relate to a predator for which harp seals are a preferred prey. A given number of predators could take a fixed number of seals, which would imply an increased predation rate as seals decline. No such predator, other than man (in some circumstances), appears to exist. The observed decrease in maturation age at lower population levels is presumed to be associated with an increased per capita food supply, and there is no reason to suppose that this mechanism would cease to operate, or indeed reverse, at very low population levels.

Biological mechanisms that could result in reduced fertility can be imagined. In the extreme, the few surviving males and females might have difficulty in finding one another. This possibility is unlikely in a species that breeds in a few large concentrations, but it is possible to imagine requirements of social behaviour, such as the need for a high density of animals of the same species, as being important to the maintenance of fertility. There is no evidence that such circumstances apply to harp seals, but the possibility might be something to bear in mind if the harp seal population declines greatly below its present level.

A critical stock size of 800,000 animals has been mentioned by Lett et al. (1979); this figure is based on the observation that, according to the authors' estimates, below this number the population parameters no longer change in a favourable direction. Leaving aside the question of whether the observation is correct – and there certainly must be limits beyond which the fertility cannot increase, nor the age at maturity decrease – it is questionable to what extent this population size is in any sense critical. If for any reason, including heavy fishing, the population is driven below this level, there will still be an excess of births over natural causes of deaths and, in the absence of exploitation, as strong a tendency to increase as in stocks just above this level. This population level is only critical in the sense that there is no additional resilience so that if some additional stress is imposed on a population that is already being heavily exploited, thus bringing it below the critical level, it cannot respond positively to the additional stress, and exploitation will have to be reduced to avert extinction. This really means that such populations need to be monitored particularly carefully.

Future Management and Monitoring

The preceding analyses show fairly conclusively that there are large numbers of harp seals (approaching two million), and that catches in the last few "normal" years were probably allowing the stock to increase. They also show that there are considerable doubts about many of the details pertaining to the dynamics of the seal populations. Therefore, there is a chance that if the 1980 policies and quotas were to be retained indefinitely, they would result in the depletion, and ultimately in the extinction, of the stock. This effect has been illustrated more conclusively by the simulation studies carried out by the UBC group under its contract with the Royal Commission (Cooke et al., 1986).

These studies show that when account is taken of uncertainties in the estimation procedures and of natural variations, there is a definite possibility that any management program, except for the most conservative, would drive the stock to extinction if it were continued over a long period without reference to what was actually happening to the stock. This situation is, to various degrees, common to many resources. It has resulted in several environmental groups calling for the implementation of very conservative policies until the doubts are removed. This, for example, is the principal reason for the International Whaling Commission (IWC) moratorium on all commercial whaling. A plea for a similar moratorium on the commercial hunt for seal pups was put forward by Dr. S.J. Holt (1985) at the London hearings of the Royal Commission.

While there are other reasons, esthetic or moral, that can be put forward to support a cessation of sealing, this approach seems to be too dramatic and scientifically less than fully justified as a solution to the undoubted problems of resource management. The dangers arising from uncertainty and from a continuation of an unmodified management policy have to be matched against the ability to collect new information and to modify management practices. Sealing practised at anything like the 1980 level would represent a long-term risk to the stocks only if it were continued for a long time without adjustment to the allowable catches. Provided that large-scale sealing is accompanied by a program to monitor the stocks, and a willingness and ability to act on the results of the monitoring program rapidly enough to correct and reverse any exploitation-induced decline in those stocks, the risk of the decline becoming serious enough to threaten the stocks should be small.

To meet these conditions seems entirely feasible. The existing management process includes annual reviews of all measures, including the size of quotas. Monitoring could be achieved by any of the methods already used to estimate the population, though, because of possible bias, tagging could be less useful than other methods. The survival index would also be a poor monitoring tool if no deliberate manipulation were made to the catches. However, deliberate year-to-year changes in catches, such as the taking of twice the allowable catches of pups in one year, followed by a zero pup kill in the following year, could serve as a good monitoring tool. If the example given were taken, it would be possible to obtain good, independent, estimates of population size from each pair of years unless the catch was a very small part of the total pup production.

Probably, though, direct aerial surveys of pup production would be the most appropriate monitoring tool. As these surveys cannot result in any large degree of overestimation (although they may result in underestimates), they are likely to be acceptable to the groups concerned about possible risks arising from overexploitation. Since the chief purpose of a monitoring program is to detect trends in population size rather than to establish absolute population figures, some degree of bias, provided it is kept constant by maintaining the same survey procedure, would be acceptable. It has been pointed out (Berkson and DeMaster, 1985) that unless the population composition is stable, which that of harp seals is certainly not at present, the trends in pup population, which is the population segment generally surveyed, will not be exactly the same as trends in the total population. The difference, however, seems most unlikely to invalidate the use of pup surveys as a monitoring tool.

Conclusions

The harp seal population has been heavily exploited for more than a century, and this exploitation has depleted its population to a point well below its original level. In particular, the very large annual catches of about 300,000 animals taken in the post-war period and up to about 1970 led to a serious decline in population levels. The annual number of pups born, which is the number easiest to estimate, is about 300,000–400,000, corresponding to a total population of well over one million harp seals and likely about two million.

The magnitude of the sustainable yield will depend on the age of animals killed, with one adult being reckoned the equivalent of about two pups, and on the values of the population parameters, several of which, especially the natural mortality rate, are not known at all precisely. The sustainable yield, if the catch is taken as pups, is probably about half the total production rate.

The catches since 1972 have generally matched the quotas set, which have corresponded to the general conclusions of the scientific advisers, though in some years, notably close to 1975, there was considerable disagreement among scientists. Fortunately, although the more pessimistic conclusions were not unrealistic on the basis of information then available, they have been proved to be too pessimistic. Currently available information suggests that catches taken since 1972 have been at or below the replacement yield, and the stock has probably increased. It is possible that it has decreased, but in either event the change has been small and impossible to demonstrate directly on the basis of current information about population size.

There is no complete agreement on a target level of population size for harp seals. The MSY level provides an initial reference level, but it may not provide the best ultimate target because of differences in interest between those who want a large population and those who want a small one, for example, in order to reduce gear damage. The present population abundance is probably below that giving the MSY. If it is desired to increase the population in order to bring the stock to the MSY level or for any other reason, then catches somewhere near recent levels, that is, annual quotas on the commercial hunt of about 170,000 animals, incorporating the recent balance between pups and older animals, would probably achieve this aim. Monitoring the harp seal population would be necessary to determine whether this objective is being achieved, and catches would need to be reduced if, in fact, the population is not increasing. If there is a wish to be certain of an immediate increase in population numbers, more conservative quotas would be necessary.

If significant catches of seals are to be made, it is essential that the numbers of seals are regularly monitored. The best method of monitoring the harp seal population, and the only feasible one in the absence of significant exploitation, is the use of ultraviolet photography or other techniques to make direct surveys of the pups and adults on the breeding patches. A repetition of earlier surveys is highly desirable, if possible involving statistical techniques to reduce the variance of the estimates obtained.

Since 1983, catches have been small and seem likely to remain low for the foreseeable future. The abundance is therefore increasing, perhaps by about 5% per year. The exact rate is uncertain, and if the impact of harp seals on fish stocks becomes a serious issue, regular monitoring of the abundance will be needed.

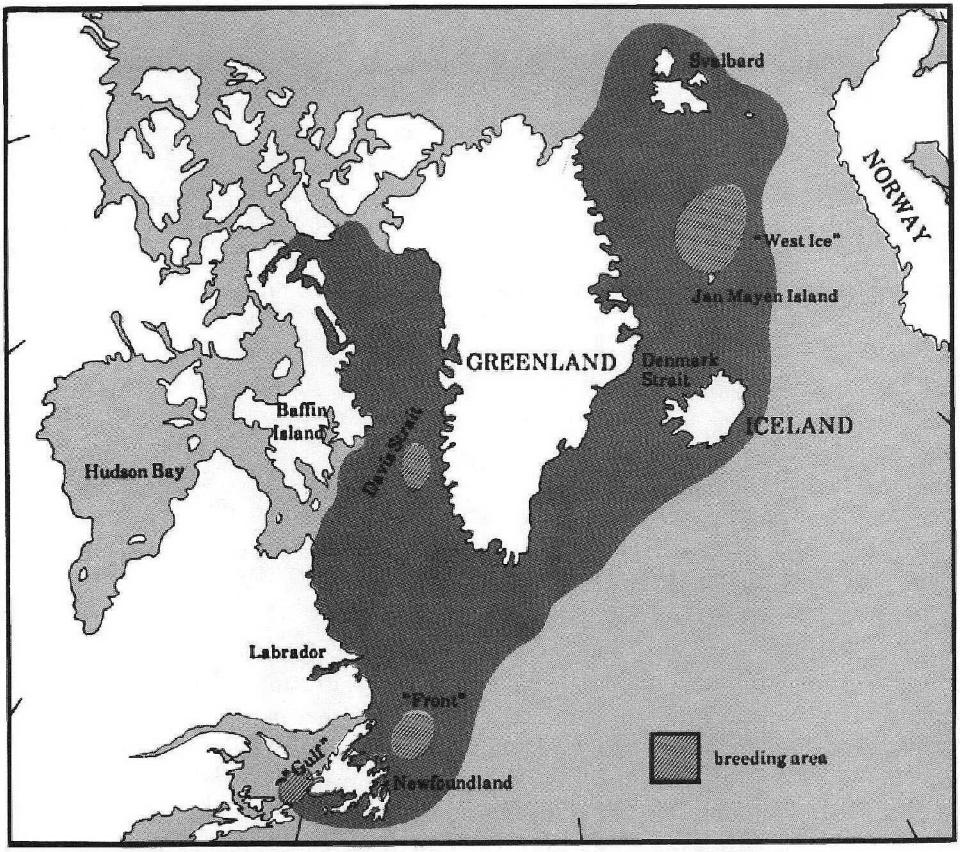
Hooded Seals

Introduction

The hooded seal is a large seal, two to three times the weight of a harp seal and with a similar life history and distribution. It breeds only in three areas of concentration: the West Ice to the west of Jan Mayen Island, the Front to the northeast of Newfoundland, and Davis Strait (Figure 21.6). The pups are born on pack ice, where they experience an extremely short period, lasting about four days (Bowen et al., 1985), of intense suckling before weaning. After breeding the western Atlantic hooded seals migrate to the north and east, and summer off the western and southern coasts of Greenland. Sealers take both adults and young (bluebacks) in the breeding concentrations, largely as part of the harp seal hunt, and all ages are taken in the summer off Greenland.

Hooded seals begin breeding between three and five years of age and thereafter produce one pup each year, with few exceptions. Maximum lifespan is about 30 years. Little is known about the feeding habits of hooded seals, partly because most samples have been collected while seals are on the breeding grounds, where they seem not to feed. Available data suggest that they feed at a greater depth than most other seals and consume rather larger animals. Food items that have been identified include squid, redfish and Greenland halibut.

Figure 21.6
Distribution of Hooded Seals



Source: King (1983).

The relationship between the groups breeding in different areas is unclear. Breeding in Davis Strait may be erratic, involving considerable exchange with the Newfoundland breeding group. Interchange between the east Atlantic (Jan Mayen) and the west Atlantic (Davis Strait and Newfoundland) is undetermined, but has been considered to be slight (Sergeant, 1974, 1979), though the most recent morphological studies (Wiig and Lie, 1984) are consistent with significant mixing. Seals tagged in

Newfoundland have turned up on the main moulting grounds in Denmark Strait, off the southeast coast of Greenland, but there appears to have been no movement of tagged seals between breeding grounds (Sergeant, 1978; Kapel, 1982; Øritsland, 1976). For the present purpose it seems best to treat the west Atlantic (i.e., Canada, Davis Strait and west Greenland) separately from the waters to the east of Greenland. This treatment might slightly underestimate the catches from the western stock in years when large catches were taken in Denmark Strait. Commercial sealing has, in fact, been stopped there since 1960, following evidence of a decline (Rasmussen, 1960).

History of Catches and Management

Significant subsistence catches have probably been taken around Greenland for a long time, though data on total catch or species breakdown are not available for the years before 1939. Northward movements of seals from the Newfoundland breeding area take most of the animals to the east side of Davis Strait; catches in arctic Canada appear to be very small. Statistics of catches from the west Atlantic since 1946 are summarized in Table 21.6. Because of their different impact on the dynamics of the population, the catches of pups and older animals have been kept separate.

The biggest catches have been taken in the commercial hunt on the breeding patches around Newfoundland and in the Jan Mayen area. Until the 1940s, hooded seals were taken incidentally to the harvest of harp seals, which, since it was more concentrated, attracted the higher hunting pressure, though catches of the two species followed similar trends. Since the 1940s, the skin of the young hooded seal (blueback) has attracted a premium price, and the intensity of exploitation of the two species has probably been similar.

At the beginning of this century commercial catches in the western Atlantic off Newfoundland were high, reaching a peak of close to 62,000 seals in 1901. Catches declined in the 1920s and 1930s to 1,000 seals annually, but picked up from the mid-1940s to a peak of 27,000 in 1966. Since then annual catches have amounted to a little over 10,000 until, with the collapse of the market, they dropped to almost zero in 1983. During this time there has been a decrease in the proportion of older animals included in the total catch.

Until 1973, there were no regulations governing the number of seals that could be killed, but in 1974, a total allowable catch (TAC) of 15,000 animals annually was introduced. The scientific basis for this number is ob-

Table 21.6
Catches of Hooded Seals in the Northwest Atlantic, 1946–1985

	The Front[a]					West	Grand
Year	Canada	Norway	Pups	Adults	Total[b]	Greenland	Total
1946–50	6,507	355	4,457	2,405	6,862	–	–
1951–55	2,374	3,598	4,442	1,530	5,972	–	–
1956–60	818	5,633	3,747	2,704	6,451	757	7,208
1960–64	1,104	4,055	3,124	2,035	5,159	1,066	6,225
1965–69	351	10,901	5,930	5,322	11,252	1,720	12,972
1970–74	847	9,413	6,176	4,084	10,260	1,952	12,212
1975	5,385	10,226	7,646	7,965	15,611	2,900	18,511
1976	3,867	8,518	6,540	5,845	12,385	3,316	15,701
1977	6,044	6,049	8,970	3,123	12,093	3,170	15,263
1978	4,189	6,315	7,966	2,538	10,504	3,635	13,275
1979	6,819	8,306	11,948	3,177	15,125	3,612	18,737
1980	7,409	5,707	11,153	1,963	13,116	3,779	16,895
1981	8,309	5,367	10,661	3,015	13,676	3,745	17,421
1982	5,831	4,562	7,757	2,636	10,393	4,398	14,791
1983	128	–	–	128	128	4,155	4,283
1984	444	–	–	–	444	2,692	3,136
1985[c]	452	–	219	233	452	–	–

Source: 1946–1967: ICNAF (1970).
1968–1978: ICNAF (1971a, 1971b, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1985).
1979–1982: NAFO (1981, 1982, 1983, 1984).
1983–1984: Moulton (1986).
1985 : Canada, DFO (undated).

a. Includes some animals taken in the Gulf, which was the result, in part, of differences in boundaries established by NAFO and by the Seal Protection Regulations.

b. Includes animals of unknown age.

c. Preliminary data for Newfoundland only.

scure and may have been no more than the opinion that the 1966 kill of more than 16,000 pups plus about 11,000 adults had been too high. In 1975 and 1979, the total Canadian and Norwegian catches, amounting to 15,611 and 15,125 seals respectively, slightly exceeded this quota, but in other years the catches were well below the quota.

In 1977, a regulation was set limiting the catch of adult females to no more than 10% of the total, and this percentage was reduced to 5% in 1979. The percentage of adults in recent (1980–1982) Canadian and Norwegian catches was stated to be 19% and 20% respectively, with the female component far below 5% in both cases (Canada, DFO, 1985, Appendix VIII, p. 14). The statistical base for this statement is not given.

The catches at Greenland seem to have fluctuated (Kapel, 1985). At the end of the 19th century, catches were as high as 10,000–15,000, and they were also relatively high, amounting to 6,000–8,000, in the period 1916–1920 (Kapel, 1978). Catches fell to a low level of 500–1,000 about 1950, but they have increased in recent years to about 4,000. In considering the impact on the stock, a figure for seals killed but not retrieved, should be added. Kapel (1985) noted that these losses are considered "high" at the beginning of the season, and "low" later, but believed that any figures representing actual percentages would be guess work.

Kapel (1985) also discussed likely trends in the effective effort devoted to hunting hooded seals in Greenland, taking account of such circumstances as growth in total population, increased proportion living in "townships", increased attention given to fishing for cod or other fish, and changes in hunting techniques. He concluded that the total number of active seal hunters did not change much during the period 1921–1972, but did not attempt to reach any conclusion on trends in effective hunting effort.

Compared with catches of harp seals, those of hooded seals seem to vary more, both from year to year and from decade to decade. Several authors (e.g., Vibe, 1967; Rasmussen, 1960) consider that environmental changes such as differences in the distribution of pack ice, and especially the higher water temperature at west Greenland in the 1930s, have had a major influence in bringing about these changes. This influence may relate more to the distribution of seals and their apparent abundance on established hunting grounds, than to true numbers.

Estimates of Abundance

Only two methods have been successfully used to estimate hooded seal numbers: the survival-index method (Sergeant, 1977) and aerial surveys (Hay and Wakeham, 1983; Hay et al., 1984; Hay et al., 1985). Some tagging has been done, but not at an intensity to provide useful estimates of abundance.

The survival index was applied to the year-classes of 1966–1971; during this period pup catches varied substantially, numbering between 1,200 in 1968 and 16,800 in 1966. These catches correlated well with the observed number of survivors, estimated as the percentage of five-year-old seals in the years 1970–1976. Applying the method directly, the regression of survival index on pup catch gave an intercept (i.e., an estimate of pup production) of about 27,000 (Sergeant, 1977). The period of analysis is so short that the adult population probably did not change much, and thus some of the criticisms of the method, such as that made by Beddington and Williams (1980) do not apply. Some correction downwards should probably be made to allow for errors in age determination. However, the numbers of pups actually killed in 1966 provides an absolute lower limit of the production in that year. Because the young are scattered it is highly unlikely that the kill actually approached 100% of the production. It can therefore be said with a fair degree of confidence that the production of pups at the Front in 1966 numbered 20,000–25,000 and possibly higher, but there is little likelihood that it was significantly lower. The usefulness of this conclusion to present-day management is, however, greatly reduced by the problems of projecting population numbers forward with any degree of reliability.

Hooded seal pups and adults on the breeding ice can be relatively easily seen and counted from the air, either visually or by means of photographs. To transform the numbers seen into absolute numbers is difficult for two reasons: the difficulty of executing a survey that covers adequately the scattered population, and the fact that the seals on the ice, and therefore visible, represent only a (possibly small) proportion of the total population.

Both problems have been examined during the 1983 and 1984 surveys of the Front and Davis Strait breeding areas (Hay and Wakeman, 1983; Hay et al., 1984; Hay et al., 1985). The problem of surveying was dealt with through a modification of standard surveying techniques (e.g., Caughley, 1977); this meant dividing the whole region in which any pups existed into a patch or patches of high density (10–100 pups per sq km) which were surveyed intensively and a much larger, low-density area of scattered pups.

Pups on the ice pass through clearly distinguishable stages - newborn, thin blueback, fat blueback - during all of which the mother is normally present - and solitary, which commences after weaning, when the mother has left. Since all pups are normally weaned by five days of age, the total length of all these stages is short. Thus, although the spread of birth dates is short, there is not one moment when all the pups have been born, but none have left the ice. For this reason any one count of pups will be less than the total pup production. By making counts on a number of days, observing the proportion of each stage, and taking account of the duration of each stage, the pattern of births on each day, and hence the total number of births, can be estimated. Hay et al. (1985) estimate pup production in 1984 as follows (with confidence limits in brackets):

Front: scattered pups	7,400	(2,700 to 14,400)
Front patch	54,700	(37,200 to 72,200)
Davis Strait patch	18,590	(13,750 to 23,440)

For the scattered pups on the Front and the Davis Strait patch it was not possible to estimate the pattern of production over time, and the figures given are for single surveys. They will therefore be biased downwards.

The surveys made on the Front in 1983 were not comprehensive enough to allow for estimates of this type. Estimates of the actual numbers present in one or another of three identified patches at the times of three surveys were as follows (Hay et al., 1984):

Middle patch	18 March	2,504	(1,312 to 3,696)
North patch	24 March	2,589	(309 to 4,870)
Middle patch	25 March	2,153	(- 489 to 4,796)

The negative lower confidence limit is clearly inappropriate; it was obtained by applying equal arithmetic limits above and below the central value.

Hay et al. (1984) note that their final 1983 estimate of about 5,000 seals, which was obtained by adding the two patches, is tentative at best. Certainly, since it contains no estimate for the southern patch or for the pups outside the patches, and no correction for pups not yet born, or for pups which have already left the ice, it must be an underestimate. The two latter factors, however, as judged by 1984 experience at the Front, would go only a small part of the way to explaining the difference from the 1984 figure of about 62,000 pups produced at the Front. Examination of the results shows that the big difference is in estimated size of patches, while estimated density within patches is roughly similar in the two years.

Estimating patch size seems to be difficult (Hay et al., 1984, Table 8), but the various surveys carried out in 1984 indicated patch sizes of a few hundred sq km (a population of up to 1,025 animals was estimated from the incomplete fixed-wing survey of March 20), while those made in 1983 varied between 32 and 106 sq km.

It is impossible that the total west Atlantic population can have increased by more than a few percent between 1983 and 1984, and while there may have been changes in the distribution and proportion of the total Atlantic population breeding on the Front, the most likely explanation of the difference between the two years is that patches, or parts of patches, were missed in 1983.

The 1984 central estimate is also considerably larger than that obtained for 1966–1971 by the survival-index method. Hay et al. (1985) conclude that the seal population has increased during the past 20 years. However, bearing in mind the wide confidence limits in both estimates and the possible different procedural errors in the two approaches, it would seem safer to consider the figures as strong, but not conclusive, evidence of an increase. Other evidence bearing on a possible population increase is presented in later sections.

Estimates of total population can be extrapolated from figures of pup production in the same way that has been done for harp seals. Since the population parameters for the two species are similar, the same ratio of 4:1 may be used as a reasonable approximation. This would suggest, from the 1984 estimates of pup production, a total west Atlantic population of 300,000 animals.

Population Parameters and Sustainable Yield

Much less is known about the vital parameters such as mortality and reproductive rates of hooded seals compared with harp seals, though they seem to be broadly similar. Females become mature when they are between three and five years old and produce pups a year later. Jacobsen (1984) gives a mean age at first parturition of 4.9 years based on data collected in 1972–1978 on the West Ice (Jan Mayen) grounds, and Born (1980) suggests a mean age at maturity, estimated from samples collected at south Greenland, of 3.2 years, which corresponds to a mean age at first parturition of a little over 4.2 years.

Born (1980) estimated a fertility rate of 91.5% and Øritsland (1975) an ovulation rate of 95%; the latter rate might be expected to be somewhat higher. There is no evidence to indicate differences in reproduction rate or age of maturity from area to area or from year to year. It would be reasonable to expect density-dependent responses similar to those for harp seals, but data are not good enough to detect them if they exist.

Hooded seals live up to 30 years or slightly beyond. Total mortality rates have been estimated from catch curves or from mean age. Even if sampling is unbiased, which is probably the case for fully mature age groups, these methods give biased estimates if there is a trend in recruitment or mortality rate, and the estimates refer to the average mortality at some period in the past, rather than to the time of sampling. Interpretation of results needs caution.

Published estimates of total mortality are $Z = 0.19$ to 0.35, from samples taken in the years 1971–1976 at the Front based on catch curves (Winters and Bergflodt, 1978); $Z = 0.22$ for the West Ice, based on mean age (Flipse and Veling, 1981, quoted in Canada, DFO, 1985); and $Z = 0.142$ (confidence limits 0.115–0.166) (NAFO, 1985) from a sample of 147 females taken in Davis Strait in 1984. It is also possible to use the age composition of samples taken on the West Ice presented by Jacobsen (1984) to derive estimates using the catch-curve method. The combined Norwegian samples for 1972–1978 (Jacobsen, 1984, Table 2) gave a good log-linear fit for ages 6–20, corresponding to $Z = 0.20$. Since it is more likely than not that over the relevant years (roughly 1955–1968) year-class strength was declining, this may be an underestimate of the actual total mortality in the mid-1960s to mid-1970s.

These estimates are too few, too imprecise, and too uncertain as to the years in which the estimated mortalities occurred to make useful comments on the differences in mortality between areas or periods, though it is tempting to ascribe the relatively low estimate for Davis Strait to lower fishing mortality on that group of seals. The ICES working group report (ICES, 1983) noted that "estimated mortality rate levels decreased substantially in most recent years, and this is consistent with the reduced kills of breeding females since 1977." The basis for this statement is unclear. It would be surprising if reduced kills after 1977 would be apparent, through the use of catch curves or similar methods, in samples taken as early as 1980.

The fishing mortality can be estimated, independently of age data, as the ratio of catches to total numbers for all or any specified part of the population. Winters and Bergflodt (1978) used this method to estimate the fishing mortality on females in 1966–1971. Their estimate of $F = 0.135$ has been challenged by the U.K. Nature Conservancy Council (NCC, 1982) on the basis that too low a fertility rate had been used. In view of the doubts about population size (and in some cases, the size of the catch), not much precision can be expected from this approach. It does show that unless population sizes were much greater than believed, fishing mortality on the older animals is significant, perhaps amounting to 0.10 or more. By the same argument, the estimates of total mortality are significantly larger than those of natural mortality. No direct estimate of natural mortality is possible, and it remains reasonable to use a similar range of values (about 0.10 or a little higher), as used for harp seals.

These parameter estimates are hardly good enough to provide the basis of an attempt to estimate sustainable yield, but Table 21.8 of Appendix 21.1, which covers many of the more likely combinations of parameters for hooded seals, can be used to provide an indication of the sustainable yield as a proportion of total pup production. This proportion will depend critically on the ages of seals harvested. If the harvest is taken wholly as pups, it might (if $M = 0.10$, and the age at maturity is 4) be some 57% of the production, but with the same parameters the sustainable harvest of adults would be only 28%.

The Present Situation

In 1983, it was possible, and probably desirable, to take a gloomy view of the state of the hooded seal stocks. No good estimate of population abundance was available for the stock since about 1971. Catches were high, and though there were no clear signals of impending stock collapse, it was quite possible that the stock was low, and declining rapidly.

The present situation is quite different. The results of the 1984 aerial survey make it clear that the population is much greater than many people had feared. Present (1983–1985) catches, following the collapse in the market, are obviously less than the sustainable yield (with a small reservation described below). The important question is whether the stock was increasing under the catch rates occurring about say, 1980, and in particular, whether the quota of 15,000 seals was reasonable.

A comparison of the estimates of pup production, of approximately 25,000 in the period about 1970 (from survival index) and approximately

60,000 in 1984 (from surveys), strongly suggests that the population had increased during the intervening period. An increase of roughly twofold during the same period is also suggested by the trend in catches at west Greenland; these catches were up from fewer than 2,000 annually before 1970, to over 4,000 in 1984. Kapel (1985), in his analysis of trends in catches, stresses the problems in evaluating the trends in effective hunting effort and hence the dangers in using annual catches as indicators of trends in seal abundance. However, his analysis does not identify any changes that would suggest a twofold, or greater, increase in hunting effort. The trend in different areas (Kapel, 1985, Figure 3) indicates that increases occurred in all areas, but were proportionally greater in the northern areas and possibly earlier in the south than in the north. This would suggest that changes in distribution could have been a factor. Nevertheless, the data are more supportive of an increase in abundance than of no significant change or a decrease.

Comparison of catches with likely values of sustainable yield, which should take into account the proportion of different ages and sizes in the catch, are made difficult by the non-availability of a breakdown of catches by age and sex. Though there is no question of a large surplus of males, as may arise in the case of fur seals or sperm whales, an imbalance in the sex ratio in the 1970s, as a result of heavy exploitation of adult females in earlier years, may have allowed significant catches of adult males to be taken for a few years without significant effect on the stock.

Between 1978 and 1982, averages of just under 10,000 pups and 2,600 adults were taken by Canadian and Norwegian sealers, and of 3,800 seals of all ages at Greenland. Assuming, for the purposes of rough calculation, that one adult seal is equivalent to two pups (which may be an overestimate if significantly less than half the adult catch is female), and that one seal caught at Greenland is equivalent to 1.5 pups, the total annual average was equivalent to about 20,900 pups, that is, about 30% of the central 1984 estimate of the total pup production on the Front. This rate of harvesting is sustainable under some, but by no means all, of the feasible combinations of population parameters. That is, it is possible, though far from certain, that the population was increasing under the pattern of exploitation existing in the years immediately preceding the collapse of the market for skins in 1983. Similar calculations can be applied to earlier periods. For example, in the period 1960–1964, the catches, in round figures, were 3,000 pups and 2,000 adults at Newfoundland and 1,000 at Greenland, equivalent, on the assumption made here, to 8,500 pups, that is, about 35%–40% of the estimates of pup production. With the obvious exception of 1966, when over 16,000 pups and nearly 11,000 older animals were killed, it is possible, perhaps even probable, that the catches were below the sustainable yield over most of the postwar period.

In summary, therefore, there are three pieces of evidence bearing on changes in abundance: the difference between 1966–1970 and 1984 estimates, catches at west Greenland, and estimates of sustainable yield. The first points strongly and the second moderately to an increase, and the third is neutral. The most reasonable interpretation is that abundance has increased, although this point is not conclusive. Under 1983–1984 conditions of low catches, it is almost certain that the stock is increasing. The exact rate of increase is uncertain. In the absence of information on density-dependent effects, no estimate can be given of the level to which the abundance might tend.

A complication is that there is evidence from the long-term fluctuation in catches, that even in the absence of exploitation, the apparent abundance of hooded seals is not constant, but subject to variations over periods of several decades. These changes may reflect only changes in distribution, but to the extent that they reflect real changes in abundance, trends resulting from natural changes may partially or wholly overrule the effects of changing hunting practices. For this and other reasons, it is difficult to make a quantitative comparison between the present abundance and that that would occur in the absence of any exploitation, or that would correspond to any target level such as maximum sustainable yield (MSY).

Effects of Management

The commercial hunt for hooded seals has been carried on largely as an adjunct to the more significant hunt for harp seals, as has the management of these animals. The distribution and migration patterns of hooded seals are similar to those of harp seals, and the early management of both species had to wait for the establishment of the necessary international mechanisms. When the first quotas were set for harp seals in January 1971, it was judged that there was insufficient information for sound scientific advice, and no quota was recommended for hooded seals. The first quota was set at 15,000 for the 1974 season, as recommended by the 1973 meeting of the scientific advisers of the International Commission for the Northwest Atlantic Fisheries (ICNAF).

In the next few years scientific attention was focused on the harp seals, and although a meeting of the Canadian sealing industry on 5 December 1975 expressed concern about the hooded seal and suggested a reduction in quota to 10,000 animals, the quota has remained at 15,000. Except in 1975 and 1979, when catches of 15,611 and 15,125 hood seals were made, the actual catches (excluding the Greenland catches, which were not included in the regulations) have been well under the quota, averaging a little over 12,000 between 1974 and 1982. In 1983 and later, catches fell to nearly zero. This pattern differs from that of harp seals, of which the catches by Norwegian and large Canadian vessels were usually close to the quota. It seems that the regulations had little effect on catches, though they may have discouraged any larger-scale development of catching hooded seals.

Conclusions

As a result of the 1984 aerial surveys, significant additional information has been collected on hooded seals that allays most of the fears expressed recently. It is possible that the stock was increasing even before the drop in catches in 1983, but there is considerable uncertainty about the value of the sustainable yield. It is far from certain that TACs of 15,000 or 12,000 seals were sustainable, even if most of these animals were taken as pups. It would be sensible, if hunting recommences, to ensure that the stock does not decline by setting more conservative figures, at least pending the gathering of further information. More explicit attention should also be given to the ages of seals making up the TAC. Further aerial surveys of the breeding grounds would be highly desirable.

Grey Seals

Background

The grey seal is an animal of temperate waters. It is found on both sides of the Atlantic, though the largest numbers – about two-thirds of the total population – are found off the coasts of the United Kingdom. It is a seal of moderate size but the males are rather larger than the females; the males average about 230 kilograms as compared with an average of 150 kilograms for the females.

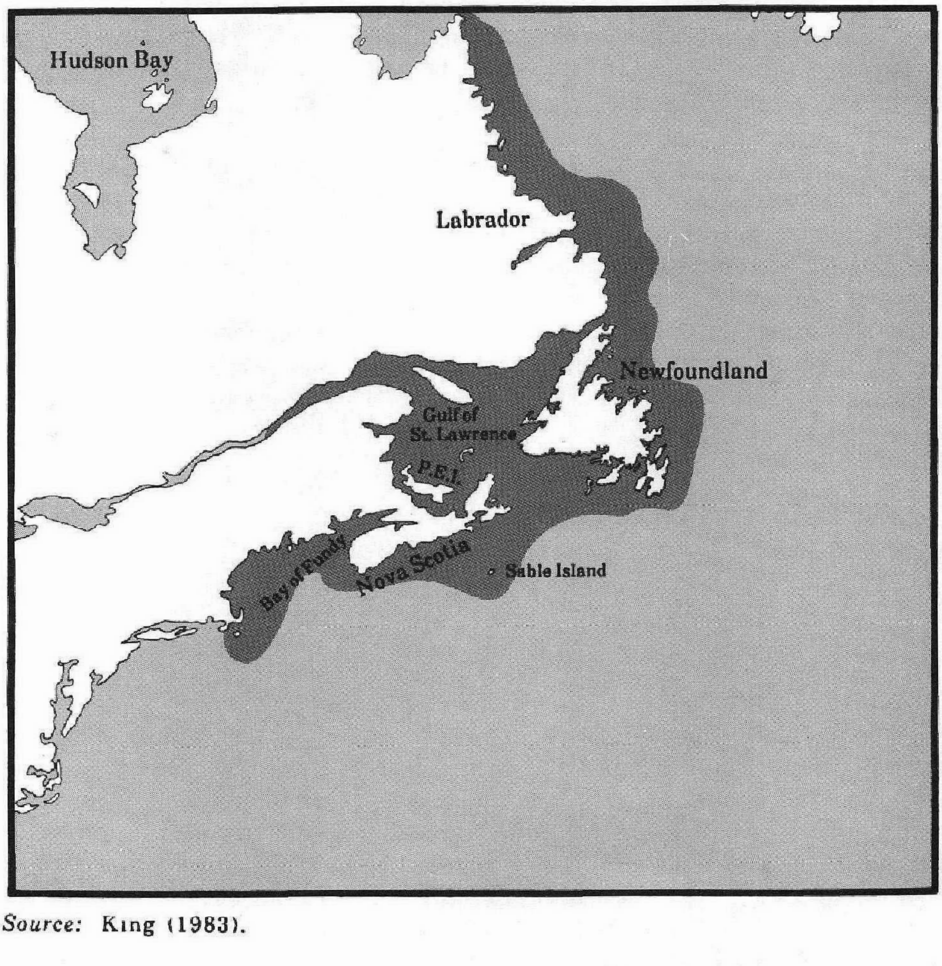
The grey seal breeds in colonies, which are often quite small; these colonies mostly exist on islands and usually in rocky areas, though there are colonies on the sandy areas of Sable Island and on Scroby Sands in the United Kingdom. This species also breeds on fast ice in Northumberland Strait and the Gulf of St. Lawrence. The young seals are born in January–February on the west Atlantic coast, though rather earlier (September–January) in the east. After the breeding season there is considerable dispersion from the breeding colonies, though there is little suggestion of directed migrations (Mansfield, 1967a).

Though grey seals are found on both sides of the Atlantic, there does not seem to be any interchange among colonies on both sides of the ocean. On the west side they have what is now a large breeding colony on Sable Island, and they also breed in the Magdalen Islands and in other locations in the Gulf of St. Lawrence and the Atlantic coast of the Maritimes. There is also a small breeding colony on Nantucket Island (Mansfield, 1967a). They are found in summer as far north as northern Labrador (Figure 21.7). It is believed (CAFSAC, 1984) that there is a single population in the northwest Atlantic, with considerable mixing between the Gulf and Atlantic components. Recoveries of grey seals tagged on Sable Island show wide dispersion of the species over much of its reported range, but this finding could still be consistent with fairly clear separation of breeding groups (CAFSAC, 1983). The ratio of tagged (mostly Sable Island) to untagged (mostly Gulf of St. Lawrence) animals showed a very high separation of pups, and a moderate distinction in older animals, between those inhabiting waters inside, and those outside, the Gulf (Zwanenburg, 1984).

Grey seals can live for up to 40 years. They feed mostly on fish, including herring, flounder, cod and other commercial species (Mansfield and Beck, 1977). Some records include appreciable quantities of salmon (Rae, 1968), but these may be biased as they relate mostly to seals killed near salmon nets. In fact, recent studies made in the United Kingdom and based on the examination of faeces suggest that sand eels and other small fish are a more important element of the grey seals' diet.

Grey seals are of low economic value, and these animals have not been the subject of recent commercial exploitation (Mansfield, 1967a). Historical records indicate that they were probably heavily exploited in the 17th and 18th centuries, both on Sable Island and in the Gulf (Chantraine, 1980), and reduced to very low levels from which they are only now recovering. Since 1967 they have been subject to a government cull program and since 1976 to killing by fishermen under a bounty program (Mansfield and Beck, 1977). Taken together with small research kills in some years, the numbers killed by humans and officially recorded have increased fairly steadily, rising from 200 in 1967 to over 3,000 in 1983. However, the number of kills decreased after 1983 when the cull program was discontinued. In 1984 and 1985, research and bounty kills (combined) numbered 580 and 446 respectively (Hoek, 1985; Beck, 1985). Despite these losses, the grey seal population appears to have increased in recent years.

Figure 21.7
Distribution of Grey Seals in the Western Atlantic



Source: King (1983).

Current Status

The number of grey seal pups produced on Sable Island, where conditions are unusually favourable to direct counts, has been estimated annually (with a couple of exceptions) since 1962 by this method (Mansfield and Beck, 1977; Canada, DFO, 1985, Appendix LVII). Numbers of pups have also been estimated from tagging experiments conducted on Sable Island and in the Gulf of St. Lawrence.

The Sable Island counts show a steady increase in numbers of pups from about 350 in 1962, to nearly 6,000 in 1984 (Mansfield and Beck, 1977; Zwanenburg et al., 1985). A rough log-linear plot indicates that this increase has taken place at a fairly constant exponential rate of 13% per year, with no sign of any slowing down. The difference between this rate and the 12% rate mentioned in some CAFSAC documents is not significant.

Between 1977 and 1983, nearly all the grey seal pups born at Sable Island were tagged (in all, nearly 22,000); in addition, some 1,300 pups were tagged in the Gulf up to 1983, and a further 1,441 were tagged in 1984. Estimates of total pup production were obtained from comparing the ratio of tagged to untagged animals in later catches, particularly those made by hunters. Corrections have been made for tag losses, and consideration has also been given to the possibility of tagged-induced mortality (which is probably small). The resulting estimates from the pre-1984 tagging experiments (Zwanenburg, 1984, Table 7) were as follows:

Tagging Year	Estimates of Pup Production	Confidence Limits
1977	15,825	11,026–24,904
1978	11,180	8,596–15,135
1979	14,754	10,521–21,986

This method, however, depends on equal mixing of tagged and untagged animals. Figures 2 and 3 of Zwanenburg (1984) show this equal mix does not occur. Though the animals aged one year and older are better mixed than pups, there is still a big difference in the ratio of tagged to untagged seals taken in the inner Gulf (about 0.20) and those taken off the eastern coast of Nova Scotia (about 1.0). Since the observations cover most of the distribution of grey seals, an upper bound to total production can be obtained by using only the returns from the inner Gulf of St. Lawrence, but it is difficult to set a lower bound. Without more detailed information on tag returns, especially the returns from non-Sable Island tags, it is difficult to quantify these bounds. Casual inspection of the data suggests that the upper bound may be only slightly higher than the estimates given above (i.e., about 15,000), and the lower bound (based on tagging data) may be only slightly higher than the Sable Island production. These estimates would be consistent with the tagging results if most Sable Island seals stayed offshore or off Newfoundland, and if only a few hundred animals moved into the Gulf to mix with a few hundred locally born seals.

Another estimate of the Gulf pup production, based on the ratio of animals, seen on Sable Island or killed in the bounty programs, which were either tagged in the Gulf or carried no tag, has been given by Zwanenburg et al. (1985). The condition of uniform mixing of tagged and untagged animals in this data set is much more likely to have been satisfied; in fact, four independent samples gave rates that were not significantly different, averaging about 1:4, equivalent to a 1984 Gulf production of 6,336 ± 2,106 animals.

Other estimates of the production of pups in areas other than Sable Island are based on aerial surveys, and on the culling and tagging programs. Though conditions in these areas are much less favourable for direct counts than conditions on Sable Island, aerial surveys have been made both during and outside the breeding season. The survey made in January 1984 estimated that there were 2,650 pups in Northumberland Strait (Clay and Nielsen, 1984), which seems to be the main breeding ground in the Gulf of St. Lawrence. Lower limits to the total pups born in the Gulf are based on the numbers killed in the cull or tagged. In 1982, 654 pups were tagged, and 1,663 were culled; in 1983 at least 1,610 pups were killed or tagged, and in 1984, 1,441 were tagged; this latter number represented as many pups as could be found. Nevertheless, untagged 0+ animals exist in appreciable numbers. Out of a sample of 48 pups taken later in 1984, 35 were not tagged. Sergeant et al. (1984) estimated a pup production of 6,004 animals (for 1984) and 3,912 (for 1982) based on these returns of 0+ seals tagged away from Sable Island, but the numbers returned are too few, and the problems of incomplete mixing are too large to conclude more from these data than that the pup production away from Sable Island is larger, and probably substantially larger, than the numbers tagged or culled. Sergeant et al. (1984) consider where the "missing" pups might have been born, but without more concrete evidence on the likely numbers of pups not accounted for, this exercise is not worth pursuing very far.

Estimates of the total grey seal population can be obtained by extrapolation from the pup estimates, using figures for mortality and other pertinent rates. It would be difficult, on the basis of the present information, to improve on Zwanenburg's (1984) estimate, which he bases on Leslie matrix analysis, though he stresses the weaknesses in the results. Zwanenburg estimated that in a stable age composition, age 0 animals should make up 17.8% or 17% of the total, depending on whether the population is increasing at a rate of 7% or remaining constant. This is to say that the total population is roughly six times the number of pups.

Given that in 1984 nearly 6,000 pups were known to have been born on Sable Island, and that 1,440 pups were tagged in the Gulf, the minimum 1984 pup production, allowing for only a handful of other births, was some 8,000 animals. A reasonable upper bound is difficult to set, but the unproductive consideration of the location of "missing" pups suggests that undetected pups were not very numerous, probably amounting to no more than those born on Sable Island: say an upper bound of 12,000 for Sable Island and the Gulf together. These numbers correspond (rounding the lower and upper bounds down and up) to total grey seal populations of 40,000 to 75,000. These figures, especially those representing the lower bound, are lower than most quoted figures, but the latter seem to take too much account of the unreliable estimates based on the Sable Island tagging. The most recent results of tagging of pups in the Gulf (Zwanenburg et al., 1985) suggest a total pup production of 12,000.

Most documents that deal with the grey seal population take it for granted that the population is increasing, but quantitative evidence of an increase in pup production exists only for Sable Island. CAFSAC (1984) noted that the rate of increase in the Gulf component is not fully known, but it seems closer to the fact to say that for the moment, it is not even known whether the pup production in the Gulf is increasing. There is plenty of anecdotal evidence from fishermen and others that there are now more grey seals along most of the Canadian east coast than there were 10 or 20 years ago, but this change could be accounted for by the increased numbers of grey seals breeding on Sable Island.

Future Prospects

The present rate of increase, whether at 13% per year or at some lower rate, cannot continue for ever. Even at a rate of increase of 7% per year, the population would double each decade, and increase by a thousandfold, to some tens of millions, in about a century. The question is, therefore: When will the growth cease (or reverse itself), and at what level of abundance? Put differently, what factors are causing the present increase, and when, and at what population level, will these factors cease to operate, or when will other factors arise to balance them?

On the east side of the Atlantic the grey seal inhabiting waters around the United Kingdom is also increasing, at about 6%–7% per year. This increase has been interpreted as the recovery to some earlier level of a population that had for a long time been undergoing reduction by traditional subsistence hunting at many of the breeding sites (Bonner, 1982). The past effect of humankind on grey seal stocks in the western Atlantic is unclear. During the present century the numbers of these animals officially recorded as killed in culls and bounty hunts only became significant at about the same time that their increase on Sable Island became apparent and was, in fact, a response to that increase. Previous to these culls there are few records of grey seals being killed, and indeed, few seals at all were recorded. Allen (1880), however, going back to what even in his time was ancient history, refers to Dodsley's 1761 translation of letters written by Charlevoix to the Duchess of Lesdigureves in 1721, describing what appears to be killing of grey seals in the Gulf of St. Lawrence. Chantraine (1980) indicates that they were heavily exploited in the 17th and 18th centuries. It may be that the low numbers of grey seals in the 19th and early 20th centuries were the result of earlier overexploitation.

The only published explanation for the increase in numbers of grey seals seems to be that of Brodie and Beck (1983), who attribute it to a decrease in large sharks in the northwest Atlantic. Though there is no good direct information on the numbers of large sharks in the northwest Atlantic, it is likely that these fish have decreased, as a consequence of the development of a directed shark fishery by Norwegian fishermen in the 1950s and, more recently, as the result of the increase of longlining for swordfish and large tunas, a process which produces large incidental catches of sharks. Sharks are known to be significant predators on grey seals off Sable Island (Brodie and Beck, 1983), though probably not elsewhere. The argument that a decrease in sharks is the cause of the increase in seals is therefore persuasive, though not conclusive. Sable Island lies in the middle of the fishing grounds for sharks, as Figure 1 of Brodie and Beck illustrates, but the other breeding areas of grey seals are well away from the shark areas.

However, the seals killed in the cull and bounty programs were taken exclusively in the Gulf of St. Lawrence and along the coast of the Maritimes (45% in Quebec, and 55% in the Maritimes), and thus these programs would be expected to affect the seals breeding on Sable Island less than they would those breeding elsewhere. The future trends in shark population are difficult to project; the most reasonable assumption would be that as long as the swordfish longline fishery continues, the shark population will remain relatively low.

Another factor that will clearly affect future trends in the seal population is the number of these animals killed in culls or bounty programs. Two points should be made. First and obviously, the killing of say 1,000 seals will, in the short term, reduce the seal population by 1,000. Secondly, as long as the factors causing the present increase in the seal population continue, this reduction will be strictly temporary. The considerable kills made during the past 18 years have not stopped the continuing increase in the numbers of seals. Presumably, the current (1985) number of seals is lower than it otherwise would have been, but unless the cull is continued, the difference it will make by 1990 or 1995 will be very small. Thus the past culling is largely irrelevant to the future size of the stock. The effect of any future culling or bounty program will be discussed after a consideration of what might happen if no seals are killed by man.

The critical factor is the point at which density-dependent effects operate to counteract the forces currently increasing the seal population. On the Farne Islands in the North Sea, pup mortality is known to increase with pup density over the range of 20–100 young per 100 metres of accessible shore (Bonner and Hickling, 1971), but it is not known whether this is the only density-dependent effect, nor is it known whether it would apply at other grey seal colonies. It is possible that direct effects of crowding of this type could apply to the southern Gulf of St. Lawrence, especially in years of little ice, but not to Sable Island. No direct information seems to be available about stocks of grey seals in Canadian waters. All that can be said with confidence, therefore, is that in the absence of a cull, the present increase will continue, probably at a slightly increased rate, at least away from Sable Island, but that it will certainly not continue for ever. If the general belief is valid, that the sustainable yield curve has a maximum (MSY) at a high proportion of the unexploited stock, the density-dependent factors can be expected to begin to be effective rather suddenly. They may therefore be difficult to detect until the population gets quite close to the limiting abundance.

Cull Programs

The principle guiding a cull or bounty program is the same as that guiding a management program for sustained yield of an economically valuable resource. If the appropriate number of animals (adjusted as necessary to the age and sex of the kill) are killed each year, then the population will be maintained at its current level. If more or fewer than this number are killed, the population will decline or expand, ultimately to extinction or to the limits set by the carrying capacity of the environment. If the current population is not at the desired level (e.g., MSY), the numbers killed have to be adjusted for a short period.

If, therefore, a bounty or cull program is being considered on the grounds that the seal population is too large, it has to be planned on a continuing basis according to the standard sustainable yield calculation. In addition higher kills will be necessary for a period if the population is above the desired target level. At present this target level is not defined. A need for a cull has been expressed because of damage done by seals to fishing gear, consumption of commercial fish, and the transmission of parasites. For each of these circumstances, there is presumably a different optimum level of seal abundance which balances the impact on fisheries with the costs of control. These levels are at present unknown.

So far, no such calculations seem to have been made. Some existing proposals, such as that made in the October 1983 report of the Task Force on Seal Borne Parasites (Canada, DFO, 1983), lack any estimates of sustainable yield and seem to imply, in places at least, that culling would be a short-term exercise. The information is not available for making a good estimate of sustainable yield (i.e., the cull necessary to prevent further expansion of the number of grey seals), but for a population of about 60,000 animals which is expanding by some 10% annually, the sustainable yield (cull) would be about 6,000 animals. The actual numbers would be greater if the kill were concentrated on pups.

Summary and Conclusions

The grey seal population off Canada's east coast is believed to number between 40,000 and 75,000 animals; the upper part of this range is the more probable. The group of animals breeding on Sable Island is increasing rapidly, at a rate of about 13% annually. It is not known what is happening in the other breeding groups, though the population as a whole is almost certainly increasing. The reasons for the increase are uncertain, but they may include reduced predation by large sharks. There is no certain relation between the present population abundance and the equilibrium carrying capacity of the present environment or some of the standard target levels, such as that giving MSY, but the population is well above the level at which there would be concern for its continuation, and it may be above the level that is readily acceptable to the fishing industry.

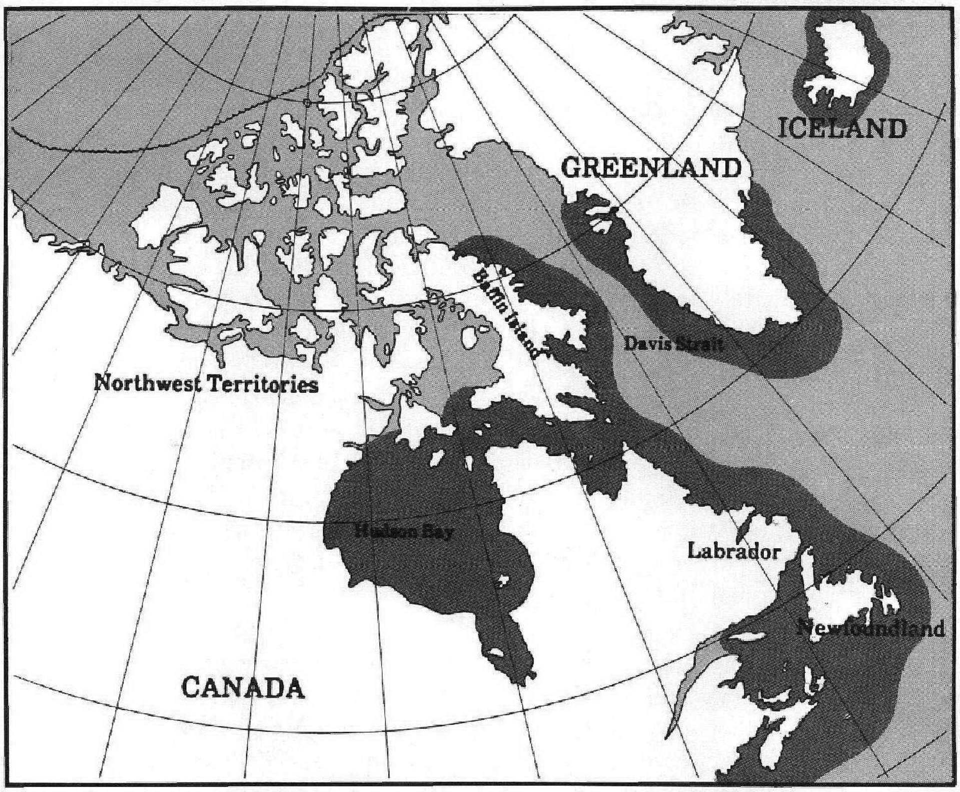
Harbour Seals

Background

Harbour seals are distributed widely, without any marked concentration, over much of the western Atlantic from Maine, off the Maritimes, Quebec and Newfoundland, and as far north as Ellesmere Island and Hudson Bay (Figure 21.8). Their habitat also extends into fresh water more than does that of most seals, for harbour seals have appeared as far up the St. Lawrence as Montreal (Bonner, 1979; Mansfield, 1967a). Their biology and population dynamics have been examined by Boulva and McLaren (1979). There is little evidence of long-distance movements, and information on the number of post-canine teeth (Boulva and McLaren, 1979, Table 2) suggests that there is a fair degree of distinction among groups. Harbour seals feed close inshore or in shallow waters, where they appear to take a variety of fish, cephalopods and crustacea, varying their diet according to the species available.

The small scattered groups typical of the harbour seal have not been subject to major commercial hunts, though in northern Canada the species is subject to significant subsistence hunting to provide meat and blubber for man and dogs, as well as for its skin. From 1927 to 1976, it was subject to hunting for a government bounty, which from 1949 required the submission of the lower jaw. This eliminated false claims based on grey seals or other material. The number of bounty claims fell at an approximately constant exponential rate of 8%–9% per year, from 1,000 pups and 300–400 older animals in 1950 to 200 pups and 50 older animals in 1967 (Boulva and McLaren, 1979). In that year, the reward was increased, and there was some resurgence in kills until 1976, when the bounty was discontinued. The number of pups killed is roughly equal to the number of bounty claims, or larger, since most pups killed are recovered, and there may be some claims on pups that have died naturally. According to data provided by Boulva (1973), however, only about 65% of the older seals killed are recovered, and so bounty claims should be increased by 50% to reflect the actual number killed (Boulva and McLaren, 1979).

Figure 21.8
Distribution of Harbour Seals in the Western Atlantic



Source: King (1983).

Population Numbers

Since harbour seals are often scattered in inlets or on small islands, they are difficult to count. The most thorough attempt at a census was carried out by Boulva (reported in Boulva and McLaren, 1979), who, on the basis of questionnaires, interviews and distribution of bounty kills, estimated a total population in eastern Canada (excluding the areas from Labrador northwards) of 12,700 in 1973, of which some 5,500 were in the Maritimes, excluding Sable Island. The latter figure compares with an estimate of 10,000–15,000 in the same region in the 1940s, though that estimate is based on less extensive surveys conducted by Fisher (1949).

This evidence of a decline during the post-war period is consistent with the decline in the number of bounty claims. Boulva and McLaren (1979, Figure 17) show that between 1950 and 1966, the claims on pups and older animals showed an annual decline of some 8.2% and 9.4% respectively. They believed that these figures overestimated the true decline in seals, as a result of falling interest in hunting for the bounty. When the bounty was increased in 1967 reported kills increased, but not to the level of 1950. The decreases in reported kills that occurred between 1950–1952 and 1968–1971 were equivalent to annual rates of some 6% for pups and 3% for older animals. These figures agree with the 4% rate of decrease in population inferred from the differences between the surveys in the 1940s and 1973, which Boulva and McLaren considered reasonable. Such a decrease would imply, from the total 1973 census, the existence of some 28,000 seals in eastern Canada (excluding the northern part) in 1950. At that time bounty rewards were given for some 400 adults and 1,000 pups. Allowing for animals lost, this gives a total bounty kill of some 1,600 animals annually, or 6% of the population; this percentage is of the same order of magnitude as the supposed decrease in population.

A more precise analysis, based on reproductive and mortality rates, including an observed difference in mortality rates between areas of high and low hunting intensity, was made by Boulva and McLaren (1979). They concluded that the data were consistent with a decrease in population of 4% per year, caused entirely by hunting. They also considered that age of maturity may have showed a density-dependent response. There is no direct evidence for this in eastern Canada, but there is a difference of about one year between the heavily hunted populations in British Columbia and the less heavily hunted ones in eastern Canada. Under an assumption of density-dependence, Boulva and McLaren found a sustainable yield of 1.5%, that is, a rate of increase in the absence of hunting of 1.5% per year.

Since the bounty was discontinued in 1976, there is little quantitative information on harbour seal populations. It is reported (Canada, DFO, 1985) that fishermen are increasingly complaining about damaging and robbing of nets by harbour seals, and that the Sable Island population is increasing. Increased damage may be caused by the seals' greater boldness in the absence of shooting. There is anecdotal evidence of this response in the United States, following the enactment of the United States *Marine Mammal Protection Act of 1972*. Given that the current population of harbour seals is below its 1950 level and hence presumably below the carrying capacity of the environment, it would be expected to increase. However, the data recorded from 1950 to 1976 do not suggest that this rate of increase is likely to be large; the suggestion is that it would amount to no more than a few percent per year. On the assumption that the population decreased from 1973 to 1976, when the bounty was discontinued, and increased slowly thereafter, an informed guess at the 1985 population would be not far from the 1973 level, or around 13,000. All the information provided so far in this paragraph refers to the area south of Labrador. Very little quantitative information is available for the area farther north. Templeman et al. (1957) indicated that the biggest concentration of harbour seals in the whole Labrador-Newfoundland area was in south-central Labrador around Hamilton Inlet.

Farther north the harbour seal population is reported by Davis et al. (1980) to be sparsely and locally distributed. Mansfield (1967b) noted that because of this localized distribution, the population could, in places, be susceptible to pressure from local hunting, and that it appeared to have been eliminated from some places in Ungava Bay and Southern Baffin Island. Reported harvests of harbour seals in the Northwest Territories amount to only a few tens annually, but the species may not always be distinguished from ringed seals (Smith and Taylor, 1977).

Future Prospects

In the absence of hunting, the harbour seal population in the more southern areas might be expected to increase for some time. There is little information from which to estimate the limiting size of the population, or the degree to which this size might be changing as a result of environmental changes or human activities such as general disturbance, pollution of all kinds, or reduction of stocks of fish species on which harbour seals feed. Some possible effects of these factors on seal biology are described by Reijnders (1983). In the absence of information on large-scale human kills before the start of the bounty program in 1927, it is tempting to consider that the 1927 population was close to the carrying capacity. Extrapolation back from 1950, assuming a steady decrease between 1927 and 1950 – an assumption that could be modified by better information on bounty kills before 1950 – would give a 1927 population of approximately 70,000 animals.

Since harbour seals are very coastal animals, they seem to be more vulnerable than other species to human disturbance and the effects of pollution. For example, organochlorine compounds have been found in seals in the Wadden Sea, and this population has collapsed (Bonner, 1979; Reijnders, 1978). The present carrying capacity for harbour seals in eastern Canada south of Labrador may well be lower than it was 50 years ago. In any case, the rate of increase towards any limiting size will be slow. The kill that would maintain the population at its present level is correspondingly small. In the absence of any killing of harbour seals by humans there has presumably been some increase in abundance since 1976, which would be expected to increase the sustainable yield, but the bounty kills were clearly above the sustainable yield, perhaps by a factor of 2 or more. Taking the factor of 2 for the purposes of illustration, kills of 150 pups and perhaps 75 animals aged 1+ would maintain the population at about its current level. Any figures used as targets in a management program aimed at maintaining present abundance, whether kills represent part of a cull, bounty or other activity, would be highly tentative, and would need revision after careful monitoring of the population.

It may be noted that in the absence of any killing, the estimated rate of increase of the population of a very few percent per year is slower than that for the Pacific harbour seals, or for the more severely depleted stocks of other species of seals (see Chapter 22). If the rate of increase is correct, and not merely an estimation problem, it suggests that present population numbers may not be much below the carrying capacity.

Conclusions

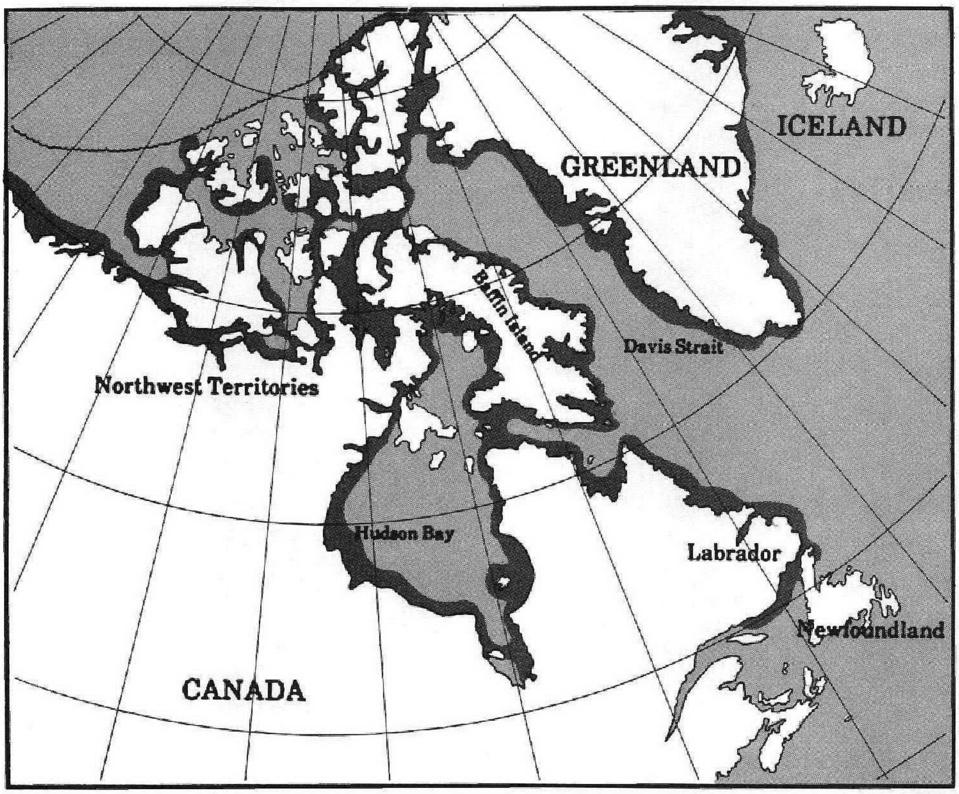
The abundance of harbour seals on the Atlantic coast was reduced by bounty kills at an annual rate of approximately 4% per year until 1976, when the bounty was discontinued. The current population numbers about 13,000 animals, and is most likely increasing very slowly.

Ringed Seals

Background

The ringed seal is widely distributed throughout the Arctic, including the whole of the Canadian Arctic from northern Newfoundland to the Alaska border, including Hudson Bay and James Bay (Figure 21.9). It is probably the most abundant seal in the northern hemisphere and the second most abundant (after the crabeater seals in the Antarctic) in the world; its total population is estimated as 6.7 million, though this figure should be interpreted with caution (Stirling and Calvert, 1979). It is generally solitary, with no marked aggregations. Large-scale movements are little known, but there are some seasonal movements associated with changes in the distribution of ice in the Beaufort Sea and off Greenland.

Figure 21.9
Canadian Distribution of Ringed Seals



Source: Mansfield (1967a).

Ringed seals are strictly arctic animals. They can remain in the Arctic year-round because of their unique ability to maintain breathing holes in ice up to two metres in thickness. Their numbers are, nonetheless, highly sensitive to annual regional variations in ice conditions, food, and predation. In the Beaufort Sea, for instance, the seal population fell by half during the severe 1974–1975 winter, which produced unusually heavy ice, and which may have depressed the production of plankton as well. Immigration had restored the Beaufort Sea stock by 1978 (Stirling et al., 1982). Annual dispersal of young-of-the-year, often over long distances of several hundred kilometres, is necessary to maintain the overall population by replenishing coasts depleted by natural conditions or heavy predation (McLaren, 1958a; Miller et al., 1982).

Ringed seals require a stable platform for pupping in spring, preferring land-fast bay and fjord ice rough enough to collect deep snow for excavating birth lairs (McLaren, 1958a, 1962; Alliston and McLaren, 1981; Miller et al., 1982). They therefore tend to be most numerous and to produce the largest pups along complex coasts such as the shores of Baffin Bay. Ringed seals also colonize pack ice, and while pack-ice seals are more thinly scattered and produce earlier-weaned, smaller pups, they utilize a much larger habitat and may outnumber fast-ice stocks (Miller et al., 1982). Inuit have long distinguished coastal bay-ice seals (*tuvamiutaag*) from the smaller pack-ice seals (*pulajuraag*) that migrate inshore in summer (McLaren, 1958a; Miller et al., 1982). In either habitat, however, ice cover can vary yearly by a factor of two, and poor snow or an early break-up can be catastrophic.

Ringed seals are opportunistic feeders. They prefer arctic cod (*Boreogadus* and, to a lesser extent, *Arctogadus*), but they will also take advantage of summer swarms of crustaceans such as *Parathemisto* and the local availability of other prey (Finley, 1978; Lowry et al., 1980b; Lowry and Frost, 1981; Bradstreet and Finley, 1983). Arctic cod are schooling fish subject to seasonal movements, and their numbers and distribution vary considerably from year to year. Ringed seals follow arctic cod inshore in summer (Finley and Gibb, 1982) and may emigrate from coasts depleted of fish (Bradstreet and Finley, 1983), but in winter, when they cannot stray far from their breathing holes, they cannot escape local variability in food supplies (Finley, 1978). They also compete with bearded and harp seals for arctic cod and possibly some crustaceans, chiefly in summer (Lowry et al., 1980a; Lowry and Frost, 1981; Smith, 1981; Finley and Evans, 1983).

The chief predator of ringed seals is the polar bear. Bears open birth lairs and hunt seals basking or swimming along the floe edge (Stirling and Archibald, 1977; Stirling and Latour, 1978; Furnell and Oolooyuk, 1980; Smith, 1980). In the eastern Arctic, it is estimated that bears require one seal every five days (Miller et al., 1982). Although polar bears are completely omnivorous and can sustain themselves on birds and plant foliage if these foods are available (Russel, 1971), a decline in the number of seals usually leads to a decline in the number of bears (Stirling et al., 1982). Bears tend to eat only the calorie-rich blubber of seals, leaving the carcasses for scavenging by the arctic fox and ravens (Stirling, 1974; Smith, 1980). Foxes also commonly open seals' lairs themselves, especially in the western Arctic (Smith, 1980). Ringed seals, polar bears and arctic foxes are all of considerable economic significance to Inuit and must be managed as a single interrelated system (Brakel, 1977).

Ringed seals are the most important seals in the Inuit economy, having long supplied meat for humans and dogs, skins for clothing and boats, and blubber for lamps. Some skins are traded commercially. Prior to 1962, these amounted, at a maximum, to some 20,000 skins annually, representing about half the kill (or probably, to be more accurate, half the animals recovered). After 1962, skin prices increased. Mansfield (1967a) reported that 70,000 skins were sold annually, representing most of the kill. Recent statistics for skins traded are given in Table 21.7. These statistics are for several species of seal; however, as shown in Chapter 13, nearly 90% of these skins would be from ringed seals. In recent years these skins may represent most of the seals recovered, but there is substantial loss of shot seals that sink before recovery. This loss of up to 50% of the kill is highest in the summer (see Davis et al., 1980, Table 12). The subsistence hunt has existed from time immemorial, but apart from the recent data, discussed later, there is little information on long-term trends. There has never been significant commercial European hunting.

Population Numbers

The main methods currently usable for estimating ringed seals are direct counts from ships or aircraft. Counts have been made, using dogs, of the numbers of breeding pairs in small areas, but it is difficult to cover a large area in this way. Because the seals are scattered over a huge area, counts have to be made in sample areas and extrapolated to the whole area of interest, perhaps taking into account ice conditions. A good time for aerial surveys seems to be late June, when seals bask on the ice (McLaren, 1966), but under even the most favourable conditions there are problems of seals under the water or not seen. Quite big differences exist among observations, some of which can be accounted for by such factors as the observer's position in the aircraft and speed of aircraft. Correction factors to account for seals not seen or not hauled out range from 1.2 to 2.0 (Davis et al., 1980). The most systematic surveys are probably those of Stirling et al. (1975, 1977) for the eastern Beaufort Sea, but even these have quoted confidence limits of 20%.

Allowing for possible systematic errors, the real range of likely values is greater than this figure, and the range of other estimates is even larger.

Table 21.7
Seals Sold to the Hudson's Bay Company, 1943–1984[a]

	Northwest Territories			
	Western	Central	Eastern	Quebec
1943–1952[b]	94	387	4,080	1,792
1953–1962[b]	734	867	8,501	2,519
1963–1972[b]	8,185	6,302	24,348	7,197
1973–1982[b]	4,043	2,283	23,506	2,075
1983	1,154	184	9,376	46
1984	372	23	4,084	13

Source: Hudson's Bay Company.

a. Nearly 90% of these skins would be from ringed seals.
b. Average number for the period shown.

A number of estimates have been published for different parts of the Canadian Arctic. Roughly in chronological order, these include one million for the area south and east of Lancaster Sound (McLaren, 1958a); 70,000 around the Belcher Islands in southern Hudson Bay (McLaren and Mansfield, 1960); 71,000, 36,000 and 59,000 in Home Bay, Hoare Bay and Cumberland Sound respectively, all on the east coast of Baffin Island (Smith, 1973); 455,000 and 61,000 for Hudson Bay and James Bay (Smith, 1975; though Davis et al., 1980, in re-examining the data suggest estimates of 407,000 and 56,000, and even these figures depend on a high value of 2 for the correction factor for animals under the ice); and between 67,000 and 177,000 on the fast ice and 417,000 to 787,000 on the pack ice off the east coast of Baffin Island (Finley and Renaud, 1980). Apart from this last figure pertaining to the pack-ice seals off Baffin Island, which looks high in comparison with Smith's (1973) estimate for selected areas along the east coast, the figures seem fairly consistent, at least in view of the fact that they are largely made in different places, at different times, and by different survey methods, and that no confidence limits have been attached to several of the figures.

It seems reasonable to conclude that the total Canadian population of ringed seals probably reaches seven figures, and that in smaller areas such as Cumberland Sound, there are local "stocks" numbering in the tens of thousands.

Trends in Abundance and Catches

Several of the available reports and other documents consider, implicitly and explicitly, that the abundance of the ringed seal is roughly constant. For example, the DFO (Canada, DFO, 1985) brief states, "[the population estimates] all indicate a relatively stable population of ringed seals in the Canadian Arctic since 1700–1800." The basis of this belief is not clear. One of the documents referred to in the DFO brief (Stirling and Calvert, 1979) states that "population levels are probably the same as in the 18th and 19th century, though this is not well documented." The other DFO reference on this point (Davis et al., 1980) merely mentions that "current population levels are believed to be similar to historic levels."

There are, in fact, very few records that might exist (other than references to seals' complete disappearance from old areas or appearance in new areas) that could be expected to throw light on changes in abundance since the 18th or 19th centuries. It is simply not known whether or not present population levels are similar to those of 100 or 200 or more years ago.

Similarly, it is not known whether the population abundance is now changing. Given that the precision of current census techniques is no better than ± 20%, it is unlikely that pairs of surveys would detect differences of less than 40%. That is, a decrease of 5% per year (which for a long-lived animal like ringed seal is significant) would only be likely to be detected in a pair of surveys if they took place eight years or more apart. Such long base lines do not yet exist. (The statistical argument here has been highly simplified to make the point. A more complex, and more correct statistical analysis would change the numbers slightly.)

The total kill does not seem to have remained steady. After a rapid rise to nearly 70,000 in 1964, the numbers of skins sold to the Hudson's Bay Company fell to fewer than 30,000 in 1978. The very low sales in the last two or three years (1982–1985) can be ascribed to low prices, but in the late 1970s, the prices were twice those in the 1960s. Although these sales figures are the best quantitative data available, they must be interpreted with care. They reflect hunting effort, and the proportion of skins brought in for fur, as well as changes in availability of skins. There is also considerable variation over a period of a few years. These fluctuations are more noticeable in sales at individual settlements, and the years of peak sales are not always the same at different places. The years 1964–1965, 1969, and 1975 seem to be good ones, while sales in 1968, and 1971–1972 were poor. Such fluctuations are common in the land animals of the Arctic, though in the case of long-lived animals such as the ringed seal they presumably reflect changes in availability, or possibly changes in numbers in one or two year-classes, rather than changes in the abundance of the total population; nevertheless, Stirling et al. (1975, 1977) note fluctuations in numbers and reproductive rates in the Beaufort Sea. The fluctuations do, in any case, make it more difficult to determine the state of the population on the basis of one or two years' observations.

Sustainable Yields

Several estimates of sustainable yield (e.g., McLaren, 1962; Smith, 1973) have been made. Though details differ, the estimates are based on life tables and reproduction rates. The problem with interpreting these results is that the interpretations have to assume either a value of natural mortality or that the population is not changed. Though the calculations do show that the sustainable rates of exploitation, such as those found by Smith, are reasonable and that the 5%–10% range is consistent with the sustainable rates for other seals with similar population characteristics, there is no direct evidence that the assumptions are correct. In any case, since the observations cover a single situation, they can hardly indicate the position or value of the maximum sustainable yield (MSY) unless "we assume that the equilibrium population of southern Baffin Island is in fact experiencing maximum possible mortality" (McLaren, 1962), or make some similar assumption.

Estimation of MSY and the population abundance at which it occurs requires some knowledge or assumption about the density-dependent responses of ringed seals, or the factors controlling their abundance. Little is known about density-dependent responses, but it has been suggested (e.g., Davis et al., 1980) that the availability of stable fast ice suitable for breeding is a limiting factor controlling abundance. The younger animals are found breeding on the less stable ice, where the young are smaller and are often starved (McLaren, 1958a). If they are forced into this ice by high density in more favourable conditions, this circumstance could provide a density-dependent response. It would also suggest, to the extent that a significant part of the population is breeding in unsuitable areas, that there is still scope for some resilience in the population. It does not, however, show whether the present population is above or below the level giving MSY, or how it compares with the limiting size of the population in the absence of any hunting.

Present Status

Considerable ignorance surrounds the present status of ringed seals. It is not known whether the population is increasing or decreasing either locally or as a whole, nor how the local or overall populations compare with the MSY or some other target level. Given the comparatively sedentary nature of the animal and the differences between hunting intensities, say, between Cumberland Sound and Home Bay (Smith 1973), great variation in status may be expected among groups of seals in different areas.

Given, too, the increase in reported catches since 1962, there are grounds for concern for at least local overexploitation. This is no new concern. Smith (1973) warns that "these developments [i.e., increased hunting efficiency] might have serious consequences in depleting the stocks in [some] areas." Davis et al. (1980) note that "there is evidence that local populations can be over-harvested", and DFO (Canada, DFO, 1985) mentions the possibility of local overexploitation.

Future Prospects

Because of the ringed seal's wide range, large total population, and relatively sedentary nature, there is no short-term cause for concern for its population as a whole, provided that there is no major change in environmental conditions. It is, however, quite possible that the catches made in some areas prior to 1983 have exceeded the sustainable yield, and the decline in sales of skins apparent in some areas in the mid-1960s might be a sign of this. If so, resumption of catching at the 1970s level might see the collapse of some of these stocks. Even if the worst effects may be reduced by increased immigration from less heavily exploited areas, and there is no increase in hunting pressure, it is possible that stringent management measures may be needed. With increasing human population in many areas (see Chapter 13), it is more likely than not that hunting pressure will increase. Management of the ringed seal harvest, backed up by adequate scientific advice on what is happening to the stocks, is therefore a matter of some urgency. It may well be that further research will show that the status of the stocks may be better than the gloomy possibilities suggested here. However, until the range of uncertainties in population numbers and recent changes in numbers are reduced, a cautious approach is essential.

A complication that should be taken into account in managing the stock of ringed seals is the status of polar bears and arctic foxes. Both species are important predators on ringed seals, though foxes prey only on pups. Both have been heavily hunted, but hunting of polar bears is now fairly strictly controlled, and fox hunting has also declined as a result of reduced fur prices and increased costs. It is possible that an increase in polar bears or foxes could disrupt a temporary balance between seals and hunting. Likely trends in predator populations should therefore be taken into account in setting management policies for ringed seals.

Conclusions

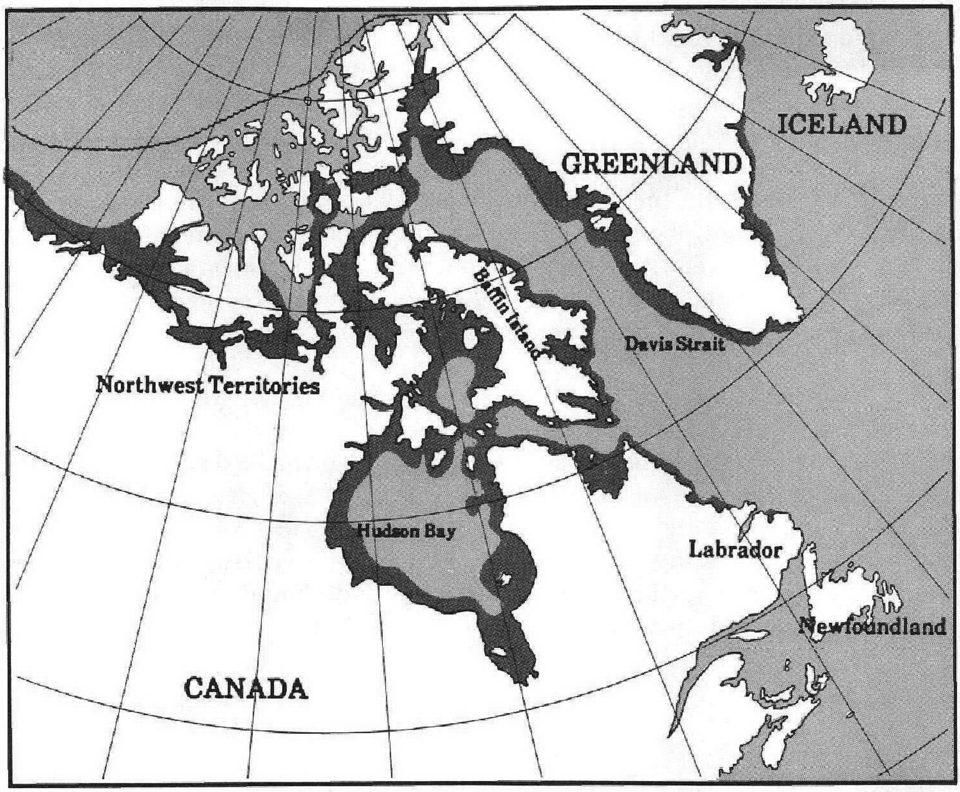
There is a possibility, to put it no more strongly, that current catches of ringed seals in some areas are exceeding the sustainable yield, and that stocks in those areas are declining. It is also possible that even if current catches are sustainable, little or no increase in catch would be sustainable. Urgent attention should therefore be given to devising management procedures for ringed seals that are matched to the traditions and customs of the people involved. Any management should be backed by research aimed, *inter alia,* at monitoring the trends in population abundance. Apart from surveys, attention should be given to the possible derivation of indices of relative abundance from hunting records.

Bearded Seals

Background

The bearded seal is a large, solitary seal, widely distributed throughout the Arctic. In Canada the species is found from Labrador to the Alaska border (Figure 21.10). There are indications (e.g., Mansfield, 1967a) that its abundance is relatively high along the east coast of Hudson Bay and the west coast of Baffin Island, but quantitative information is sparse. Like the ringed seal, the bearded seal is believed to be relatively sedentary but it may undertake regular long-distance migrations in response to movements of ice fields (Davis et al., 1980). It is more dependent on open water than the ringed seal, less often maintaining breathing holes in the ice. Its main food items are bottom invertebrates, especially molluscs, though it occasionally takes fish, particularly arctic cod.

Figure 21.10
Canadian Distribution of Bearded Seals



Source: Mansfield (1967a).

The bearded seal is hunted by Inuit. It is particularly prized for its tough and flexible skin, although this material is now largely replaced by nylon and other imported materials. The meat is also eaten by humans and dogs. The total number of bearded seals taken is not recorded. Furthermore, because many of these animals sink when shot (McLaren, 1958b), the number killed is considerably larger than the number recovered.

Population Abundance and Status

Bearded seals are even more difficult to survey than ringed seals, and few quantitative estimates of abundance are available, even from small areas. The most reliable estimates are those for the eastern Beaufort Sea, of 1,000–3,000 in 1974 and 1975 (Stirling et al., 1975, 1977). McLaren (1958b) extrapolated from the estimates of ringed seals to bearded seals on the basis of the ratio of the two species seen from survey ships. The resulting estimated figure of 185,000 for the area south and east of Lancaster Sound probably gives a useful rough guide to the numbers of bearded seals, but must be subject to even more uncertainty than the figures for the ringed seal.

Since even rough figures for the present catch are lacking, it is impossible to evaluate the status of the bearded seal population. There is also too much doubt about some important parameters of its life history (whether it breeds every year, for example, or only every two years) to permit any attempt to estimate its likely response to exploitation or the likely value of its sustainable yield as a percentage of the current abundance.

Given this uncertainty and the known fact that bearded seals have been prime targets of Inuit hunters, many of the concerns expressed for ringed seals apply also to bearded seals. There are no grounds for confidence that the stocks in areas of high hunting intensity are not being depleted. Urgent attention should be given to collecting more information about bearded seals, including estimates of the numbers killed, the numbers present, and trends in these numbers. Attention should also be given to possible management measures.

Appendix

Appendix 21.1 Calculation of Sustainable Yields

These calculations are based on equilibrium conditions, with a stable age composition corresponding to the exploitation pattern under consideration. An observed population will have a rather different age composition; for instance, one that has recently had a large kill of pups will have relatively fewer young animals so that the actual sustainable yield, that is the yield that can be maintained indefinitely, and the replacement yield, that is the yield that will leave the same population numbers, though not necessarily the same population structure, at the end of the year (Gulland and Boerema, 1973), will be slightly different.

Pup Harvest Only

Let M_i be the natural mortality of seals at age i, let t be the age at which females, on the average, first produce a pup, and let p be the proportion of females, aged t or greater, that produce a pup in a given season. Then, if N is the number of pups born and Y is the number of pups harvested, the number of females reaching age t, assuming an equal sex ratio, will be

$$A = 0.5\,(N - Y)\exp[-\Sigma M_i],$$

where ΣM_i is the sum of the M_i up to age t.

The total number of female seals, age t or greater, will be $A / [1 - \exp(-M)]$, assuming that M_i is a constant M for $i > t$, and the number of pups born will be $pA / [1 - \exp(-M)]$, since the population is in equilibrium. Then

$$N = pA[1 - \exp(-M)] = 0.5p(N - Y)\exp(-\Sigma M_i) / [1 - \exp(-M)],$$

and on rearranging terms

$$Y/N = 1 - 2p^{-1}[1 - \exp(-M)]\exp(\Sigma M_i).$$

Harvest of Adults Only

Let F be the fishing mortality on adults. Then A, the number of seals breeding for the first time will be given by

$$A = N\exp(-\Sigma M_i).$$

The total number of adults will be $A / [1 - \exp(-F - M)]$, the number of pups produced will be

$$0.5pN\exp(-\Sigma M_i) / [1 - \exp(-F - M)], \text{ and}$$

$$Y = FA / (F + M).$$

Putting the number of pups born equal to N, since the population is in equilibrium, yields an equation that can be solved for F.

$$N = 0.5pN\exp(-\Sigma M_i) / [1 - \exp(-F - M)] ,$$

and hence

$$F = \ln[1 - 0.5p\exp(-\Sigma M_i)] - M ,$$

and Y/N can be calculated.

An interesting feature of these equations is that the natural mortality rates in the period before first breeding, which are hard to estimate, appear together in a summation term. This makes it possible, for the purpose of calculation, for different sets of assumptions about these maturities and the time taken to reach maturity to be lumped together in the single expression ΣM_i. The following tabulations were calculated on the basis that natural mortality in the first year of life is three times that among adults, and that among older immature animals it is 50% higher (i.e., $M_0 = 3M$ and $M_i = 1.5M$ where $0<i<t$). Thus, the sum of the natural mortality up to the age of maturity, for $t = 4$, is $(3+1.5+1.5+1.5)M = 7.5M$. The same sum would be attained for lower maturity rates and a higher t (e.g., for $t = 6$ if $M_0 = 2.5M$ and $M_i = M$ for older animals). The table below can be interpreted accordingly.

Table 21.8
Sustainable Yield Rates (as percentages of number of pups) for Different Combinations of Natural Parameters[a]

t	ΣM_i	$M = 0.08$			$M = 0.09$			$M = 0.10$			$M = 0.11$			$M = 0.12$		
		P	A	P/A	P	A	P/A	P	A	P/A	P	A	P/A	P	A	P/A
3	6.0M	74	47	1.6	69	42	1.6	63	36	1.7	57	31	1.8	50	26	1.9
4	7.5M	70	40	1.7	64	34	1.9	57	28	2.0	49	23	2.1	41	18	2.3
5	9.0M	66	34	1.9	59	27	2.2	50	21	2.4	40	16	2.5	29	11	2.6
6	10.5M	62	28	2.2	53	22	2.4	42	16	2.6	30	10	3.0	15	5	3.0
7	12.0M	57	23	2.5	46	16	2.9	38	10	3.3	17	5	3.4	No	No	
8	13.5M	52	18	2.9	38	12	3.2	22	6	3.7	4	1	4.0	No	No	
9	15.0M	46	14	3.3	29	8	3.6	9	2	4.5	No	No		No	No	
10	16.5M	39	11	3.5	19	4	4.7	No	No		No	No		No	No	

a. A - Adults; P - pups.

Table 21.8 gives the sustainable exploitation rate, expressed as the number of pups or adults, that would be taken per 100 pups born, if the population is stable and being hunted at the sustainable yield. The ratios of the numbers taken under the alternative harvesting regimes directed at taking pups only or adults only are also shown. The values have been calculated for a range of values of M (from 0.08 to 0.12), and t (from 3 to 10, or ΣM_i from $6M$ to $16.5M$), and for a reproductive rate among adults of 0.94. Table 21.9 shows the effect of different reproduction rates on sustainable yield for one set of M_i.

Table 21.9
Sustainable Yield for Different Natural Mortality and Pregnancy Rates[a]

M	$p = 0.96$	$p = 0.94$	$p = 0.90$	$p = 0.85$	$p = 0.80$
0.08	63	62	60	58	56
0.09	54	53	51	48	45
0.10	43	42	40	36	32
0.11	31	30	27	22	17
0.12	17	15	11	6	0.4

a. Age at first pregnancy is six years.

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