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# Salmon Farm - Pinniped Interactions in British Columbia: An Analysis of Predator Control, its Justification and Alternative Approaches

G.S. Jamieson and P.F. Olesiuk

Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C.
V9T 6N7



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**Abstract**

Predator control is widely practised in most forms of agriculture and aquaculture, including salmonid fish farming. Canada has a process whereby fish farmers can obtain authorisation to kill predators, particularly pinnipeds (seals and sea lions), but to date, the details of this process, how it is being used by industry, and alternative measures to minimise the need for such killing have not been scientifically assessed. Here, we describe existing Fisheries and Oceans Canada (DFO) policy and culling permit requirements associated with predator control; the impacts marine mammals are having on cultured fish production; the annual, seasonal and spatial pattern of kills; how this pattern is related to the abundance, distribution of haulouts and seasonal movements of pinnipeds; and the availability, effectiveness and use of alternate methodologies to deter pinniped impacts on fish farms. Establishment of Canada’s Oceans Act in 1997 gave DFO the mandate for marine ecosystem management. With the recent growth in the coastal ecotourism industry and the economic value and public interest now associated with pinnipeds, there is a current need for this information. Pinnipeds are near the top of the marine food chain, and although they are not commercially exploited, their continued presence and occurrence in natural ecosystems at appropriate levels of abundance are important resource management objectives.

## Résumé

La plupart des activités d'agriculture et d'aquaculture, y compris l'élevage de salmonidés, font communément appel à des mesures de lutte contre les prédateurs. Le Canada a en place un processus permettant aux pisciculteurs d'obtenir l'autorisation de tuer les prédateurs, en particulier les pinnipèdes (phoques et otaries), mais jusqu'à maintenant, les détails de ce processus, comment il est utilisé par l'industrie et les mesures de remplacement visant à minimiser le besoin d'abattre les prédateurs n'ont pas été évalués au plan scientifique. Sont décrits dans le présent document la politique relative à la lutte contre les prédateurs de Pêches et Océans Canada et les exigences du permis d'abattage sélectif; les incidences des mammifères marins sur la production de poisson d'élevage; la répartition annuelle, saisonnière et spatiale des animaux tués; le lien entre cette répartition et l'abondance, la distribution des aires de terrissage et les déplacements saisonniers des pinnipèdes; et la disponibilité, l'efficacité et l'utilisation d'autres méthodes pour prévenir les incidences des pinnipèdes sur les piscicultures. La *Loi concernant les océans du Canada*, adoptée en 1997, a conféré au MPO le mandat de la gestion des écosystèmes marins. Ce type de renseignements est requis à la lumière de l'essor récent de l'industrie de l'écotourisme maritime, ainsi que de la valeur économique des pinnipèdes et de l'intérêt que ceux-ci soulèvent chez le public. Les pinnipèdes occupent les échelons supérieurs de la chaîne alimentaire marine et, bien qu'ils ne soient pas chassés commercialement, leur présence dans les écosystèmes naturels à des niveaux d'abondance appropriés est de ce fait un important objectif de gestion des ressources.

## Introduction

Potential predators of aquaculture (finfish and shellfish) crops in British Columbia are predominantly piscivorous birds, marine and aquatic mammals, fish, and crustaceans. Predation problems arise in most aquacultural endeavours. Some predatory species are protected by law, making lethal methods to reduce predation unacceptable unless a permit is obtained. Aquaculture technologies that efficiently and economically reduce crop loss without significantly affecting predator populations or their roles in ecosystem health are considered desirable (OTA 1995).

Marine mammals are at the top of the food chain, are important consumers of fish and invertebrates, and are thought to have a major influence on the structure and function of aquatic communities. Marine mammals also play a dynamic role by transferring energy and nutrients, although many of these ecological processes remain poorly understood (Bowen 1997, Trites 1997). The expansion of fish farming in British Columbia, both in number and spatially over the past few decades (Tables 1-4, Figure 1), coupled with the recovery of pinniped populations, has resulted in increased interaction between marine mammals and finfish aquaculture operations. Like the concerns cattle and sheep farmers have about wolves preying on their animals, aquaculturists also want to maximise their profits by minimising fish losses from marine mammal predators. The simple solution is to kill marine mammals preying on, or in close proximity to, farmed fish, but this is becoming less and less a viable option. In contrast to culling, which is a term generally used in wildlife management to denote a general reduction in numbers in an area, kills by fish farmers are directed at a relatively small number of specific animals in the vicinity of salmon farms. The issue of pinniped killings has become particularly complicated because: 1) in some coastal areas (e.g., Clayoquot Sound and the Broughton Archipelago), the number of salmon farms has increased significantly over the past decade; 2) with the expanded development of marine ecotourism focused around marine mammals, marine mammals now have significant economic value; 3) increased public recognition of the value of maintaining and sustaining natural ecosystems; and 4) new laws (e.g. Canada Oceans Act 1997) that now require an ecosystem approach as one of the principles of a governance structure to manage Canada's ocean environment. To achieve this approach, a precautionary-approach framework with the following elements has been proposed (O'Boyle 2000):

1. Conservation objectives to maintain, within acceptable bounds, the diversity of ecosystem types and species, ecosystem structure and function, and marine environmental quality;
2. Exploitation strategies based on reference points, where appropriate;
3. Account of uncertainty, including reversal of the burden of proof, stake-holder involvement in the determination of acceptable level of risk, and monitoring of indicators and associated pre-agreed management actions that are essential for management;
4. Implementation of a decision-making process, including pre-agreement on actions (decision rules) to be taken, depending on the circumstances; and
5. Evaluation of management system performance, including the relevance of the objectives, and the applicability of the indicators and reference points.

The publicity in spring, 2000, around the discovery of a substantial number of sea lions killed by finfish farmers in Clayoquot Sound, coupled with the increasing value of pinnipeds to the ecotourism industry, raise a number of science questions about: 1) the actual impacts pinnipeds have on finfish farming; 2) methodologies available to minimise potential impacts; and 3) the implications of pinniped killing, both as a preventative measure to minimise salmon losses and on pinniped population dynamics. The quantity and quality of the science data supporting the justification of pinniped killings has not been assessed formally by DFO. Here, we bring together the most recent data available, discuss the requirements and processes to generate data of credible quality that we suggest should be available, and make recommendations as to how issues relating to pinniped killing by fish farmers should be dealt with in the future.

There is little doubt that predator-salmon farm dynamics have changed greatly since the industry first established itself in the 1980s. Seal and sea lion populations have changed in both distribution and abundance, while salmon farms have grown in number, size, and sophistication. What might have been true in the 1980s may well be significantly different at present. However, for some topics, only data from the early development of the aquaculture industry are presently available. In these cases, caution should be applied to the use of such information, but given that these are the only data available, they are nevertheless presented here to illustrate the extent and quality of existing data and where new data need to be compiled.

**Regulations relating to the killing of marine mammals by fish farmers**

Historically, marine mammals have been extensively harvested and controlled by humans in B.C., either in directed fisheries (e.g., sea otters and whales) or as perceived nuisance predators competing with humans for fish (e.g., sea lion culls and harbour seal bounties from the turn of the century up until the late 1960s). In recent decades, however, synthetics have largely replaced products derived from marine mammals, and a better understanding of the basic biology of animals (food requirements, feeding habits) has indicated that control programs were largely ineffective (Fisher 1952, Spalding 1964, Malouf 1986, Olesiuk 1993). At the same time, changing public attitudes raised concern about the need to kill marine mammals, and the killing of these species has become of particular concern in contrast to that of most other marine species. Being relatively advanced mammals, there are, for example, regulations to ensure that their deaths are achieved as humanely as possible. We believe it is thus useful to briefly summarise existing regulations within Canada and American States adjacent to B.C. to put concerns and issues around the killings of pinnipeds in context.

Statutes administered by DFO that affect the development and operation of the salmon farming industry in B.C. include the Fisheries Act, the Fish Inspection Act, the Navigable Waters Protection Act, the Canadian Environmental Assessment Act and the regulations pursuant to each.

Seals and sea lions have been protected under the authority of the federal Fisheries Act since 1970. Originally, commercial fishermen were allowed to shoot seals and sea lions to defend their catch and gear, but that clause was eliminated in 1984. *Marine Mammal Regulations*, enacted under the federal *Fisheries Act* in 1993, prohibit anyone from disturbing a marine mammal except when fishing under the authority of these Regulations. They further provide that any attempt to kill a marine mammal must be made in a manner that is designed to kill it quickly, the equipment necessary to retrieve it must be available, and a reasonable effort must be made to retrieve a dead animal immediately after it was killed.

The three species of pinnipeds that are known to interact with salmon fish farms in BC are harbour seals (*Phoca vitulina),* California sea lions (*Zalophus californianus*) and Steller sea lions (*Eumetopias jubatus*). Dixon (1989) reviewed the statutory and administrative frameworks regarding predator control on finfish farms, and identified gaps in the legislation and regulations of the day for salmon farmers to deal with problem wildlife. At that time, marine mammals were protected under Section 32 of the *Fisheries* Act. Although anecdotal evidence indicated that the practice of illegally shooting seals by farm staff was taking place, between 1986 and 1988 no charges were laid for contravention of Section 32 of the *Act* (Dixon 1989). In an effort to regulate the killing of marine mammals at fish farms, DFO established a predator licensing program in 1989. The program allows DFO to issue permits to aquaculture operators allowing shooting of problem seals and sea lions pursuant to subsection 22(1) of the Fishery (General Regulations), and subsequently under subsection 4(1) of the Marine Mammal Regulations and (DFO 1997).

These licences are issued subject to a number of terms and conditions that typically include the following:

- only harbour seals, California sea lions and Steller sea lions may be killed;
- only seals and sea lions that are actually taking or attempting to take fish in seas cages may be killed;
- the area of killing is limited to the immediate site of the sea cages and killing must not occur outside the boundaries of the lease or licence of occupation for the farm;
- employees who kill seals or sea lions must meet one of the following qualifications:
    - certification from the Conservation and Outdoor Recreation Education Program,
    - completion of a basic firearm safety course, or
    - possession of a provincial hunting licence;
- firearms used must meet certain specifications;
- every attempt must be made to retrieve for biological sampling killed seals and sea lions; and
- the licence holder must submit quarterly reports listing the number and species of animals killed and the date each animal was killed.

At the time of the initial application for a licence, the applicant must satisfy the DFO that it has tried other measures in an attempt to deal with problems with seals and sea lions before a licence to kill them will be issued (DFO 1997) including the use of predator nets, seal scares, dogs, extra lighting and increased vigilance by farm operators (EAO 1997). However, it appears this information is not in fact being requested by DFO, as there is no database of the measures that may have been taken by applicant farms and the form by which a licence is requested does not ask for this information (Appendix 1). When the licence (Appendix 2) is issued, the DFO notifies the R.C.M.P., the provincial conservation officer and the federal fisheries officer. A licence is issued for a period of one year and, in recent years, licences have been renewed automatically unless evidence is provided indicating non-compliance with the terms and conditions set out in the licence, and in particular, the submission of quarterly reports on marine mammals killed. This is a self-reporting system and the DFO has no formal auditing system in place. There have been no prosecutions for violations of these licences by salmon aquaculture operators. At present, most, if not all, operating farms possess a valid licence to kill seals and sea lions (EAO 1997). Between 1990-96, the number of sites licensed to undertake pinniped killing increased from 60 to 82 (DFO 1997).

The BC Environmental Assessment Office Salmon Aquaculture Review discussion paper (EAO 1997) on aquatic mammals and other species reviewed the interactions between marine mammals and the salmon farm industry, including the predator control program. The EAO report (Iwama et al. 1997) was critical of the lack of DFO resources applied to this program, implied by the limited enforcement of the conditions of predator licenses. One recommendation for improvement of the system was the requirement for all operations to develop and implement a "predation control plan", which would be enforceable if incorporated into the aquaculture operating license. Another recommendation is that a rigorous survey be conducted on the interactions between the industry and aquatic mammal predation including a more rigorous quantification of the degree of predation (Iwama et al. 1997). However, neither of these recommendations have been implemented by DFO to date.

**American regulations**

Regulations relating to the killing of pinnipeds in the American states adjacent to B.C. are presently quite different than those in Canada. From 1988 to 1995, if non-injurious predator control were ineffective and stocks were under substantial and immediate threat, under the Marine Mammal Protection Act (MMPA), salmon farmers (falling under the category of commercial fisheries) were permitted to kill seals, subject to registration and reporting requirements. Since March 3, 1995, amendments to the MMPA prohibit commercial fisheries/salmon growers using lethal force to control predators, excepting for the protection of human life (NMFS 1996).

NOAA (1999) recommended that in situations where pinnipeds conflict with human activities, such as at fishery sites or marinas, lethal removal by government officials would be authorised only after non-lethal deterrence has been ineffective. Lethal removal would only be used when: (a) an individual pinniped is repeatedly involved in a conflict situation, such as raiding fish pens; and (b) non-lethal deterrents applied have been ineffective. Two types of pinniped behaviours would indicate ineffective use of non-lethal deterrence, as shown by the following examples: (1) a pinniped is on a dock and does not leave when non lethal measures are attempted; and 2) an individual pinniped reacts to deterrence measures by leaving the area and returns repeatedly after the person who has used the deterrence has left the immediate site. These guidelines are felt to most effectively resolve specific pinniped conflict situations.

Since passage of the MMPA in 1972, West Coast populations of California sea lions and Pacific harbour seals have increased at average annual rates of 5-8%. As of 1997 (NOAA 1997), there was no conclusive evidence that populations had reached their optimum sustainable population level (OSPL), although more recent data indicates that harbour seal populations in Washington and Oregon may now be at this level (NOAA 1999).

Finally, it should be noted that the U.S. legislation and regulations may have implications for fish farms in Canada. The U.S. Marine Mammal Protection Act of 1972 as Amended, Sec. 102 (c) (3) (Marine Mammal Commission, 1995) states that "[it is unlawful to import into the United States] any fish, whether fresh, frozen, or otherwise prepared, if such fish was caught in a manner which the Secretary has proscribed for persons subject to the jurisdiction of the United States, whether or not any marine mammals were in fact taken incident to the catching of the fish". This would seem to indicate that fish harvested from fish farms in a manner that would not be permitted in the U.S. (by shooting seals and sea lions) might not be able to be sold in U.S. markets, but a legal interpretation is required to evaluate this.

The U.S. National Marine Fisheries Service (NMFS) has classified the Steller sea lion population stock west of 144 degrees W. longitude (a line near Cape Suckling, AK) as endangered, with the remainder of the Steller sea lion population remaining as threatened, effective June 4, 1997. This measure, authorized by the Endangered Species Act of 1973 (Act), corresponds with a determination to reclassify this species based on biological information indicating that there are two distinct population stocks, as authorized under the Act, by the NMFS which has jurisdiction for this species. The listing limits whether animals can be killed, and U.S. stock assessments include estimates of numbers of animals killed in neighboring countries. The listing may therefore also have implications for salmon farming in Canadian waters.

**Documentation of Salmon Losses**

The published information from British Columbia on losses of farmed salmon that are attributable to predators is very limited, and it is therefore necessary to bring forward material that is dated or derived from other jurisdictions where the situation is not truly comparable. It would appear that the salmon farming industry or salmon farmers have not collected and compiled any more detailed or current information. Our analysis has been based on the information available, some of which may be of limited validity or of tenuous quality.

A lack of substantiated, quantified data documenting salmon losses due to pinniped predation is a world-wide phenomenon (van de Wetering 1989, Howell and Munford 1992, Arnold 1992, NMFS 1996, Iwama et al. 1997, NOAA 1999). However, there are various estimates of salmon aquaculture losses due to direct or indirect marine mammal interaction. Table 5 summarises the losses reported over the past 12 years. Another source of information where salmon losses have been documented is insurance company claim records (Table 6). However, these numbers are considered to underestimate the actual number of losses because reported claims are in excess of deductibles and claim thresholds, which can be as high as 20% and 80% respectively (Nash et al. 2000).

A recent BC government review (EAO 1997) of finfish farming stated "about half of all farms in B.C. experience fairly substantial predation losses. A 1989 estimate based on a survey of fish farmers put salmon losses from predation mortality and escapes due to predator net damage at 1.5

per cent *[this includes otter and bird predation]* of total industry production in that year - over 200,000 fish eaten. If salmon losses due to only sea lions and seals are considered, then the estimated loss rate was 1% (Rueggeberg and Booth 1989).

There are several reasons why it is difficult to accurately determine the number of salmon losses related to pinniped interaction. Marine mammals can cause salmon losses directly by predation or through escapement due to net pen damage (DFO 1997), and indirectly such as increased losses from disease associated with injuries, decreased feeding and growth from stress, and decreased value of damaged fish. It would seem simple to calculate an initial estimate of lost stock through direct seal predation or escapement by subtracting the number harvested plus the mortalities found in the pens from the initial number of fish stocked. However, stock numbers are often only accounted for at harvest, making it difficult to accurately determine losses when the number of fish initially stocked in the pens has an unknown estimated measurement error and deaths due to causes other than pinniped predation (e.g. disease) may not all be counted (Parkinson and Deegan 1989; A. Thomson, DFO, Nanaimo, BC, pers. comm.). David Groves (Sea Spring Salmon Farm Ltd., BC, pers. comm.) estimated the introduction measurement error at 1-2% if accurate counting of mortalities in net pens is conducted at appropriate time intervals. This should be done every few days over the first couple of weeks after the salmon are first introduced to salt water pens. Small salmon rot away completely in 3-4 d, so monitoring of mortalities has to be quite frequent. Weekly monitoring of mortalities is acceptable with large fish.

It may be possible to estimate some direct predation losses based on counts of the number of carcasses in the net pens showing evidence of pinniped attack (Campbell 1991). Fish subject to seal attacks can exhibit certain characteristics such as parallel scrapes and puncture holes caused by seal canines (Pemberton et al. 1991, Tillapaugh et al. 1993). Other evidence includes remains of the fish head, tail and/or backbone, which are sometimes left behind when seals suck out the gut contents of the fish through the net (Ross 1988, Rueggeberg and Booth 1989, Campbell 1991, Tillapaugh et al. 1993). Recent amendments to the BC Aquaculture Regulations now require fish farms to inspect farm mortalities for signs of predator attacks and record predator-related mortalities in a written inventory record. These amendments, effective October 31, 2000, should improve the quantification of salmon losses attributed to pinniped predation.

Marine mammals can also contribute indirectly to losses through predation-related injury or stress, which is considered by some to cause more damage to farm stocks than direct predation losses (Tillapaugh et al. 1993). Half of BC fish farm survey respondents perceived increased disease incidence in salmon due to myxobacterial infections was related to wounds or descaling. An increase in vibrio outbreaks, such as Bacterial Kidney Disease (BKD), have also been attributed to predation-related stress (D. Kieser, DFO, pers. comm.). Disturbance in feeding behaviour caused by seals in the vicinity of net pens were also reported in the survey, having the greatest affect in the spring when fish appetite and growth rates are most rapidly increasing (Tillapaugh et al. 1993).

Some farmers blamed salmon losses on certain predators without actually observing the predation taking place (Rueggeberg and Booth 1989, Pemberton et al. 1991). Survey results of

BC salmon farms demonstrated that although 37% of farms experienced predation problems, only 27% actually reported losses, indicating that in some instances predation may be more of a perceived problem than a documented one (Rueggeberg and Booth 1989). In some cases, pinnipeds may be drawn to the vicinity of net cages and only feed on wild fish attracted to the outside of cages by uneaten feed pellets and waste material (Campbell 1991, Howell and Munford 1992). There may be a lack of visual evidence of pinniped predation because most attacks occur at night (Pemberton and Shaughnessy 1993, Tillapaugh et al. 1993). Failure to properly distinguish between pinniped species is also a problem. Because visual observations are often only of the upper portion of the animal's head when its above water, and usually at a distance, it can be difficult to accurately identify seal and sea lion species (van de Wetering 1989). Also, it is possible that predation-related losses by wildlife other than marine mammals may be attributed to pinnipeds. In British Columbia, river otters (*Lutra canadensis*) have been identified as the most frequent non-marine predator at fish farms (Rueggeberg and Booth 1989, Fraker 1996), and in one survey, otter-related salmon losses were estimated to be 30,600 fish on 22 farms in 1988 (Rueggeberg and Booth 1989). Accurate identification of predator species is important in order to institute the proper predator control measures at fish farms (Fraker et al. 1998).

Further circumstantial evidence implicating pinniped-related salmon losses include the observation of animals in the vicinity of the farm just prior to discovery of holes in the net pens (Rueggeberg and Booth 1989). Because the location and size of holes are indicative of the type of predator attack, it should be relatively easy to distinguish the species involved (Campbell 1991). However, holes can also be created in net pens by damages from flotsam, logs, equipment snags, cleaning, boat propellers, poor net handling practices, lack of net maintenance and old age, heavy currents, and severe weather (Rueggeberg and Booth 1989, ARM 2000). World-wide claims of predator-related net damage in 1999 were listed by one insurance company as relatively infrequent, but found seal damage could still take place even with apparently strong nets (ARM 2000).

Tillapaugh et al. (1993) suggested that indirect losses are greater than direct losses, and indicated that 1991 losses in B.C. exceeded $8 million, i.e., $4 million direct plus >$4 million indirect). Fraker (1996) estimated a loss of $10 million due to pinnipeds, and although DFO (1997) has referred to this value, it is unclear how these estimates were derived. Fraker's estimate was 6.4% of the value of the industry in 1996, according to the 1996 farm-gate production value of $156 million (Figure 2). With a 1% loss (Booth and Rueggeberg 1989), the estimate should be about $1.5 million. Apparently, the $10 million estimate included losses not only from direct losses (mortality and escapes) but also indirect losses from increased susceptibility to disease, decreased feeding/growth rates, etc. (M. Fraker, TerraMar Environmental Research Ltd., Sidney, BC, per. comm.). This estimate was apparently determined based entirely on opinions of persons involved in the industry. There was no attempt to document the losses, so there appears to be no known credible database that documents salmon losses due to pinnipeds by fish farm, geographical location or as a percentage of the production of the farm. In 1996, salmon production was 27,756 t, and almost doubled to 49,100 t in 1999 equating to a farmgate production value of $292.2 million (BC Fisheries 2000a, DFO 2000) (Figure 2). It remains unclear that salmon losses due to predation have increased proportionally over this time period, since many countermeasures against predation are being utilised. Regardless, while a loss rate of 1% may be substantial in an absolute amount, as a percentage of production it seems to be well within the limits of measurement error and can thus be considered statistically insignificant on a site production basis. If nets are torn by pinnipeds at a specific farm and a large number of fish escape, then this would be more significant at that site, but also probably indicative of a lack of use of appropriate predator protection devices, described below.

The above observation is not intended to suggest that predation losses may be more of a perceived problem than a real one. While published, scientific documentation of the magnitude of kills is lacking, some losses are obviously occurring and the potential for great loss through net damage is high. Individual fish, particularly brood stock, are valuable and no farmer wants to lose any fish.

**Development of Predation Control Methods**

Efforts to develop more effective devices to protect farmed fish from pinniped predation and to reduce the need for lethal methods of predator control continue. Negative public opinion of salmon farmer's killing seals was identified as an industry problem in the late 1980s (Dixon 1989, van de Wetering 1989). In an effort to minimise the killing of pinnipeds, the BC Salmon Farmers Association (BCSFA) announced on May 4, 2000, the formation of a special task force composed of federal and provincial government officials and fisheries stakeholders to identify non-lethal solutions to the recent rise in conflicts with marine predators. Until the recommendations of the task force are received, their news release stated "…salmon farmers will protect their farm stocks by focusing on predator prevention and deterrence. Destroying sea lions or other predators will be reserved as a last resort, and will only occur when they threaten human safety, or threaten to cause significant escapes of farm salmon or extraordinary losses to farm stocks." Particular concern was expressed about the recent killing of predators at fish farms in Clayoquot Sound, where some farm sites have now apparently voluntarily removed firearms, in consideration of the United Nations Biosphere Reserve designation (BCSFA 2000b).

Several studies have found an increase in predation problems with increased proximity to seal haulouts (Ross 1988, Pemberton and Shaughnessy 1993). Locating salmon farms an appropriate distance from seal haulouts may not always be a solution, as pinnipeds tend to be widely distributed and have numerous haulout sites (Olesiuk 1999). Tillapaugh et al. (1993) suggested that pinnipeds may relocate to haulouts close to a farm if pinniped attacks are successful, although there is no evidence of this actually occurring. Seals and sea lions begin to attack salmon when they reach 400-800 g (Fraker 1996). Seals and sea lions, because of their intelligece, relatively large size, high energy need, and high trophic level in the ecosystem, are persistent predators that will continually probe a farms defenses, looking for opportunities to meet their food needs. Tillapaugh et al. (1993) observed that pinnipeds can hunt in groups. They may wait until fish are herded into a corner by the movement of the pliable net in the undulating waves, then attack by pushing against the net wall and pinning the fish against an opposite wall where they can be caught or wounded.

Business risks to net pen farmers from marine mammals are both production and market related. Production lost to marine mammals occurs in several ways. First, there is direct predation. The higher freeboards and strength of modern net pens makes it more difficult for predators to get inside, but incidents still occur. The majority of attacked fish die almost immediately, their livers and soft bellies eviscerated. Grower testimonies give a consistent description of seal attacks on pens. Visual observations from the surface and physical evidence (net damage, fish remains) indicate that an attacker rushes the pen underwater. The fish respond by grouping tightly in a corner or pocket of the net, where they can be attacked from below, i.e., through the lower sides or bottom of the net. A net may not necessarily be damaged, but the attacker is able to bite off and suck parts of the fish through the net (NMFS 1996, NOAA 1997). The location of the attack can be identified by damage to the net, fish parts smeared in the net, and marks or a clearing in the bio-fouling on the nets. Growers report that attacks will continue to occur at a particular spot on a particular pen even after nets have been repaired and cleaned.

Secondly, there can be lost production by a loss in body weight of the fish. The stress on a population subjected to repeated attacks by predators shows itself in poor feed conversion efficiency. Stress may also manifest itself in greater vulnerability to disease (D. Kieser, DFO, Nanaimo, BC, pers. comm.). Some attacked fish are merely injured, not killed. Growers report that injured fish are particularly susceptible to disease where flesh or scales are damaged. Once a disease, such as furunculosis or BKD, finds a host in an injured fish, all fish in the pen are at greater risk. Studies show that environmental stresses enhance production of cortisol in some anadromous fish. Cortisol is a steroid hormone that, at high levels, suppresses a fish's immune system and increases its susceptibility to disease [Pickering and Pottinger 1985, as cited in Ross (1988) and Anderson (1990)].

Thirdly, there can be lost production through escapement. Fish escape from net pens through holes in the net walls made by marine mammals biting through the fabric. Incidents by BC farmers for holes in nets increased from 10% to 20% over the 3 years 1995 – 1997 (Fraker et al. 1998), with predators cited as the main cause (Nash et al. 2000).

Salmon farmers go to considerable lengths to prevent or deter predation-related losses. The extent of predation and the deterrence strategies employed varies among farms. There is no standard strategy. Some growers claim dogs on a farm reduce predation. Measures that have been tried or considered for reducing or eliminating pinniped predation on salmonids are harassment, aversive conditioning, exclusion from selected areas, removal of offending pinnipeds, and pinniped population control. Appendix 3 summarises the pinniped deterrent observations of Fraker et al. (1998), and approaches tried to date are briefly discussed below:

### 1. Harassment

Methods to directly deter pinnipeds from fish predation include noise and tactile and vessel harassment. Deterrence efforts involving noise (underwater firecrackers, cracker shells, acoustic devices, and predator sounds) are based on the assumption that noise startles, warns, scares, or causes physical distress to pinnipeds, thereby moving them from the area. Some non-lethal deterrence measures may be effective initially or be effective on new animals, but become ineffective over time or when used on new animals in the presence of other animals that do not react to deterrence.

a) **Seal Bombs –** powerful underwater firecrackers have been used to disperse pinnipeds. They have been effective short-term, but over the long-term with repeated use, sea lions and seals learn to ignore the noise (Fraker et al. 1998). Because seal bombs are explosive, there is an inherent danger that they will explode when being handled by salmon farm staff.

b) **Cracker Shells –** Cracker shells are shotgun shells containing an explosive projectile, designed to explode about 50-75 yards from the point of discharge. Although the noise may startle the pinnipeds and cause them to temporarily flee, there is usually no physical discomfort to the animal involved since the explosion is in the air or on the water surface. They have been used with limited effectiveness because pinnipeds learn to avoid or ignore the noise.

c) **Acoustic Harassment/Deterrent Devices (AHDs and ADDs) –** These are electronic sound-producing devices intended to generate sounds that are irritable or painful to predators and hence keep them from fish farms. Terminology to describe them has not been used consistently. Originally, they were referred to as “acoustic harassment devices” (AHD) (Mate and Harvey 1987), but in 1993, DFO coined and adopted the term “acoustic deterrent device” (ADD). The term ADD is now widely used to refer to low amplitude devices, commonly referred to as “pingers”, that are used to indicate delineate the presence of nets, while the term AHD refers to high-amplitude devices intended to produce sounds loud enough to be irritable or painful.

   Over the course of development, AHDs have become more powerful. The original AHDs developed in the late 1970s and early 80s were relatively low-power units (135-140 dB) that operated on the principle of producing unfamiliar sounds that startled seals, but animals quickly habituated to these devices (Anderson and Hawkins 1978, Mate and Harvey 1987). In the early 1990s, more powerful ADDs (195-220 dB) generated sounds uncomfortable to seals. A recent AHD model, which has yet to be tested due to environmental concerns, can emit sounds up to 240dB, along with associated shock waves (National Marine Fisheries Service (NMFS) 1999).

With the advent of increasingly powerful AHDs, concern has grown over the impact on non-target animals, such as whales and porpoises. In 1993, the DFO adopted an interim policy allowing the experimental testing of a limited number of high amplitude acoustic devices, along with the formation of an Underwater Sound Impact Steering Committee (USISC) to investigate effects on non-target animals. Between 1993 and 1996, the number of authorised AHDs increased from 6 to 17. In all cases, authorisations were conditional upon the farms maintaining operational records detailing periods of operation along with observational records of marine mammal activity. During this period, the USISC completed a number of studies including an assessment of sound levels and propagation characteristics (Haller and Lemon 1994) and an assessment of the behavioural response on harbour porpoise (Nicol and Sowden 1994, Olesiuk et al. 1995b). The studies found that the sounds propagated great distances and would be audible to porpoise up to 40-60 km, and that there was a dramatic decline in porpoise abundance within at least several kilometres of the source when the devices were activated (Olesiuk et al. in press). Similar observations have since been shown by Johnston (1999) and have been noted for other cetaceans in general (Morton 2000).

While the environmental impacts of AHDs were of concern, it also became obvious they were ineffective at deterring seals (Nicol and Sowden 1994, Olesiuk et al. 1995a, Norberg 1998, from Nash et al. 2000). Indeed, some of the largest harbour seal kills at salmon farms occurred while AHDs were in use, and seal attacks did not decline until AHD use was discontinued and larger enclosures installed (see the example in Figure 14). The loss of effectiveness is presumably due to hearing loss or impairment over time (Reeves et al. 1996). Given their far-ranging impacts on a variety of non-target animals, potential for injury and hearing loss to seals and sea lions, and ineffectiveness at deterring predators, DFO has adopted a policy, as recommended by the EAO (Iwama et al. 1997), of phasing out and prohibiting their use. No permits have been issued in recent years to operate the devices.

d) **Predator Sounds –** The effectiveness of pinniped predator vocalisations to frighten sea lions has not been consistent. Pinnipeds have sometimes shown immediate avoidance responses to the projection of killer whale sound recordings, but generally they become habituated when killer whales do not appear.

e) **Chasing by Vessels –** Chasing or hazing sea lions with a vessel proved to be ineffective at the Ballard Locks, as animals learned to avoid the vessel (Gearin et al. 1986, 1988). Hazing is time consuming, relatively expensive and usually unsuccessful.

f) **Tactile Harassment –** Tactile harassment involves shooting pinnipeds with non-lethal projectiles such as rubber bullets or blunt tipped arrows. Blunt tipped arrows were tested by the Washington Department of Fish and Wildlife (WDFW) on sea lions at the Ballard Locks, Seattle, WA, with no significant change in predation rates (Gearin et al. 1986, 1988). Rubber projectiles discharged from a shotgun were tested by the Oregon Department of Fish and Wildlife (ODFW) on sea lions at Willamette Falls, with limited success.

g) **Aversive Conditioning –** Aversive conditioning is the application of an unpleasant or painful stimulus to train animals to avoid a specific behaviour. Taste aversion is a form of aversive conditioning that involves putting an emetic (lithium chloride) into a prey species to induce vomiting when the prey is consumed. This was attempted on sea lions at the Ballard Locks with little success (Gearin et al. 1986, 1988). A variation of this method is to dart lithium chloride directly into the pinniped when it consumes a fish or enters an area (Pemberton et al. 1991). This latter approach has not been field-tested in Canada.

h) **Predator Models –** Although media reports on the use of a killer whale model indicated that it was effective in repelling seals from net pens in Scotland, use of the same model at net pens in Maine had no effect in repelling seals. Observations of pinniped behaviour in the presence of their predators and during field-testing of the model has shown that these methods are ineffective over the long term.

## 2. Pinniped exclusion from selected areas around salmon farms

Predator netting, maintenance of net rigidity, using rounded and larger nets, reduction of net mesh size, and installation of perimeter fencing, including electric fencing to primarily deter river otters, have been used to keep marine mammals away from net pens (NMFS 1996).

a) **Predator Nets –** These are usually made of a large mesh heavy nylon or polypropylene twine and hung outside and around individual or groups of net pens. The most common design has panels hung from the walkways to a depth several meters greater than the pen, and in most cases have a floor. The foot of the predator net is usually weighted. Predator nets represent substantial initial and recurring cost to the growers. Consequently, not all farms employ the nets on all cages. In addition to materials and installation, costs are incurred regularly for servicing, repairing, replacing, and cleaning. Predator nets are only effective if they prevent seals from accessing the pens. If the nets are left too slack or the space between the predator net and net pen is insufficient, the current can push the pen against the predator net, exposing the fish to possible attack (Arnold 1992). If a predator net is present, the predators have to either:

    1. wait for the current to bring the primary net into contact with the predator net,
    2. force the predator net into contact with the primary net,
    3. wait for or create a hole in the predator net, or
    4. find a way over the predator net.

b) **Perimeter nets –** Perimeter nets are hung from piles along the perimeter of the lease site. They can be problematic and expensive (piles, repair, cleaning, getting to and from the pens). Certain types of nets will entangle predators, leading to drowning. Shark guards are relatively small-mesh netting suspended beneath net cages to prevent dogfish from scavenging dead fish, or “morts”, that have fallen to the bottom of the cage and creating holes in the net in the process. Such nets are unlikely to entangle pinnipeds. There are, however, no data on the number of pinnipeds being entangled and drowned at B.C. salmon farms. The drowning of marine mammals has been deemed to be inhumane in Canada (Malouf 1986). However, the use of nets (e.g. gill nets) in Canada that might potentially cause pinniped entanglement is legal, and if pinnipeds are caught, then this becomes a bycatch issue (M. Joyce, DFO, Vancouver, BC, pers. comm.).

c) **Bio-Fouling of Nets –** Fouled nets are much heavier and the seals have greater difficulty pushing in the net and getting at the fish. Also, fouling reduces a pinniped’s ability to bite and suck fish through the mesh. The detrimental effects of fouling are the reduced water flow, increased drag, and increased weight in handling. Fouled nets may also obscure or conceal the fish (Fraker et al. 1998). The treating of nets with anti-foulants has increased in recent years, which may indirectly have caused an increase in the number of holes in nets, but a cause and effect relationship has not been proven. The average age of netcages has increased, and it is also possible that older, weaker nets are more vulnerable to holing (Fraker et al. 1998). The use of Flexgard 11 (Flexabar-Aquatech Corporation, Lakewood, N.J., USA), a particularly heavy water-based latex, copper oxide anti-foulant, is considered a key to the success Stolt Sea Farms has had in mitigating predator attacks (Gary Robinson, Stolt Sea Farms, pers. comm.).

**3. Non-lethal Removal of Offending Individual Pinnipeds**

Capture and relocation efforts with California sea lions at Ballard Locks, Seattle, WA, indicated that transporting captured sea lions relatively short distances was not effective, as the sea lions quickly returned (Gearin et al. 1986, 1988). Translocation of harbour seals off Vancouver Island was also concluded to be ineffective, as the vast majority of animals (including those translocated from Nanaimo to as far away as Bamfield) returned to the capture site (Olesiuk et al. 1997). pinnipeds are not easily captured, particularly those that have been once-captured.

**4. Lethal Removal of Offending Pinnipeds**

In situations where non-lethal measures are successful on the majority of pinnipeds in an area, lethal removal of the experienced/habitual predators combined with non-lethal deterrence may be an effective short-term means of controlling pinniped predation on farmed salmonids. However, such an approach should be considered a last resort and only be utilised if all other approaches have failed

A Royal Commission of Seals and Sealing in Canada conducted a detailed assessment of lethal predator control (Malouf 1986). The Commission's recommendations and DFO responses represents government policy on the issue of predator control. These recommendations are summarised here, as we believe it is important to bring all relevant information together in this one report to give readers a better understanding of how DFO has previously addressed the issue of killing pinnipeds. Malouf's recommendations and DFO's responses were as follows:

1. Any population control should be done under government supervision. **DFO response: DFO agrees with this and our first priority will be to ascertain whether a cull is able to be performed by trained government employees. If such is not the case we will certainly have the cull done under government supervision.**

2. Fishermen fishing fixed gear, including aquaculture establishments, may be given licences to kill "nuisance" seals in the vicinity of their gears under strict controls, with provision for a recompense for return of biological material of value to research programs. **DFO response: The government agrees but will require proof that such licences are necessary, that seals will be killed humanely and that there is no threat to the seal stock.**

3. Any population control programs should be designed to provide detailed data on such matters as the number, age, sex, location, and parasite load of the animals killed, and be associated with continued monitoring of the population concerned to determine any changes in number, structure, and principal biological parameters of the population, as well as the efficacy of the population control measures. **DFO response: The government agrees. Research necessary to monitor the effects would be part of any seal population control programs.**

**4.** In view of the suffering involved, the government should take action with a view to phasing out, as rapidly as possible, the netting of seals 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. **DFO response: The government agrees.**

Many of the above recommendations appear not to have been applied by DFO to pinniped killings by salmon farmers in British Columbia: 1) killing of pinnipeds is not being done under government supervision; 2) a low number (see below) of pinniped carcasses are being recovered for biological sampling, and biological data collected are not being analysed in a timely manner; and 3) pinniped populations are not being assessed in all areas where pinniped kills are being made.

**Predator Control Program**

The first marine mammal predator control permits in B.C. were issued in 1989 to two salmon farms in response to serious predator problems. The number of predator control licences issued increased markedly in 1990 (Fig. 3) as the DFO Aquaculture Division promoted the issuance of permits. By 2000, a total of 116 predator control permits were issued. The recent increase is largely attributable to a procedural change that occurred in the mid-1990s, when licenses began to be renewed automatically each year. As a result, recent figures include some sites that are now either fallow or otherwise inactive. The number of sites actually reporting predator control kills has increased only slightly since the program was introduced.

The geographic distribution of sites holding predator control permits has remained fairly constant over the last decade (Fig. 4). In order to facilitate an assessment of the impact of predator control on pinniped populations, geographic areas were chosen to correspond with those used to monitor and assess harbour seal populations (see Figure 1a in Olesiuk 1999a). Main concentrations of fish farms occurred in the north-east Strait of Georgia (10%), mid-west Vancouver Island (23%), and the Broughton Archipelago (12%). A substantial number of the licensed farms (38%) occurred in areas where harbour seals have not been systematically surveyed, mostly between the north end of the Strait of Georgia and the south end of Queen Charlotte Strait - Broughton Archipelago.

In 1990, marine mammal Stock Assessment Division staff in the Marine Mammal Program worked with Aquaculture Division staff to develop a predator control and monitoring program. The primary purpose of the program was to obtain estimates of the numbers of seals and sea lions killed, so as to provide a means of assessing impact on pinniped populations. This was achieved by requiring that quarterly reports, including nil reports, be submitted. The reports specified information on the date, species, and certainty of kill. Farmers were also required to retrieve and sample carcasses, in order to facilitate more detailed assessment, since sustainable kill rates can vary depending on the age and sex of animals killed. Realising there would be no way of independently verifying the information provided in the reports, the program was designed to provide no incentive for under-reporting, such as quotas. A copy of the instructional material for biological sampling and the quarterly report form to be submitted by licence holders is included in Appendix 4. Information provided by the quarterly reports was recently compiled in a geo-referenced database, which forms the basis of the assessments that follow.

**Harbour Seal Kills**

Over the course of the predator control program (to December 31, 2000), an estimated 5,341 harbour seals were killed. This number was estimated by assuming that 100% of the kills reported as positive kills, 75% of those reported as probable kills, and 50% of those reported as possible kills were actually killed. Small adjustments were also made to account for quarterly reports missing or not filed (60 and 40 seal kills respectively). Numbers for 2001 were projected from reports filed for the first three quarters based on the proportion of kills taken in the first two quarters in previous years. The total also includes estimates of 3 seals killed in 1989 and 790 in 1990 provided by Aquaculture Division prior to the monitoring program being introduced. It is not clear how these two values were derived, but they appear to have been extrapolated from the number of kills made by a few sites that filed reports to the total number of licenses issued.

In addition to the estimated number killed, over the same time period, an additional 358 harbour seals were shot at but apparently escaped or were assumed to be non-lethally injured.

Since the predator control program and monitoring program was established, the annual number of harbour seals estimated killed or escaped/injured has remained fairly constant, averaging about 455 and 36 respectively (Fig. 5). Although the total number of seals killed has remained constant, the average number killed per licensed site has declined by almost half, from six to eight kills in the early 1990s to about four kills in the late 1990s (Fig. 6).

Most kills were made during winter, in the fourth quarter (October-December) and sometimes into the first quarter (January-March) of the next year, except during 1998-99 when kills per quarter were all relatively similar (Figs. 7, 8). The seasonal pattern indicates seal attacks are most prevalent during the non-breeding season; nearly half of all kills (48%) occurred during October to January.

The recovery rate of carcasses showed a seasonal pattern (Fig. 9) somewhat different than kills (Fig. 7), with peaks in the fourth quarter, but was far below kill values. In most instances (96%), the reason specified for not recovering the carcass was that it sank. One would expect recovery to be greatest during winter when animals are in peak nutritional condition and lowest during summer and autumn when reserve fat is lowest (Pitcher 1986, Boulva and McLaren 1979). However, the overall carcass loss rate (3,215 of 3,502, or 92%, of positive kills) should be lower than is being reported, suggesting that adequate effort may not being given for carcass recovery, as required by the control permit. Bigg (DFO, Nanaimo, BC, unpublished data) estimated that 50% of harbour seals shot during the commercial hunt in B.C. were lost, and Fisher (1952) estimated that 40% of harbour seals shot for bounty were lost. Lost carcasses means no biological data is obtained for those animals killed.

The introduction of the predator control program coincided with a change in the status of harbour seal populations in British Columbia (Fig. 10). During the 1970s and 1980s, prior to any predator control permits being issued, populations throughout B.C. were increasing exponentially at a rate of about 12% per annum. This increase is believed to represent the recovery of populations that had been depleted by predator control programs and commercial harvests prior to the species being protected in 1970. By the 1990s, growth rates began to subside and the population subsequently appears to have stabilised. Although the levelling-off of populations in the 1990s corresponds with the implementation of predator control at fish farms, a cause and effect relationship is unclear. The overall population trends were based on aerial surveys conducted in index areas distributed throughout the province, including some areas far removed from fish farming, such as the Queen Charlotte Islands and lower Skeena River. The stabilisation of populations may have been a density-dependent response as recovering populations attained historic levels (Olesiuk 1999). This being the case, the increase in seal attacks and introduction of the predator control program may have actually been precipitated because the population was approaching carrying capacity and competition for food resources was increasing.

Harbour seals are generally non-migratory, and usually exhibit a high degree of fidelity to a particular haulout site or area (Olesiuk et al. 1997). Animals typically forage within 10 kilometres of haulout sites (Olesiuk 1999b), although animals may undertake seasonal movements on the order of several tens of kilometres (Cottrell 1995). A number of recent molecular genetic studies on macro-geographic structure have indicated that harbour seals were philopatric on a scale of a few to several hundred kilometres and that the extent of heterogeneity was correlated with geographic distance, even in the absence of physical barriers such as open expanses of water (Westlake and O'Corry-Crowe, in press; La Mont et al. 1996; Stanley et al. 1996; Goodman 1998; Burg et al. 1999). It therefore seems appropriate to assess the impact of predator control kills on a more regional scale than the entire B.C. coast.

For each of the geographic subareas used to assess harbour seal stocks (see Figure 1 in Olesiuk 1999), we calculated the sustainable harvest rate at the Maximum Net Productivity Level (MNPL; Taylor and DeMaster 1993). The MNPL represents the maximum number of seals that can be harvested; if kills exceed MNPL the population will decrease, and if kills are less than MNPL, the population will increase the area's carrying capacity is attained. As outlined in Olesiuk (1999), MNPL was estimated to be 11.4% at 75% of carry capacity for the Strait of Georgia, and 12.1% at 70% of carrying capacity in other regions of British Columbia.

In most cases, the annual kills of harbour seal at fish farms fell below MNPLs (Fig. 11). A notable exception was the Broughton Archipelago, where during 1992-97 the number of seals killed by salmon farms exceeded MNPL by up to a factor of ~3, which would lead to depletion of the local population. Indeed, during 1989-96, the two aerial surveys conducted in the Broughton Archipelago indicated that abundance declined by 26%. This was the only area surveyed that exhibited a decline, whereas other areas surveyed showed an average increase of 20% over the same period (Olesiuk 1999). The kill at one site in Jervis Inlet in 1991 was 80% of MNPL, but dropped abruptly when the farm changed ownership the next year. Harbour seal kill rates have been increasing in mid-west Vancouver Island, and are now on the order of 70-80% of MNPL.

Most of the kills in this geographic subarea occur in the southern portion (Clayoquot Sound) where salmon farms are most concentrated, whereas seals are distributed throughout the area, so seal kills by salmon farmers within the southern portion of Clayoquot Sound may have exceeded MNPL. While it was not possible to precisely estimate MNPL for areas where harbour seals have not been systematically surveyed but which support high concentrations of fish farms (principally the area between the north end of Quadra Island and the south end of Queen Charlotte Strait – Broughton Archipelago), a crude estimate was made by applying the mean density of seals in surveyed areas to the unsurveyed area. These crude calculations indicate that seal kills by salmon farmers have been on the order of 30-45% of MNPL. Kills in other regions were generally on the order of 10-25% of MNPL, and therefore likely pose little threat to harbour seal populations.

It should be noted that the predator control kill statistics are subject to several biases, most if not all of which would tend to underestimate the impact on seal populations. There are numerous indications that not all predator control kills were accounted for in the database used for this analysis. While compiling the data, we came across notes that referred to kills for which there was no record; for example, a note on one quarterly report indicated that 28 seals had been shot by the previous owner, but there was no record of any such kills, and therefore these data could not be included. We came across and corrected several instances where kills had been inadvertently reported twice, but had no way of detecting cases where kills had inadvertently not been reported at all. Over the years, the co-author (P.O.) has been contacted on several occasions by fish farm employees who were conducting predator control, but were not aware of reporting or sampling requirements. Quarterly reports were often compiled and submitted by company head offices, so it is possible that kill records not communicated from individual sites would have been filed as nil reports. Reported kills should therefore be considered an underestimate of the number of kills that actually occurred. It should also be noted that MNPL estimates represent the sustained take for all human-induced mortality, and would thus include not only predator kills at salmon farms but predator kills at spawn-on-kelp operations, subsistence harvests, entanglement in fishing gear and debris, illegal shooting, etc.

In any given year, the harbour seal kills were not uniformly distributed among fish farm sites. Instead, most of the sites reported a small number of kills whereas a few sites reported high kills (Fig. 12). On average, the 50% of licensed sites reporting the fewest kills accounted for less than 10% of the total kill, whereas the 10% of licensed sites reporting the highest kills accounted for 40-60% of the total kill. In many cases the same sites consistently reported few kills year-after-year, whereas others consistently reported high kills. For all years combined, 10% of license holders accounted for 40% of all seal kills, whereas 50% accounted for only 10% of all seal kills.

In order to assess reasons for the skewed distribution of kills, we examined the 10% of sites reporting the highest kill rates (Table 7) in greater detail. These sites were widely distributed (Fig. 13), and in general reflected the overall distribution of fish farms (Fig. 1). Known seal haulouts are shown in Fig. 14, and it can be seen that haulout locations over much of the coast are undocumented. Minimum distance from seal haulouts (Olesiuk 1999), where data are available, ranged from 1.0 to 6.8 km (mean = 3.6 km). One-third of these sites were more than 5 km from the nearest haulout site, indicating that the current siting guideline of 1 km imposed by the provincial government has little biological basis. However, there were many additional sites within 3.6 km of harbour seal haulouts that experienced very few problems. Indeed, many of the high-kill sites were close to sites with low kills (Fig. 13). This suggests that factors other than distance from haulout sites affect the severity of seal predation problems or the perceived need to kill pinnipeds.

Several of the sites accounting for the highest kills seem to have dealt with the problem in recent years, as indicated by sharply reduced kill rates in recent years. Unfortunately, a lack of information on the type of infrastructure, production levels, and predator defence mechanisms at sites precluded a detailed analysis as to why this has occurred. Nevertheless, one example worth noting is several sites in the Broughton Archipelago owned by Stolt Sea Farms. During the early 1990s, these four sites were consistently in the 10% of sites reporting the highest number of seal kills and had an estimated combined kill of 616 harbour seals (Fig. 15). During this period, the company made numerous efforts to reduce the problem, using acoustic harassment devices (AHDs) and retensioning predator nets, but with little success. Harbour seal kills by these four sites alone were sufficiently large to have depleted the seal population in Broughton Archipelago. However, the kill rates dropped dramatically during the late 1990s when the company moved to large polar circle nets with Flexguard dipping, and the overall kill rate in the Broughton Archipelago has now been reduced to a level that would allow the recovery of the harbour seal population. This company has voluntarily removed firearms from the sites, and now contracts professional hunters to deal with the occasional nuisance seal.

**Sea Lion Kills**

Over the course of the predator control program (to December 31, 2000) an estimated 902 sea lions were killed. This includes 316 Steller sea lions, 565 California sea lions, and 21 that could not be identified to species. As was the case for harbour seals, these estimates were based on the number and certainty of reported kills, with small corrections to account for missing reports. An additional 80 sea lions were shot at but escaped or were non-lethally injured.

In contrast to harbour seals, the number of sea lions killed annually has increased sharply in the past few years, from negligible levels to a projected kill of 267 in 2000 (Fig. 16a). Since the first sea lion kills were reported in 1991, the increase has been exponential at a annual rate of 38.1% (Fig.16b), which indicates the numbers killed have been doubling every 2.1 years. The increase was reflected by a sharp increase in the average number of sea lions killed per licensed site (Fig. 17).

As was the case with harbour seals, there is a distinct seasonal pattern in the sea lion kill, with most being taken in the first two quarters (January-June) of each year, and virtually none in the third quarter (July-August) (Fig. 18). This roughly coincides with the seasonal dispersal of animals from rookeries and offshore year-round haulout sites during the breeding season in June-August, into inshore feeding areas once breeding has been complete (Bigg 1985). It also roughly coincides with the post-breeding northward migration of California sea lions, which breed off California but winter as far north as Vancouver Island (Bigg 1985, Bigg and Olesiuk 1988).

Figure 19 shows the overall seasonal pattern of sea lion kills in more detail; most kills were concentrated in January-April. Although sea lions actually begin arriving on winter feeding areas in September and have attained peak winter abundance by October (P. Olesiuk, unpublished data), predator attacks do not increase until mid-winter, which coincides with the period in which sea lions are feeding primarily on herring and follow herring schools (P. Olesiuk, unpublished data). The distribution of pre-spawning herring, especially as it relates to the distribution of fish farms, may thus be a major factor in determining the magnitude of sea lion attacks and numbers killed.

The recovery (and hence sampling) rate of sea lions reported as being positively killed showed the seasonal patterns expected, but was again far below kill values (Fig. 20). Only 64 of 724 (9%) carcasses were recovered and sampled. In most instances (96%), it was reported that carcasses were not retrieved because they sank. Recovery rates varied seasonally, with a distinct peak in March-May. This coincides with the end of the winter feeding period when animals are about to return to rookeries and offshore haulouts. Sea lions wintering off Vancouver Island undergo pronounced seasonal fattening over winter, and are comprised of 13-19% fat by spring (Olesiuk and Bigg 1986); few would be expected to sink during the months that most are killed.

Assessing the impact of predator control kills on sea lions is not nearly as straightforward as for harbour seals. Sea lions do not exhibit the same degree of site fidelity, and undertake significant seasonal movements. While the breeding rookeries and offshore haulouts occupied during the summer breeding season are stable over many decades and probably even centuries (Bigg 1985), most interactions with fish farms occur when sea lions are in winter feeding areas. During winter, the animals are highly mobile, and tend to concentrate where prey are abundant. Branding and tagging studies have shown, for example, that California sea lions captured in Puget Sound are routinely observed on the west coast of Vancouver Island and Strait of Georgia, and can move among these areas within days (P. Olesiuk, unpublished data).

Since MNPL estimates area not available for sea lions, we estimated the impact using two stock assessment procedures. First, we calculated surplus production, which is equivalent to the current rate of population increase. It represents the number of animals that can be removed that will result in a stable population. Second, we calculated the potential biological removal (PBR). PBR is a technique developed by U.S. stock assessment experts to estimate the allowable limits for human-caused mortality (Wade 1998). It represents the maximum take, with allowances for biases in data that would maintain a population at or above MNPL. As recommended for migratory and trans-boundary stocks (Wade and Angliss 1997) the estimates were apportioned based on the abundance and time the stock resides in Canadian waters.

California sea lions breed off the coast of California. Populations currently number about 167,000-188,000 and have been increasing at 5.4-8.3% per annum (Hill et al. 1997), so the few hundred animals killed at salmon farms does not pose a threat to the overall population. However, the waters off Vancouver Island represent only a small fraction of the wintering range, with the number of animals wintering in this region stable over the last decade at about 2,000-3,000 animals (P. Olesiuk, unpublished data). Assuming animals spend half the year in Canadian waters, the apportioned surplus production would be on the order of 50-125, and the PBR on the order of 60-90. It thus appears that in recent years, the California sea lion kills by salmon farms have exceeded the desired sustainable level, and in the first two quarters of 2000 did so by a factor of 2-5. Considering that the kills were concentrated along the mid-west coast of Vancouver Island (MWVANISL) (Fig. 21), which represents only about 3% of the wintering range in Canadian waters but accounts for 58% of all kills, the level of killing exceeds the sustainable take that would be apportioned to that area by a factor of about 50.

With respect to Steller sea lions, the B.C. breeding population currently numbers (as of 1998 survey) about 12,000 and has been increasing at a rate of about 2-3% per annum (Olesiuk 2001). Annual surplus production is thus on the order of 240-360, and PBR on the order of 720. During the last two years, kills of Steller sea lions at fish farms thus represent about 20-30% of surplus production and 10% of PBR for the B.C. coast. However, on a localised scale, when one considers that MWVANISL represents only 5% of the B.C. coast but accounted for 58% of the total Steller sea lion kill, the kill in that region has exceeded surplus production by a factor of 2-3 and was about equivalent to the PBR.

As was the case with harbour seals, sea lion kills were not uniformly distributed among sites. Instead, many sites reported zero or few kills whereas a few sites reported high kills, with the skewed distribution being even more pronounced than for harbour seals (Fig. 22). On average, the 80% of licensed sites reporting the fewest kills accounted for less than 10% of the total number of kills, whereas the 10% of licensed sites reporting the highest kills accounted for 60-90% of the total number of kills. However, the sites reporting abnormally high kills often changed from year to year, so the concentration was not quite as skewed when averaged over years. During the past 5 years, the period in which most of the sea lion kills occurred, 50% of licensed sites killed essentially no sea lions, the 80% of sites with the lowest kill rates accounted for only 20% of all kills, and the remaining 20% of sites with the largest kills accounted for 80% of all sea lions killed.

In contrast to the sites reporting large harbour seal kills, which were widely distributed, the sites reporting the largest number of sea lions kills (Table 7) were concentrated in Clayoquot Sound and Kyuquot Sound (Figs. 21 and 23). This suggests that the severity of sea lion problems may be related to the distribution of wintering sea lions. However, not all sites in these regions reported large sea lions kills, but due to paucity of information on infrastructure and predation defence mechanisms employed at the various sites, other factors that may have affected the severity of sea lion problems could not be evaluated.

## Discussion

Seals and sea lions have to be successful in capturing farmed salmon if they are going to become persistent and problem predators to fish farms. If they are able to satisfy their food requirements more easily without attacking a salmon farm, and are not introduced to positive experiences (i.e. salmon rewards) in obtaining salmon from salmon farms, then they would seek food elsewhere. A minimally protected aquaculture operation presents a “textbook example” of an optimal foraging situation for predators because of its high prey density and potential for a high foraging success rate. The extent of predation problems in salmon farming thus depends largely upon the type of pens used and the size of available fish in the pens at a specific farm. Based upon a report by a task force set up to study seal predation on Maine, USA, salmon farms, the NMFS (NMFS 1996) recently concluded that there is no compelling reason at this time to allow Maine salmon farmers the right to intentionally kill seals (Goldburg and Triplett 1997). Unless an aquaculture facility is made less inviting as a forage site, it has been suggested that killing predators will be ineffective predator control, as other individuals rapidly replace those killed. That appears to have been the case in British Columbia, where after a decade of predator control, there is no evidence that removing a few "nuisance" animals alone is reducing the need to continue to kill seals and sea lions.

A variety of cage shapes, designs and sizes are used throughout the salmon industry, some of which are available commercially and others that are 'home-made' to an individual farmer's specifications. Tidal regime, water circulation, extent of fouling and predation are all somewhat unique to each site, and different environmental conditions may justify different net pen designs. As a result, many farms use a combination of cage shapes and sizes, depending on the range of conditions at each site and the grades of fish in stock (Arnold 1992).

A general lack of reliable, easily accessible scientific data on the extent of the physical and economic impacts of predators on aquaculture is impeding progress toward resolving conflicts among stakeholders. Anecdotal accounts and extrapolations of data from small studies to broad, industry wide application tend to be the norm for this predation data-poor industry. Much of the available data was obtained in the 1980s and early 1990s, when fish farming was much reduced in scale and pinniped deterrent devices were in their infancy. To make reasonable approximations of economic impact of predation on any single aquaculture facility requires reliable data. Absolute loss has to be considered in the context of total salmon production and the deterrent devices in use at the time of the losses.

The farming industry is now recognising the public's feelings towards pinniped killings, and is gradually attempting to reduce production losses caused by marine mammals through the use of improved defence mechanisms. Success in reducing salmon predation losses are being slowly achieved by a combination of deliberate measures to reduce the opportunities for predators to kill or wound fish, and advances in predator control technology that would be expected from a growing profitable salmon culture industry. In British Columbia, there was one dramatic example (Stolt Sea Farms in the Broughton Archipelago) where the need for predator control was sharply reduced when the company switched to a different type of pen infra-structure. Not all industry members seem to be moving in the direction of reduced pinniped killing, and their need to use lethal techniques should not be used to justify the level of pinniped killings presently occurring.

No predator deterrent technology, however, will guarantee 100% protection against predation losses. Control methods have to be effective, economically feasible, and environmentally safe. Although available technologies will provide some protection, producers now realise they cannot rely on only one method to guard against losses. An integrated approach that combines a careful examination of facility location, design, construction, operation, and management for minimising losses due to predators along with consistent application of different effective deterrent techniques will most likely provide the best protection from predation problems.

Salmon farmers are no doubt aware that pinniped killings can harm their market. Some Shetland Island (U.K.) salmon farmers (Arnold 1992) have designed and tested several methods of increasing the rigidity of fish cages to prevent seals pushing the netting inward in order to catch the salmon, thus precluding the need for predator nets and the extra expense and maintenance that they entail. The various tensioning systems appear to have reduced seal predation at a number of farm sites. Apparently, since installing the systems, none of the operators have felt it necessary to shoot seals at their farms. Seal shooting is considered by the Scottish Salmon Farmers Association (SSFA) as a last resort, to be used when all other passive deterrents have failed, and the SSFA and Scottish Salmon Growers Association guidelines stress this emphatically.

The long-term solution for net pen complexes situated in pinniped habitats may be in engineering to improve separation of prey from predators (extracted from Campbell 1991, Tillapaugh et al. 1993, and Fraker et al. 1998). Such improvements include:

(i) tensioning and weighting of predator net walls or barriers to make them as rigid as possible. However, much futile effort has been expended in this area without success when the separation between the predator net and net pen (often only the width of the walkway) is insufficient. Recent experience suggests the rigidity created by dipping nets in heavy anti-foulant, such as Flexgard 11, may be an effective solution;
(ii) surrounding complexes or individual units or aggregation sites with improved predator nets, such as heavy duty black nylon mesh;
(iii) employing the best deterrents around floats and walkways (net, high freeboard, etc.);
(iv) redesigning the complex to avoid narrow passageways between tightly packed units where mammals may get trapped, and which provide insufficient separation between predator nets and net pens; and
(v) using larger enclosures to allow fish to take refuge from predators pressing against the outside of nets.

All these measures are becoming easier for farm enterprises to utilise, as net pen units have increased substantially in size with growing economies of scale.

The long-term solution may be for net pen farm complexes to either move away from coastal haul outs and rookeries or to become land-based. Offshore relocation is now more feasible, and the new generation of oceanic farms is moving away from gravity cages and sheltered water technology. The modern higher-class cages are built around a system of spar buoys and more rigid net panels (Ocean Spar Technologies). Fish farms in Norway are already moving further offshore in search of high quality water and to avoid near shore algal blooms.

## Identified Research Needs

Fraker et al. (1998) identified the following research requirements:

a. Presently it is not possible to reliably distinguish among fish killed by river otter, seals and sea lions. To assess the effectiveness of various countermeasures, it is important to develop means to accurately assign mortality to the proper species;
b. There are few direct observations of seals and sea lions attacking farm fish. A better understanding of how these animals respond to netcages and farm fish could lead to improved countermeasures;
c. There has been virtually no attempt to systematically study the effectiveness of various netcage systems and associated predation counter measures. An appropriate documenting of information related to predation should lead to a “weight of evidence” which will show which systems work well to prevent losses to predators;
d. The relationship between distance from pinniped haulout sites and the amount of loss from predation may be non-existent and needs to be better understood;
e. The present approach is to develop site–specific, custom netcage designs separately for each farm location. Research is needed to consider the effects of such variables as mesh size, current regime; optimal distances of predator nets from primary nets under different conditions in order to maintain an adequate separation, and how to engineer netcages to reduce drag; and
f. New materials and new treatments (anti-foulants) may offer an improved barrier to predators, and the potential here needs investigation.

Iwama et al. (1997) identified the following research requirements:

a. all pinniped haulouts should be surveyed and mapped to improve information for siting decisions;
b. pinniped population assessments in areas of aquaculture should be conducted;
c. predation problems, pinniped-farm interactions, and an inventory of pen and predator control systems should be documented and quantified; and
d. studies of pinnipeds in captivity should be undertaken to understand the dynamics of their interactions with netpens.

These research needs are likely to evolve as the industry develops and adopts new approaches for dealing with predators.  For example, treating nets with anti-foulants appears to be a promising method for stiffening nets and thereby deterring seal attacks, but environmental impacts of widespread use of such chemical now need to be considered. Industry needs to take most research responsibility, but collaboration with resource management agencies may be appropriate on some topics, such as (a), (b) and (d) above. The former BC Ministry of Fisheries was studying the degree of overlap between existing salmon farms and sensitive fish and wildlife habitats, and this may include pinniped haulouts, but no results are yet available (B. Carswell, BCMF, Victoria, BC, pers. comm.).

## Conclusions

It was concluded that:

1. There is insufficient data on which to pass scientifically defensible judgements on the current killing of pinnipeds by fish farmers in British Columbia: salmon losses, prior usage of deterrent measures and their documented ineffectiveness, and biological data on killed pinnipeds are poorly documented. Reported kill records are submitted by fish farmers, but there are no means by which to verify the data, and there is reason to expect that such reports underestimate actual kill rates.
2. There is no supporting data to indicate that killings are only being conducted as a last resort. Most killings of pinnipeds are being undertaken at a minority of tenure sites, and these are often in close proximity to sites reporting few killings. DFO policy requires strict documentation of the use of alternate deterrent measures, but such documentation is unavailable.
3. There is little evidence to date that interests from the broader client base of DFO (tourism, environmentalists, etc.) are providing effective input into developing alternative solutions to the killing of pinnipeds.
4. Data presented here suggest that kill rates of pinnipeds have been and continue to be excessive from a pinniped stock management perspective, and in some harbour seal cases, have been sufficient to reduce local populations. With sea lions, kill numbers are rapidly increasing.
5. The ecosystem implications of current pinniped kill rates remain to be addressed.
6. Additional scientific analyses will require an improved data collection process, and funding to implement required pinniped population assessments and habitat requirements.

Since there is no available evidence that documents that pinniped kills are necessary, an immediate withdrawal of predator control licences issued to fish farmers should be considered and a re-evaluation of DFO's predator control licencing system conducted.

## Recommendations

a) **Develop and maintain an on-going data base for all fish farm sites that documents: i) type of netpen and infrastructure being used; ii) predation control devices and tactics; iii) extent of salmon losses to pinnipeds by date with descriptions as to the circumstances relating to the losses. This could be accomplished by requiring each licensed site to submit a predation control plan providing detailed information. This would facilitate an up-to-date analysis of effective and ineffective pinniped deterrent mechanisms, and to document benefits and/or costs resulting from predation control measures.**
   We could find no database within DFO that documents the non-destructive predation control measures in use at farms over time, even though farmers are required to demonstrate that all such reasonable devices are being used before they could obtain a license to kill pinnipeds. As a follow-up to this, it would seem appropriate that at the farms where pinnipeds are being

killed, an annual review of such devices in use should be conducted to determine why the devices in use were not effective.

b) **Pinniped killings need to be justified and documented and, so as to insure accurate documentation, should only be undertaken by qualified licensed hunters under the supervision of DFO experts and only <u>after</u> the DFO has verified substantial farm losses, has evaluated the predation control devices in use at the farm, and has justified the need to kill selected pinnipeds. More serious effort is needed to recover carcasses and collect biological data from kills, and these data need to be analysed in a timely manner.** The high level of killings at specific farms and a lack of required data on pinnipeds actually killed (an unacceptable level of killed pinnipeds are claimed to have "sunk" and were not therefore sampled) indicates that there is currently inadequate control of pinniped killings. It must also be recognised that kill estimates are subject to biases that would tend to underestimate the number of animals killed and underestimate the impact on seal and sea lion populations. It is expected the incentive for under-reporting will grow now that there is a high public interest and because expansion of the aquaculture industry may in part hinge on the number of predators being killed. Given the DFO's mandate under the Oceans Act to minimise unjustified killing of all marine life, whether as bycatch in species-targeted fisheries or in predation controls in aquaculture, and the high economic value now associated with marine mammals, a documented and transparent process needs to be established that can be used to clearly justify all pinniped killings. Current predator control licences issued to fish farms could be rescinded, and licences to kill pinnipeds could be only issued to appropriate hunters for use under supervised situations. Approved hunters should be trained and equipped to recover and sample carcasses for biological monitoring purposes. Data and specimen collection should then be accompanied by regular analysis and interpretation. This would contribute to an improved understanding of the nature and magnitude of the interaction, and in turn could lead to more effective methods of reducing such interactions.

c) **Pinniped monitoring programs need to be developed to obtain baseline data on the abundance and distribution of pinnipeds prior to farms being located in a region, and to monitor impacts of predation control once farms have been established. Expansion of the aquaculture industry should only be permitted in areas where baseline distribution on seals and sea lions exists, so that the potential impacts of predation control can be assessed and monitored.**
DFO (1997) stated that "given that the coastal seal population is in excess of 100,000 and has an annual surplus production of about 12.5%, it is clear that this population is not compromised by mortalities attributed to predator licensing." However, given the localised movements and lack of genetic dispersal of harbour seals, it seems unreasonable to assess the impacts of kills concentrated in specific areas on a province-wide basis. The analyses presented in this assessment in fact suggest that, on a regional basis, pinniped kills by fish farmers have in some cases exceeded sustainable pinniped production levels and may have depleted local abundance. Baseline surveys are required in areas where salmon farms have already been established, particularly the area between the north end of Quadra Island and the south end of Broughton Archipelago / Queen Charlotte Strait, and in areas where industry may expand, such as the central/northern mainland coast north of Cape Caution, as has

previously been identified as a priority by PSARC (Olesiuk 1999). Monitoring programs need to be established in areas with a high density of salmon farms, such as Clayoquot Sound, which to date has only been surveyed once.

d) **Further expansion of fish farms on the west coast of Vancouver Island should not be allowed until it has been demonstrated that an acceptable resolution to the sea lion-fish farm conflict has been addressed.**
There has been a rapid exponential increase in sea lion kills along the west coast of Vancouver Island in recent years, and kill rates now far exceed what would be allocated to this region on the basis of its size. The high incidence of sea lion kills in Clayoquot Sound should be reviewed to determine whether it is compatible with the recent designation of the area as a UN Biosphere Reserve.

e) **The existing siting guideline used by the Provincial Government of not siting fish farms within one km of a seal haulout location does not appear to have a biological basis, and it is recommended that siting guidelines in relation to pinniped haulout locations be reviewed and revised.**
Most of the sites experiencing even the very highest kill rates are situated further than 1 km from the nearest seal haulout, and one-third are over 5 km from the nearest seal haulout. Telemetry studies indicate daily foraging movements of harbour seals are typically in the range of 10 km.

f) **Research and management recommendations within published reports on pinniped killings should be reviewed, priorities determined, and a plan to address them should be prepared.**
There have been a number of previous reports (e.g., Malouf 1986, Iwama et al. 1997, Fraker et al. 1998) that recommended specific research topics and/or management actions. As the lead agency responsible for pinniped management, DFO should take a more responsible and proactive role in determining whether pinniped kills are necessary and in ensuring that all kills are justified and conducted humanely, rather than leaving these decisions to the aquaculture industry.

g) **DFO should conduct an environmental assessment of enclosures that have netting heavily impregnated with anti-foulant to determine the risks of leaching .**
It appears that certain types of netpen design, such as that described above, appear to have be quite successful at reducing salmon losses due to pinnipeds, at least for harbour seals. While industry should be encouraged to move toward this type of design from a predator control perspective, it was beyond this review to consider the overall environmental acceptability of such systems. Flexgard 11 has apparently been approved by Canada for use in aquaculture, but the broader environmental aspects of this and other products should be assessed. It would also be useful to determine whether such enclosures are as effective at deterring sea lion attacks.

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Table 1: Regional summary of BC fish farm tenures in 2000. Source:  BC Fisheries 2000b

| **Region** | **No. of farms** | **Region** | **No. of farms** |
|---|---|---|---|
| North Coast | 1 | Queen Charlotte Strait | 7 |
| Quatsino Sound | 6 | Broughton Archipelago | 24 |
| Kyuquot Sound | 5 | Knight Inlet | 3 |
| Nootka Sound | 3 | Johnstone Strait | 8 |
| Clayoquot Sound | 24 | Discovery Passage | 15 |
| Barkley Sound | 4 | Desolation Sound | 9 |
| Sooke Basin | 1 | Jervis Inlet | 4 |
| Saltspring Islands | 3 | Sechelt Inlet | 6 |

Table 2. Number of salmon farming companies and grow-out sites, 1988-1996.  Sources: Price Waterhouse (1993), ARA (1994), Coopers & Lybrand (1997), and data from 3 non-B.C. Salmon Farmers' Association (BCSFA) companies. n/a.- not available. *May include some fallow sites. (http://www.eao.gov.bc.ca/PROJECT/AQUACULT/SALMON/report/V1chp2.htm)

| | **1988** | **1991** | **1993** | **1996** |
|---|---|---|---|---|
| Number of Salmon Farming Companies | 101 | n/a | 17 | 16 |
| Number of Active Grow-Out Sites | 118 | n/a | 88* | 79 |
| Average Number of Sites per Company | 1.16 | 2.27 | 5.18 | 4.94 |

Table 3. Distribution of salmon farming companies by level of production (% of total number companies). *Does not add due to rounding. Sources: ARA (1994), Coopers & Lybrand (1997), and data from 3 non-BCSFA companies.
*(*http://www.eao.gov.bc.ca/PROJECT/AQUACULT/SALMON/report/V1chp2.htm)

| **Production Level** | **1993** | **1996** |
|---|---|---|
| Less than 500 tonnes | 35.3 | 25.0 |
| 500—999 tonnes | 23.5 | 18.7 |
| 1000-1999 tonnes | 17.6 | 18.7 |
| larger than 2000 tonnes | 23.5 | 37.5 |
| TOTAL | 100.0* | 100.0 |

Table 4. Distribution of active grow-out sites by Regional District (% of total number of active sites). Sources: ARA (1994), Coopers & Lybrand (1997), and data from 3 non-BCSFA companies. *(*http://www.eao.gov.bc.ca/PROJECT/AQUACULT/SALMON/report/V1chp2.htm)

| **Regional District** | **1993** | **1996** |
|---|---|---|
| Alberni-Clayoquot | 17 | 23 |
| Comox-Strathcona | 25 | 35 |
| Mount Waddington | 28 | 27 |
| Nanaimo, Cowichan, Capital | 0 | 10 |
| Sunshine Coast & Powell River | 30 | 5 |
| TOTAL | 100.0 | 100.0 |

Table 5: Reported estimates of salmon losses due to pinniped predation.

| **Date/Timespan** | **Scope** | **Pinnipeds-related losses** | **Reference** |
|---|---|---|---|
| 1 year | Overall Scottish fish farm industry estimate of direct predation loss | £1,400,000 - £4,800,000 | Ross, 1988 |
| 1 year | 41 Scottish farm questionnaires min/max estimate of direct predation loss | £377,560 - £452,500 | Ross, 1988 |
| 1 year | 45 Scottish farm interviews min/max estimate of direct predation loss | £880,470 - £1,391.070 | Ross, 1988 |
| 1986-87 Fiscal Year | Survey of 9 Tasmanian fish farms | A$320,000 total financial loss due to seal attacks | Pemberton and Shaughnessy, 1989 |
| 1987 | 29 BC fish farms | 79,180 fish directly lost to wildlife predation | van de Wetering, 1989 |
| 1987 | 3 BC fish farms | 49,000 fish lost through net pen damage | Van de Wetering, 1989 |
| 1988 | 19 fish farms in the BCSFA | 56,300 fish lost through direct seal predation or related stress | Rueggeberg and Booth, 1989 |
| 1988 | 6 fish farms in the BCSFA | 3,000 fish lost through direct sea lion predation or related stress | Rueggeberg and Booth 1989 |
| 1988 | 68 fish farms in the BCSFA | 44,000 fish lost through net-pen damage from all wildlife (seals, sea lions and otters) | Rueggeberg and Booth 1989 |
| 1988 | 68 fish farms in the BCSFA | 1% total production due to seals and sea lions | Rueggeberg and Booth 1989 |
| 1991 | Scottish fish farm industry | 2% total production due to predator-related damage | Campbell 1991 |
| 1990 | Scottish fish farm industry | C$2.0 million estimated loss | Tillapaugh et al. 1993 |
| 1990-91 | BC salmon farm industry | C$4 million estimate from direct kills and net damage escapes | Tillapaugh et al. 1993 |
| 1 year | Tasmanian range of annual farm stock loss | A$10,000 to A$175,000 | Pemberton and Shaughnessy 1993 |
| 1 year | 1 Tasmanian farm | A$500,000 | Pemberton and Shaughnessy1993 |
| 1994 | Gulf of Maine | 10% of an annual farm-gate value of US$50 million | NMFS 1996 |
| 1994 | BCSFA | C$10-12 million = 6.1-7.3% total industry production | NMFS 1996 |
| 1996 | BCSFA | C$10 million | Fraker 1996 |
| 1996 | BC review | “Substantial” | EAO 1997 |
| October 1995 to June 1996 | 1 Puget Sound farm | 71,449 fish ~ US$1.67 million ~ 4-5% production at harvest | NOAA 1997 |
| 1 night | 1 BCSFA farm | 2,500 fish, worst reported loss | Fraker et al. 1998 |
| 1 stock generation | 1 BCSFA farm | 60,000 fish, worst reported loss | Fraker et al. 1998 |
| 2-week period | 1 BCSFA farm | 5,000 fish, worst reported loss | Fraker et al. 1998 |
| Unspecified | 216 Norwegian farms in 4 counties | 5% total production | Johansen and Eliassen 1999 |
| 1996 | 1 Puget Sound farm | 86,000 fish | Nash et al. 2000 |
| 1997 | 1 Puget Sound farm | 114,000 fish | Nash et al. 2000 |
| Recent 6-month period | Tasmanian Salmonid Growers Association | 2% production | Nash et al. 2000 |

Table 6: Insurance Company figures for fish farm claims due to predator-related loss

| **Date** | **Scope** | **Insurance Company** | **Insurance claims paid out for pinniped-related losses** | **Reference** |
|---|---|---|---|---|
| 1991 | Eastern Canada | Unspecified report | C$1,400,000, mostly due to seal damage | Tillapaugh et al. 1993 |
| 1994 | Eastern Canada and Gulf of Maine | Mitchell, Mcconnell, Daniels Insurance Brokers | C$1,000,000 | NMFS 1996 |
| 1995 to 1997 | Canada, Norway and USA | Vesta Insurance | 10-20% loss claims due to predator-related net damage | Fraker et al. 1998 |
| 1996 | Unspecified | Vesta Forsk | NKr 1.2 million | Nash et al. 2000 |
| 1997 | Unspecified | Vesta Forsk | NKr 0.52 million | Nash et al. 2000 |
| 1999 | Worldwide | Sunderland Marine Mutual Insurance Co. | 5% aquaculture claims by value; 12% aquaculture claims by frequency | Aquaculture Risk Management 2000 |

Table 7: Site locations reporting the greatest number of harbour seal and sea lion kills (top 10%). Number killed represent the total kill during 1991 to the end of the 2nd quarter in 2000.

| Site Name: | Latitude | | Longitude | | Number of Harbour Seals Killed |
|---|---|---|---|---|---|
| Barnes Bay, Okis Island | 50 | 19.3 | 125 | 15.6 | 76 |
| Wehlis Bay, Wells Passage | 50 | 51.9 | 126 | 55.3 | 81 |
| Thurlow Point | 50 | 24.5 | 125 | 20.4 | 81 |
| Eden Island, Potts Bay | 50 | 46.2 | 126 | 39.4 | 86 |
| Larsen Island, Indian Channel | 50 | 36.3 | 126 | 37.8 | 87 |
| Simmonds Point, Wells Passage | 50 | 52.7 | 126 | 54.3 | 90 |
| Conville Point, Quadra Island | 50 | 11.4 | 125 | 8.5 | 97 |
| Sir Edmund Bay, Broughton Inlet | 50 | 49.9 | 126 | 35.7 | 107 |
| Oil Bay, Read Island | 50 | 9.4 | 125 | 8.7 | 113 |
| Midsummer Island | 50 | 39.4 | 126 | 39.9 | 125 |
| Thorpe Point | 50 | 34.8 | 127 | 36.6 | 133 |
| Power Bay, North Hardy Island | 49 | 45.2 | 124 | 10.8 | 163 |
| Conville Bay, Quadra Island | 50 | 10.8 | 125 | 9.0 | 235 |
| Swanson Island | 50 | 37.2 | 126 | 42.4 | 356 |

| Site Name: | Latitude | | Longitude | | Number Sea lions Killed |
|---|---|---|---|---|---|
| Penny Creek, Alberni Inlet | 49 | 7.0 | 124 | 49.4 | 17 |
| McCall Islet | 49 | 8.5 | 125 | 43.6 | 19 |
| Saranac Island | 49 | 14.8 | 125 | 54.2 | 21 |
| Pinnace Channel, Hohoae Island | 50 | 2.0 | 127 | 12.6 | 21 |
| Bawden Point, Herbert Chnl | 49 | 18.3 | 126 | 0.5 | 26 |
| Dixon Bay, Shelter Inlet | 49 | 24.2 | 126 | 9.2 | 27 |
| Amai Inlet, Amai Pt. | 50 | 1.5 | 127 | 8.8 | 31 |
| Baxter Islet | 49 | 8.0 | 125 | 47.0 | 34 |
| Dixie Cove, Hohoae Island | 50 | 2.3 | 127 | 10.5 | 41 |
| Binns Island | 49 | 20.4 | 125 | 56.9 | 41 |
| South Shelter, Flores Island | 49 | 23.1 | 126 | 10.3 | 50 |
| Centre Cove, Whiteley Island | 50 | 0.8 | 127 | 11.7 | 93 |
| Ross Passage | 49 | 19.4 | 126 | 2.9 | 105 |

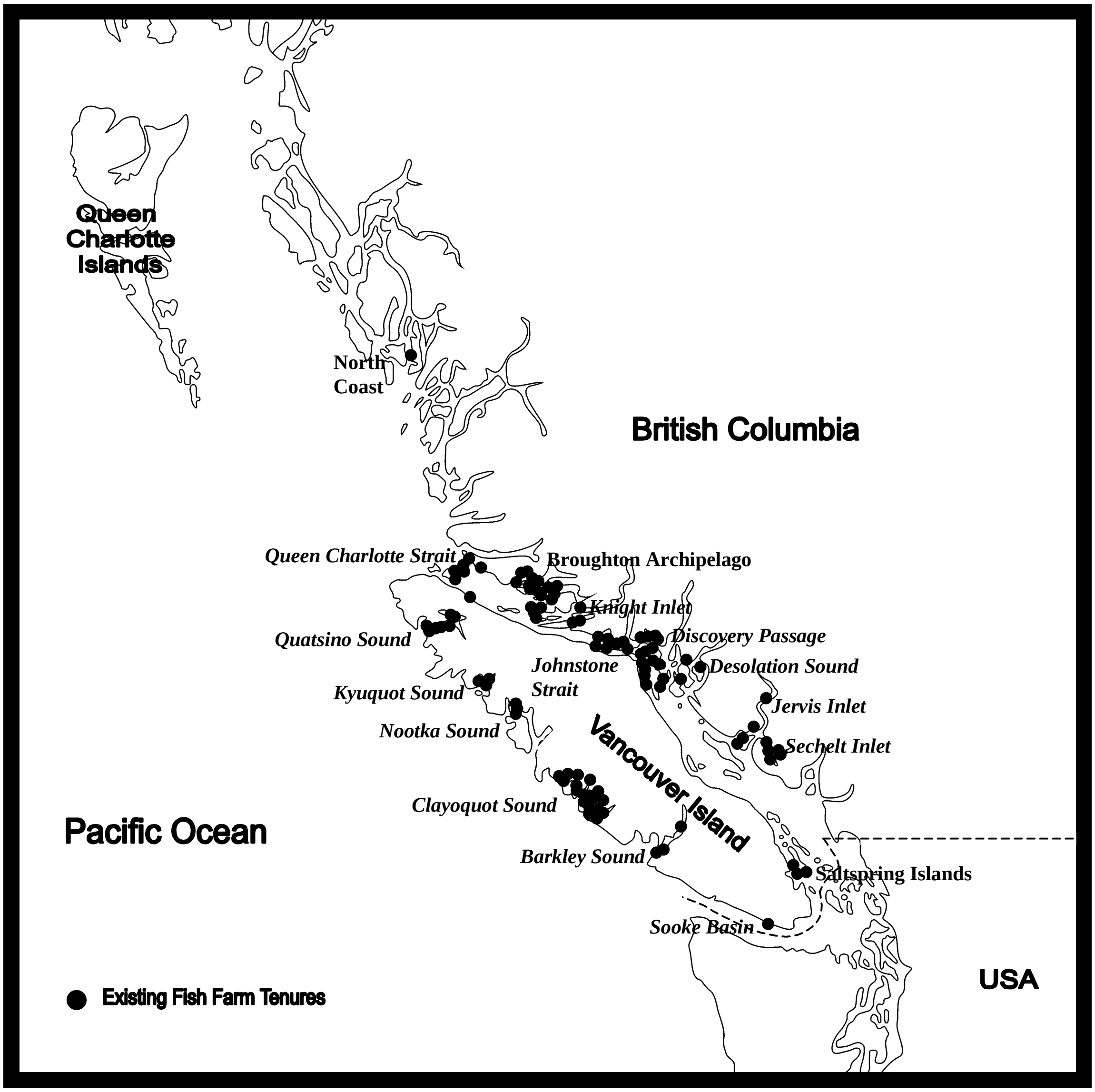



Figure 1: Locations of BC Fish Farm Tenures (BC Fisheries, 2000b)

****Please note: Color Figures available on internet****

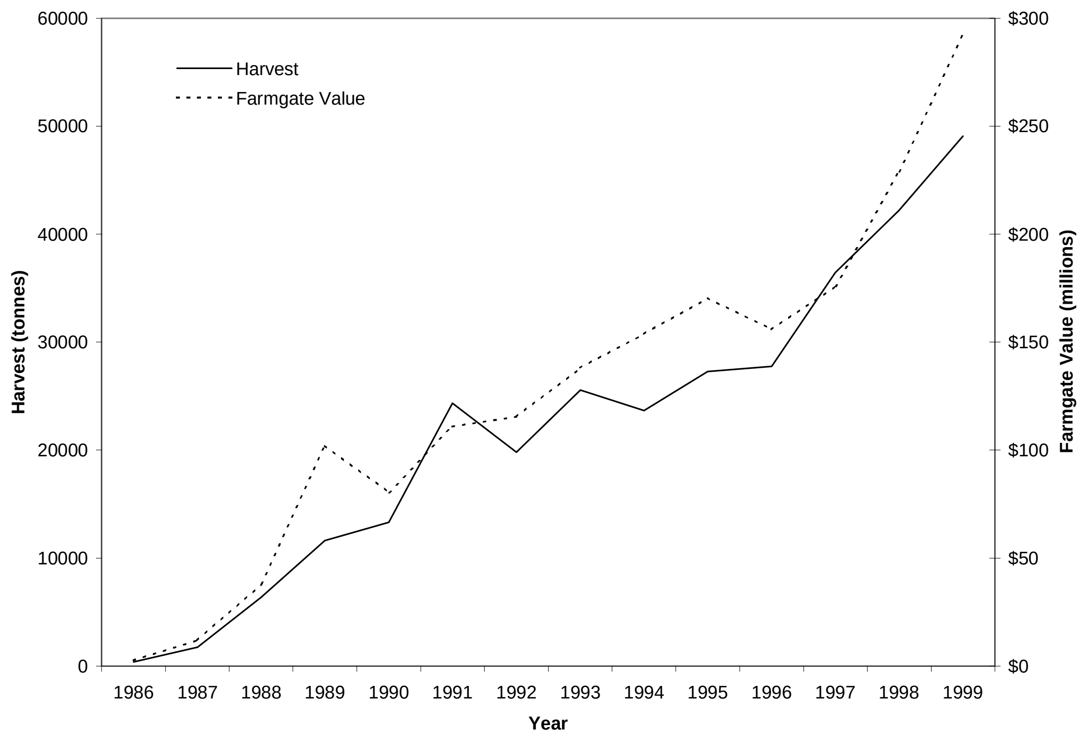



Figure 2: Salmon culture production in British Columbia (DFO statistics, http://www.ncr.dfo.ca/communic/statistics/aquacult/aqua_e.htm)

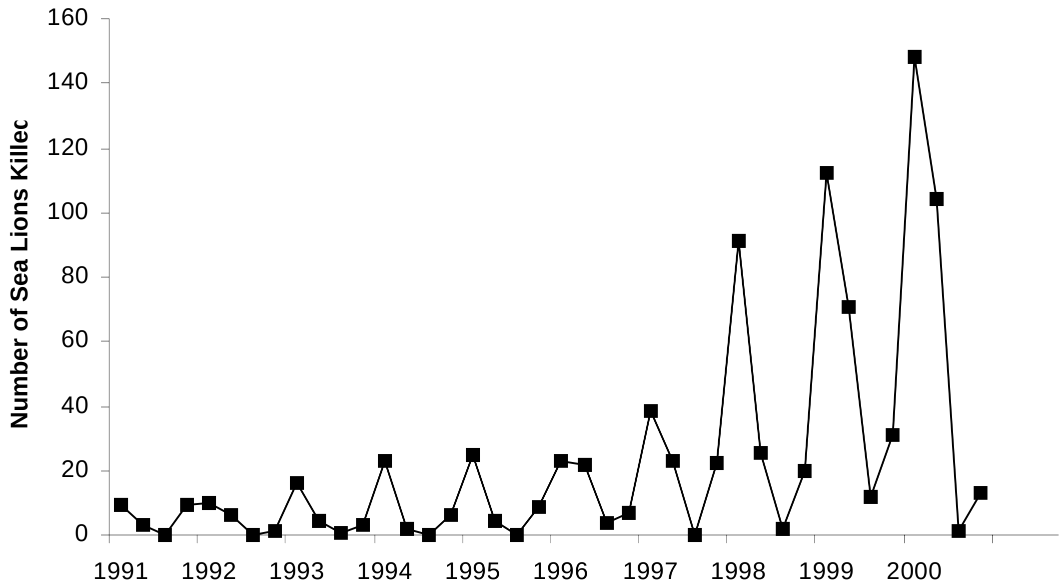



Figure 3. Number of licenses issued per year, and number of license holders reporting predator kills each year. 2001 data not included because data from the last quarter of the year is unavailable.

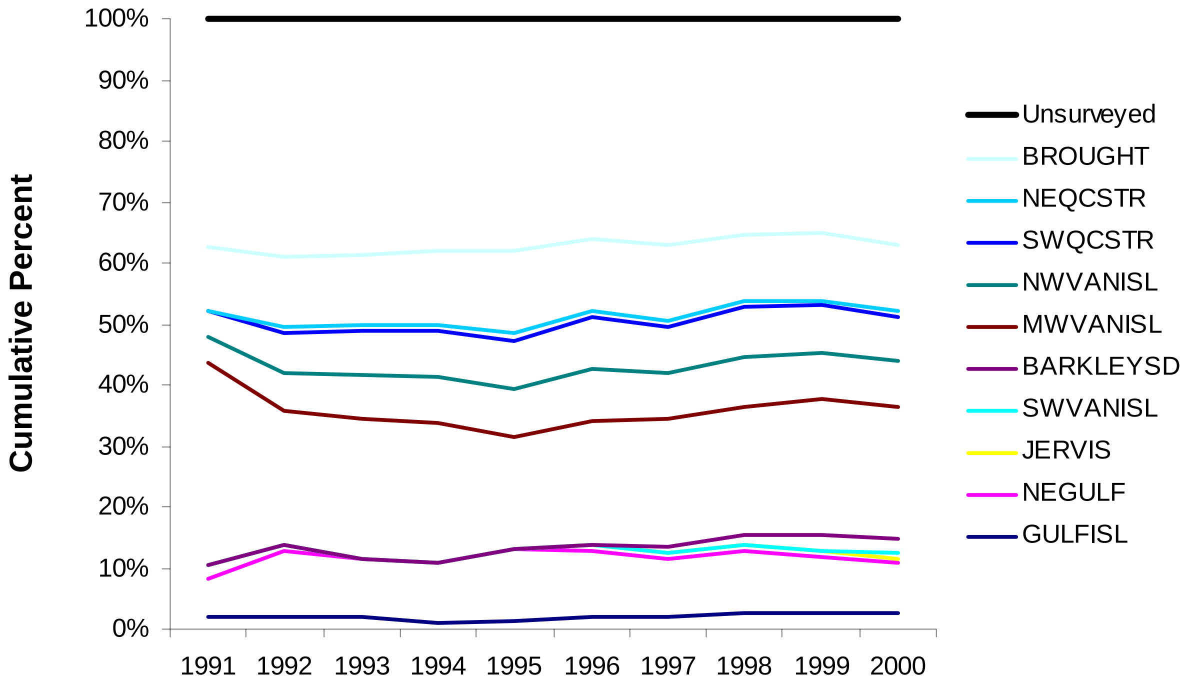



Figure 4. Distribution of predator control licenses by geographic area by year. The geographic areas correspond with those used to assess harbour seal populations (for a map of locations,see Figure 1 in Olesiuk 1999a). BROUGHT = Broughton Island Archipelago, NEQCSTR = east portion of Queen Charlotte Strait, SWQCSTR = west portion of Queen Charlotte Strait, NWVANISL = northwest Vancouver Island, MWVANISL = middle west Vancouver Island, BARKLEYSD = Barkley Sound, SWVANISL = southwest Vancouver Island, JERVIS = Jervis Inlet, NEGULF = northeast Strait of Georgia, and GULFISL = Gulf Islands.

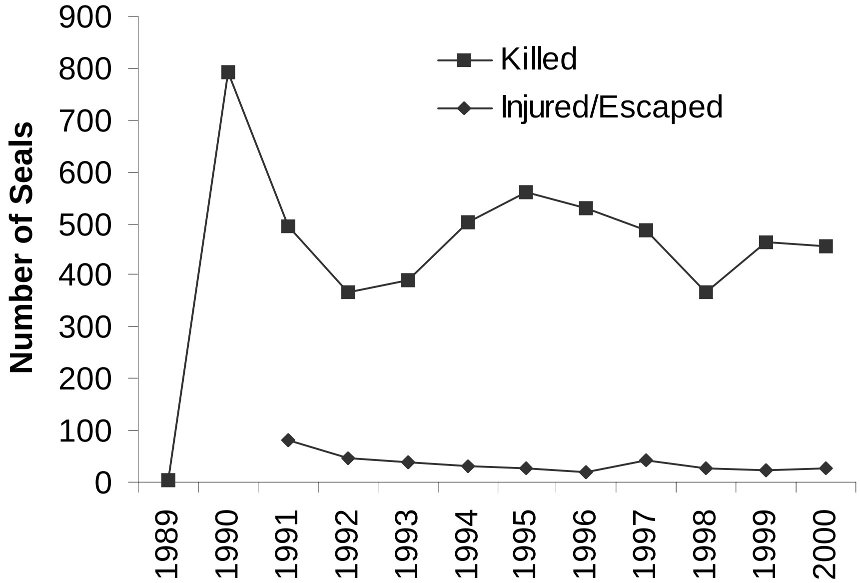



Figure 5. Estimated number of harbour seals killed and estimated number that escaped or were only injured by year.

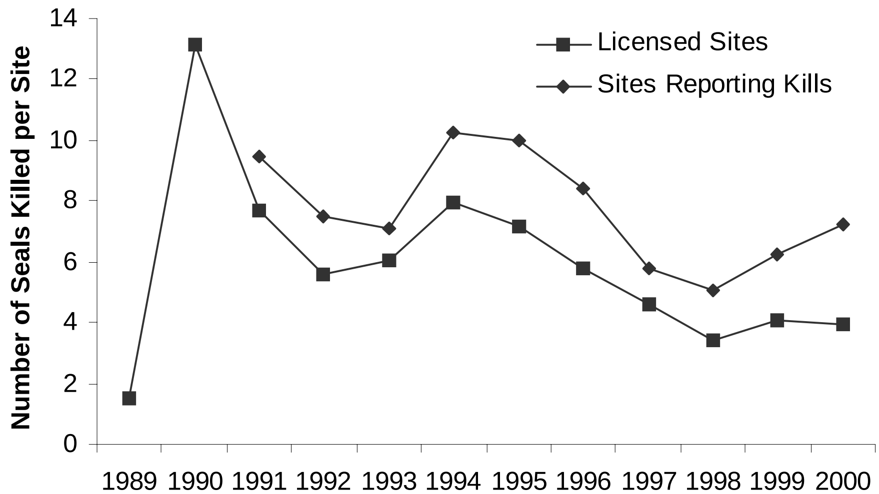



Figure 6. Estimated average number of harbour seals killed per licensed site, and per licensed site reporting kills, by year.

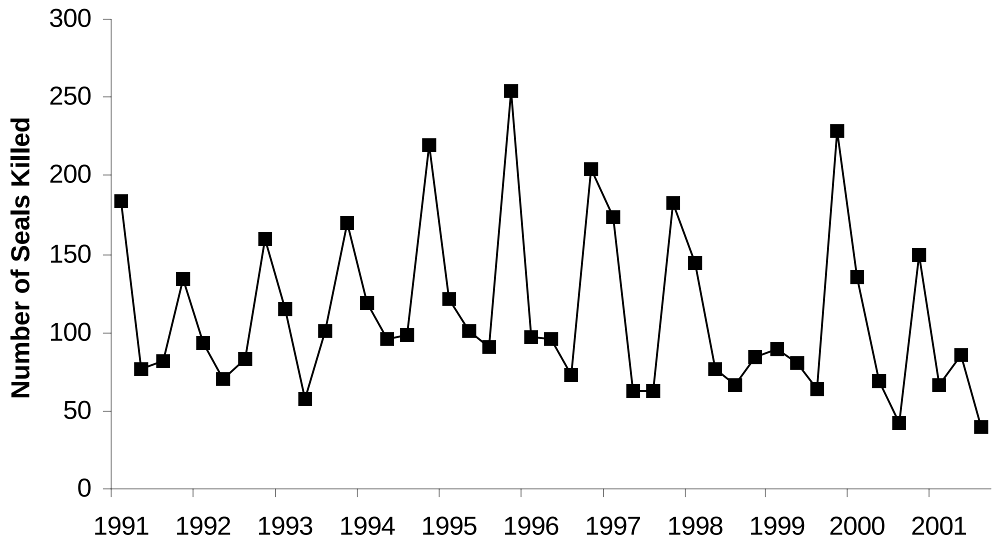



Figure 7. Estimated number of harbour seal kills by quarter by year (1991- third quarter of 2001), showing that most kills occurred in the fourth quarter (October-December) and to a lesser extent in the first quarter (January-March). Interestingly, for reasons unknown, the seasonal peak was less pronounced in 1999.

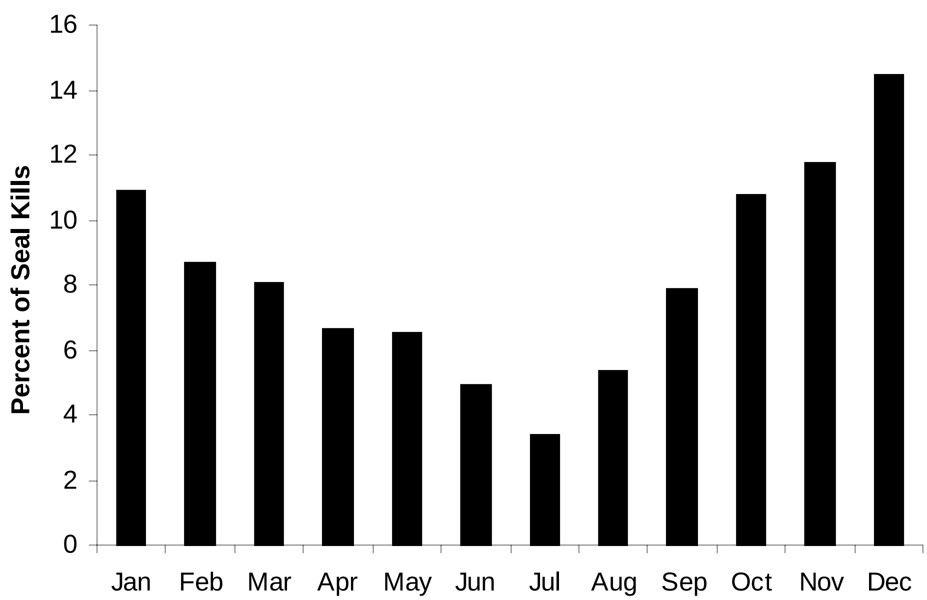



Figure 8. Overall seasonal pattern of harbour seal kills by month, all years (1991- third quarter of 2001) combined.

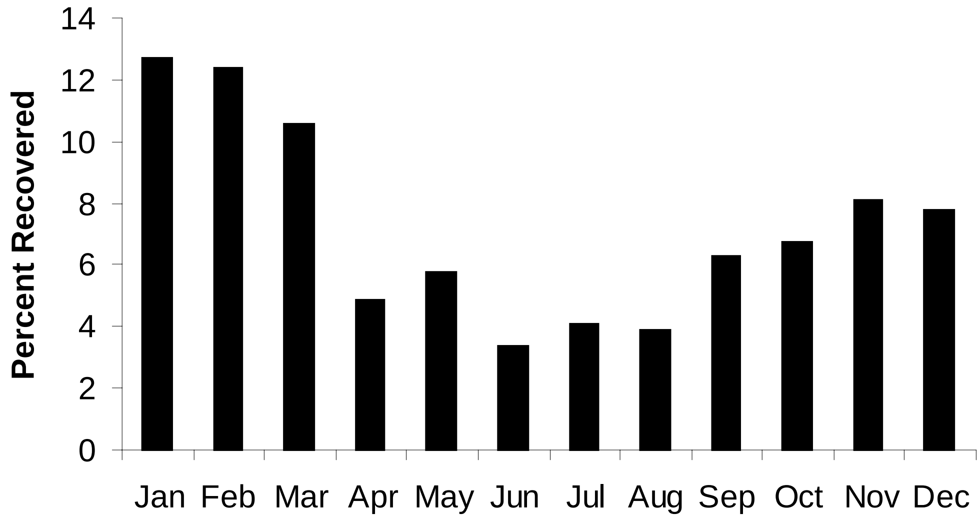



Figure 9. Recovery rate of harbour seals that were recorded as positively killed, all years (1991-third quarter of 2001) combined.

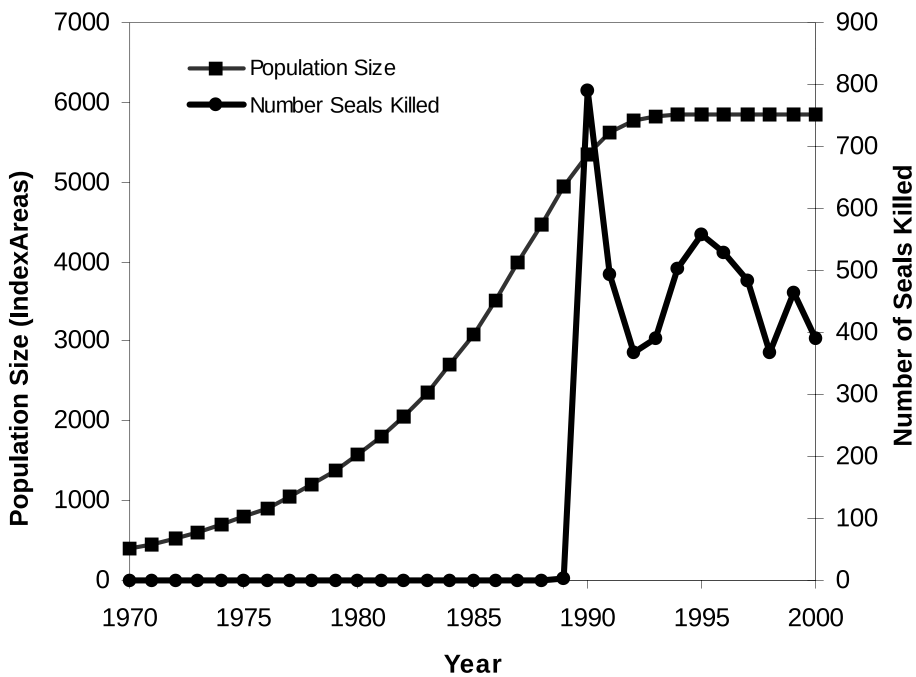



Figure 10. Trends in harbour seal abundance (squares) in all surveyed index areas outside the Strait of Georgia during 1970-2000 (modified from Olesiuk 1999a), compared to the number of harbour seals killed (circles) for predator control at fish farms since the program began in 1990.

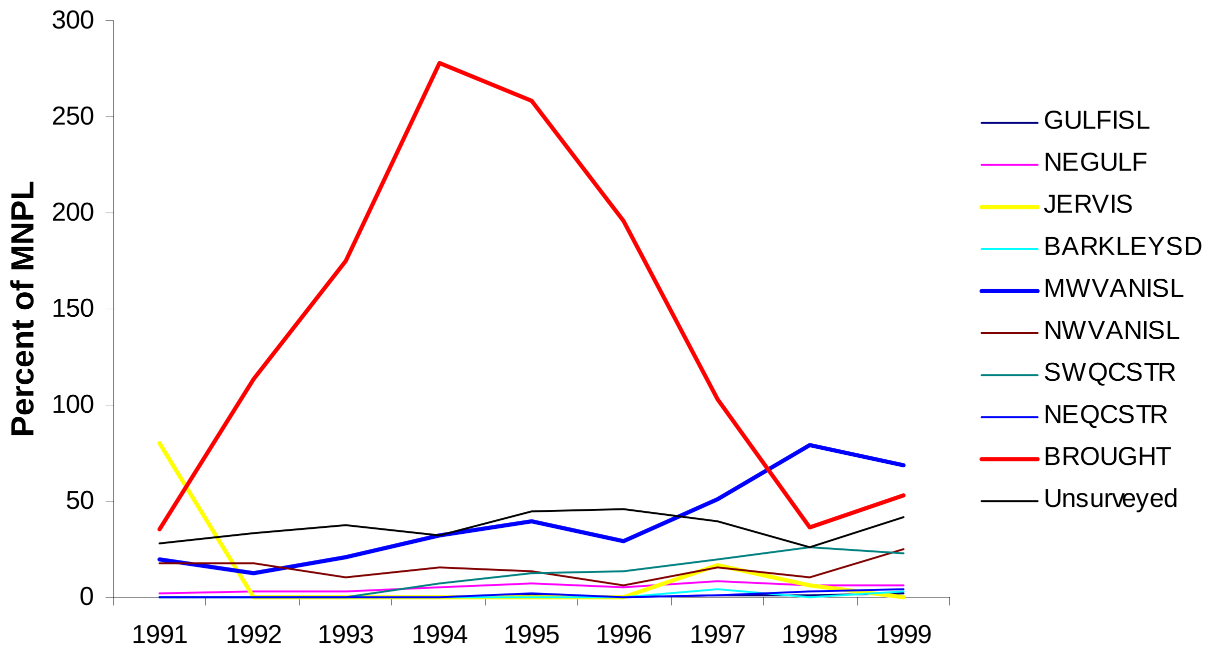



Figure 11. Level of harbour seal kills expressed as a percent of the maximum net productivity level (MNPL) by geographic area. The MNPL is the number of seal kills that could be sustained (assuming the kill is non-selective with respect to sex- and age-structure). The MNPL is estimated to be 11.4%, and occurs at 75% of carry capacity (Olesiuk 1999a). Populations decline when kills exceed 100% of MNPL and will only recover when kills are less than 100% of MNPL.

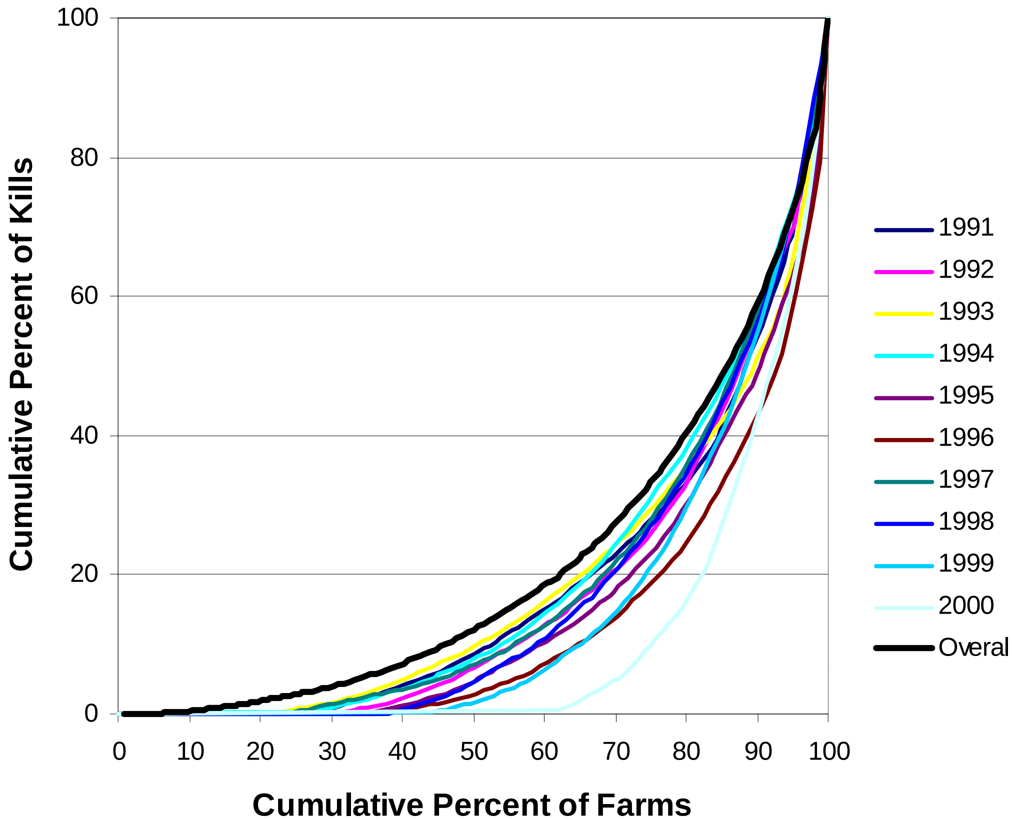



Figure 12. Relative distribution of harbour seal kills among sites by year and for all years combined (overall, thick black line), showing the uneven kill distribution among sites. Trend lines were calculated by ranking the number of kills by site from lowest to highest, and taking the cumulative sum as a function as the percent of licensed sites. An even distribution of kills would be represented by a 1:1 line. The non-linear trends indicate that kills were not uniformly distributed, but rather concentrated at a few sites. For example, the 50% of sites reporting the lowest kills accounted for less than 10% of the total number of seals killed, whereas the 10% of sites reporting the highest kills accounted for 40-60% of the total number of seals killed. Over all years combined, the concentration of kills at a few sites was not quite as pronounced, since different sites had the greatest kills in different years.

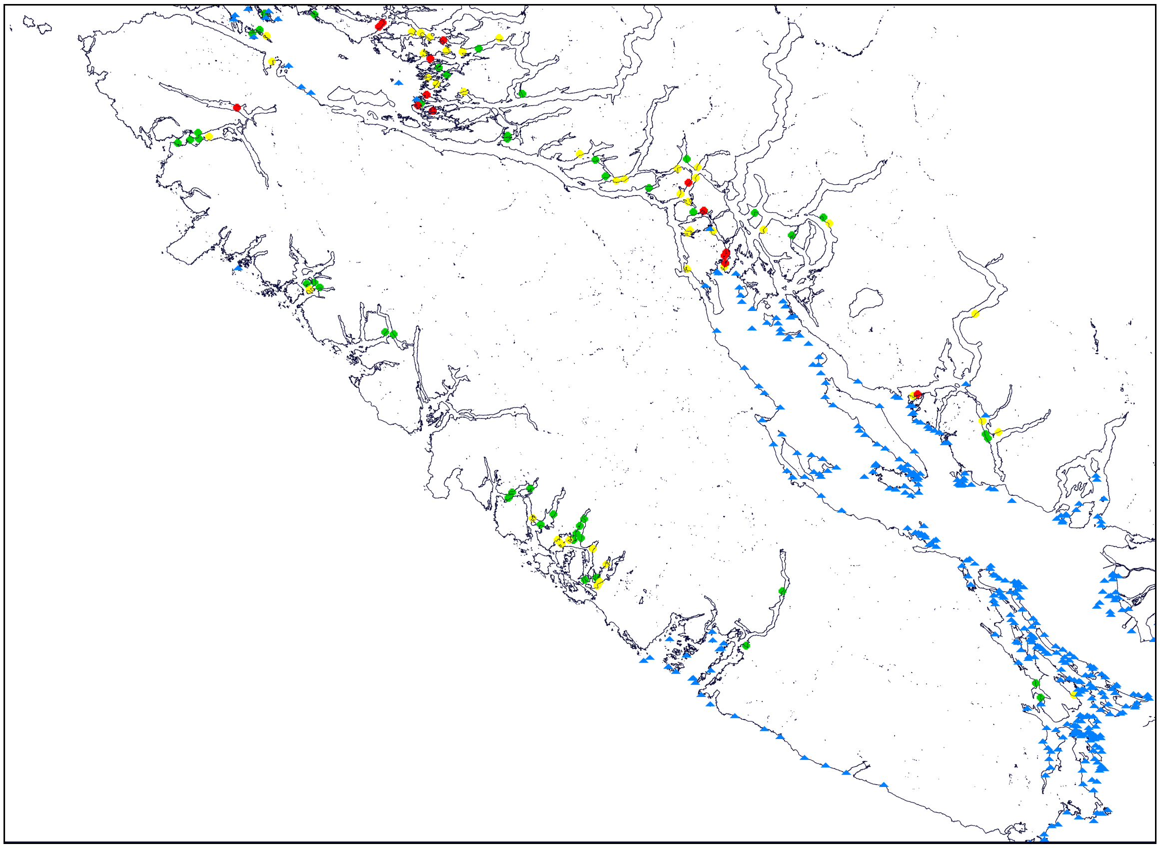


Figure 13. Map showing distribution of salmon farms (circles) and known harbour seal haulout sites (blue triangles). Colours indicate the level of harbour seal kills at each site. Green denotes the bottom 50% of sites that accounted for 12% of all kills (each site killed a total of less than 20 seals), yellow denotes the intermediate 40% of the sites that accounted for 47% of the kills, and red denotes the top 10% of the sites that accounted for 41% of all kills (sites ranged from 76-356 kills each).

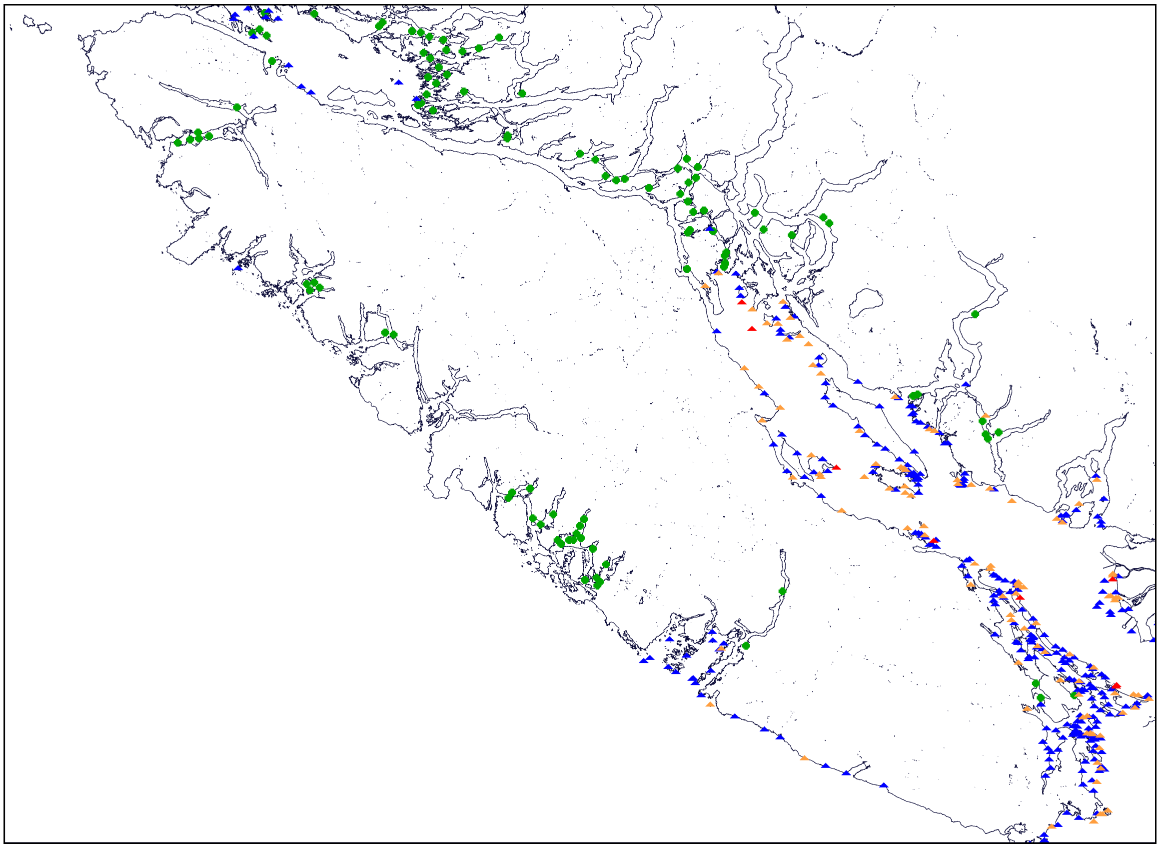


Figure 14.  Map showing distribution of salmon farms (green circles) and known harbour seal haulout sites (triangles). Blue denotes seal haulout sites of < 100 animals, tan of sites with 100-500 animals, and red of sites with >500 animals.

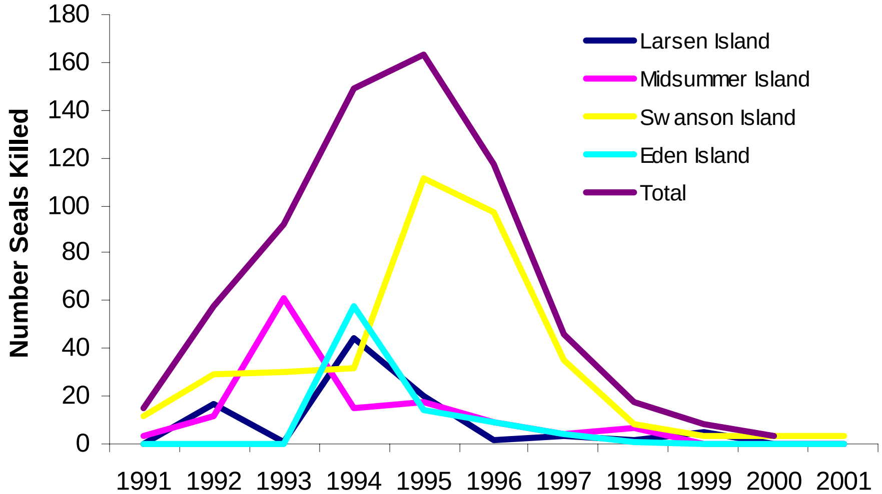
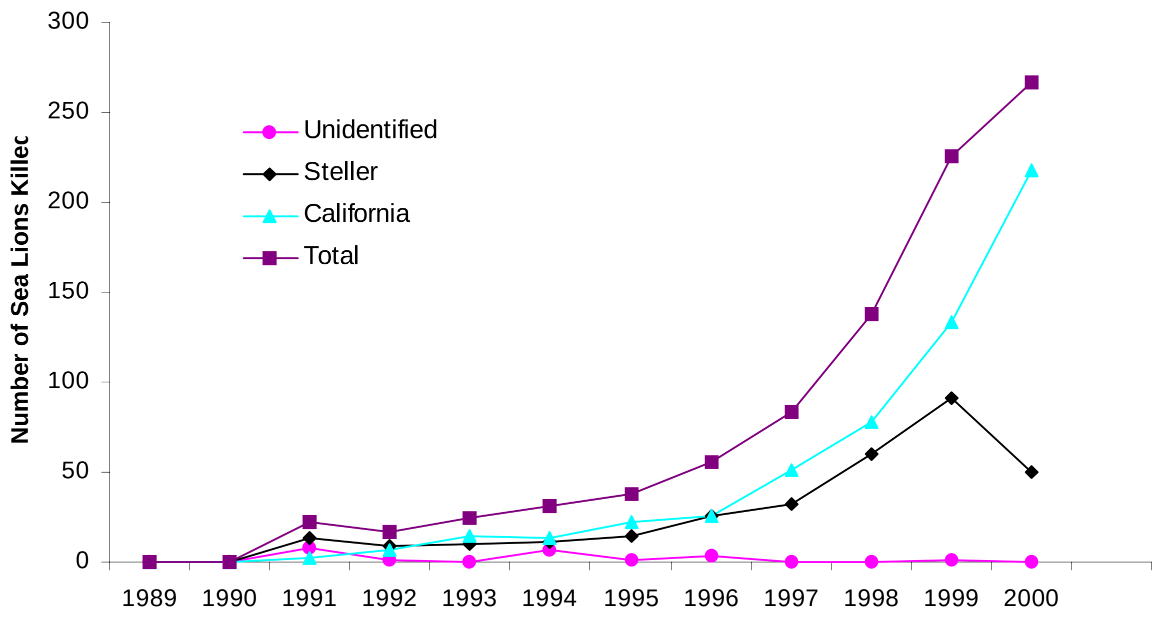



Figure 15. Temporal trends in number of harbour seals killed at four Stolt Sea Farm sites in the Broughton Archipelago. This example shows the dramatic decline in number of pinnipeds killed when the company moved to large flex guard-dipped pens in the late 1990s.

A.




B.

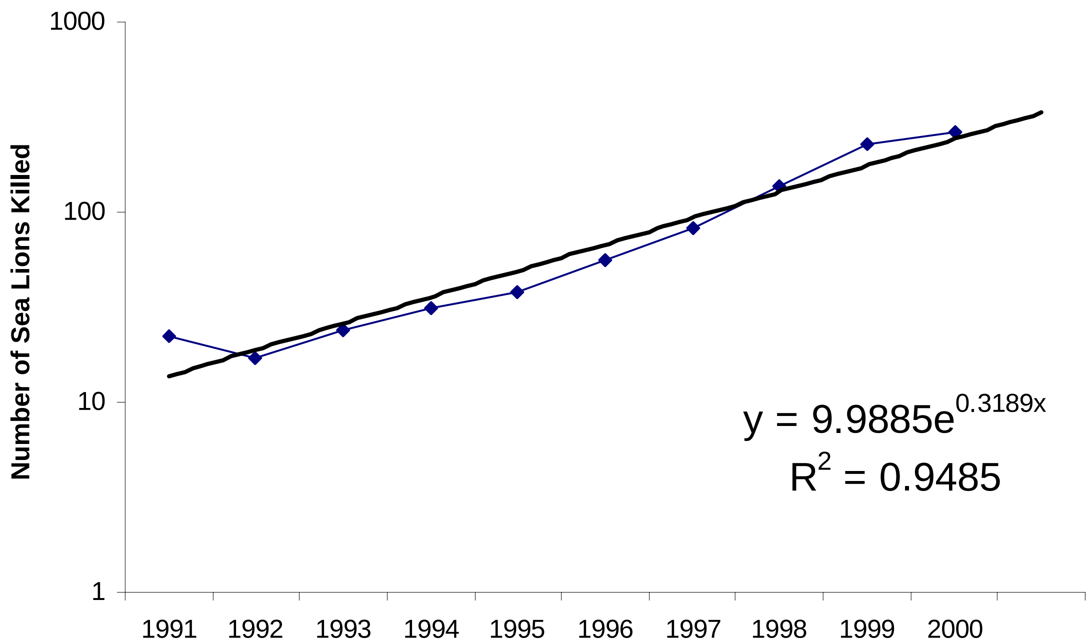



Figure 16. A. Estimated number of sea lions killed by species and year. B. Estimated number of sea lions killed per year on a logarithmic scale. 2001 data not included because data from the last quarter of the year is unavailable.

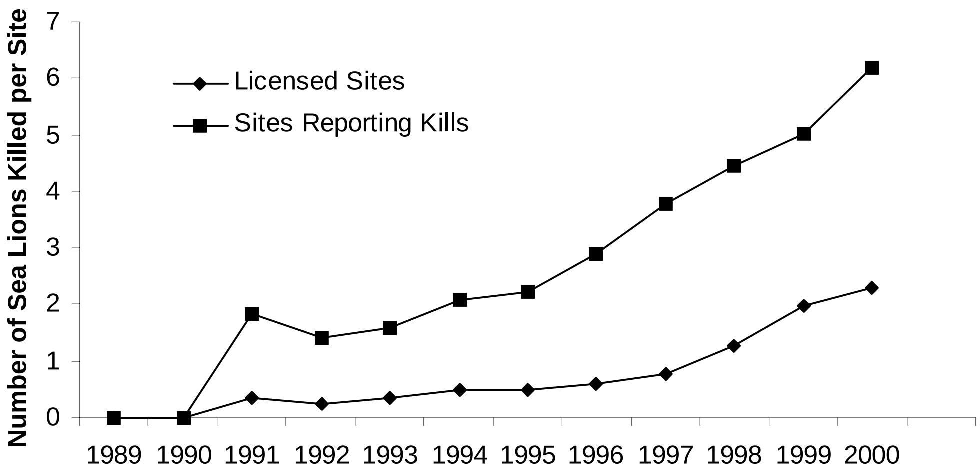



Figure 17. Estimated average number of sea lions killed per licensed site, and per licensed site reporting kills, by year. 2001 data not included because data from the last quarter of the year is unavailable.

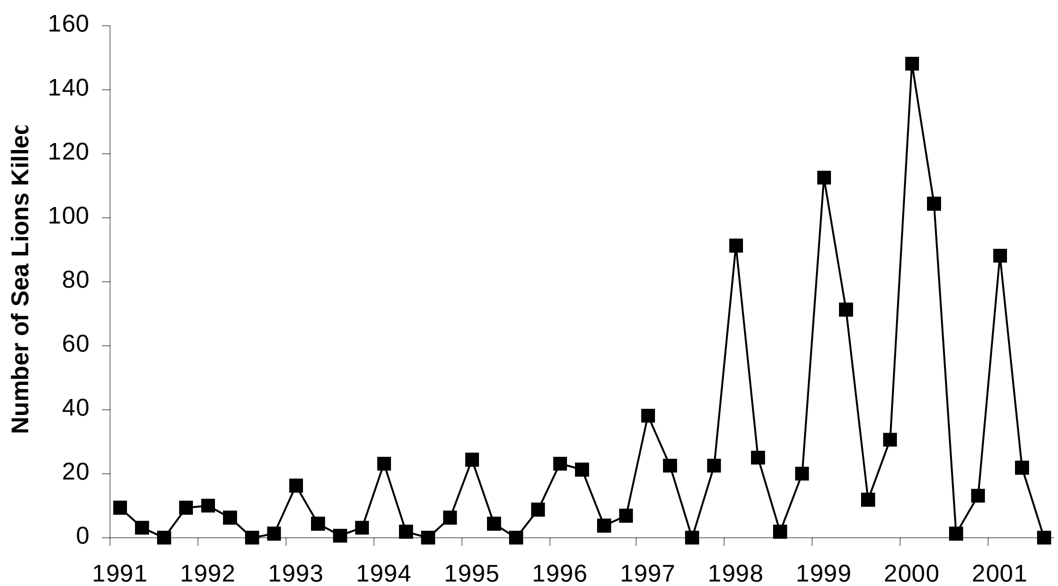



Figure 18. Number of sea lions killed by quarter, showing that most kills occurred in the first quarter (January-March) and to a lesser extent in the second quarter (April-June). Virtually no kills occur in the third quarter (July-September). Data from the last quarter of 2001 not available.

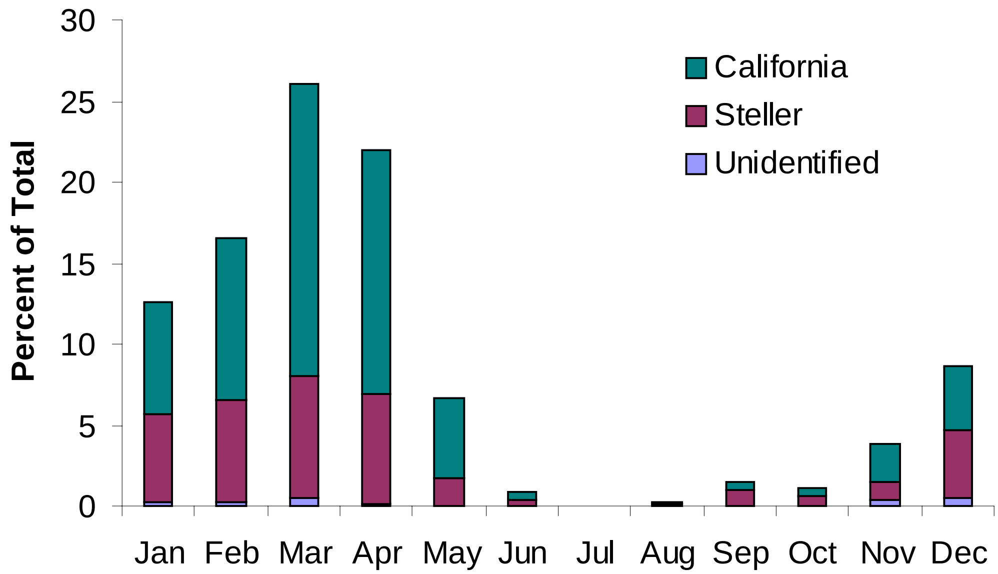



Figure 19. Seasonal distribution of sea lion kills, 1991 to fourth quarter of 2001.

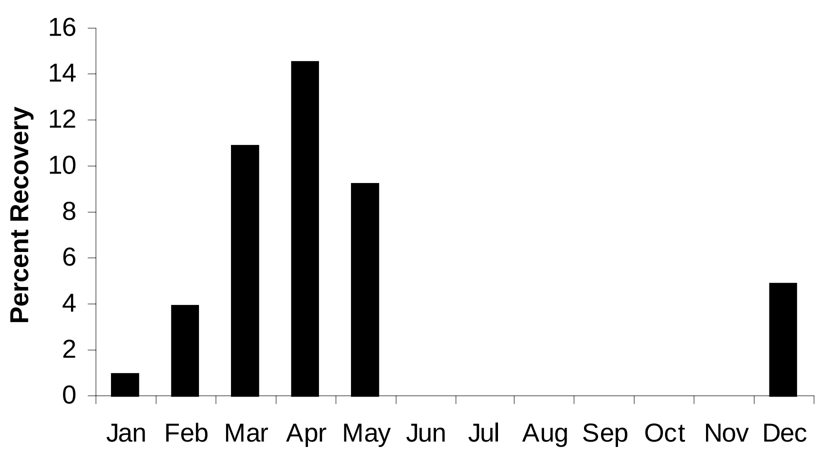
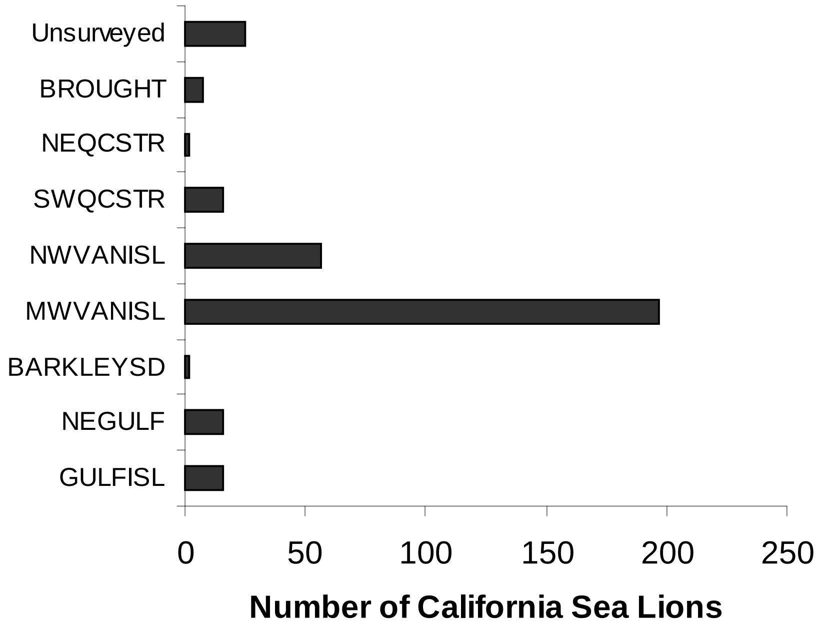



Figure 20. Recovery Rate of sea lions that were recorded as being positively killed by month, 1991 to fourth quarter of 2001.

A.




B.

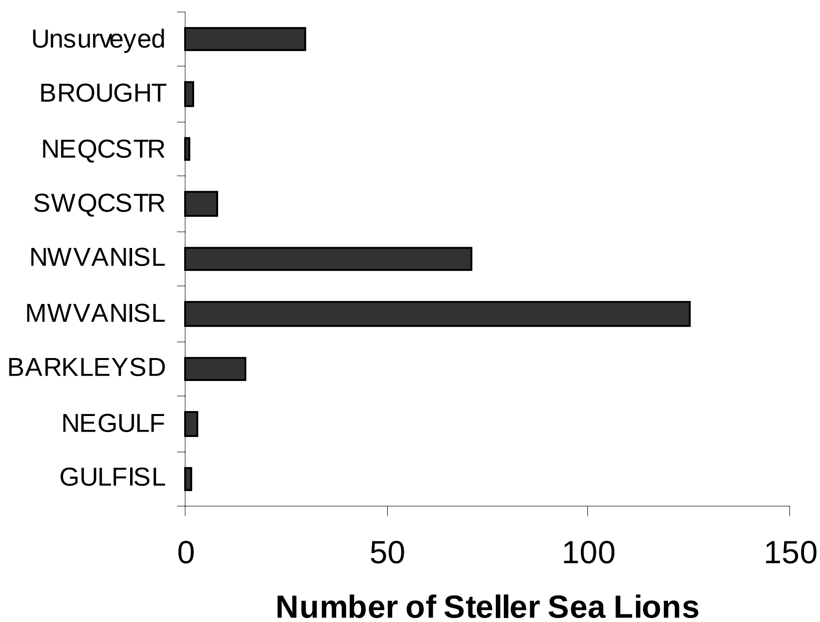



Figure 21. Geographic distribution of sea lion kills from 1991 to mid-2000. A. California. B. Stellar. For a map of locations, see Figure 1 in Olesiuk 1999a: BROUGHT = Broughton Island Archipelago, NEQCSTR = east portion of Queen Charlotte Strait, SWQCSTR = west portion of Queen Charlotte Strait, NWVANISL = northwest Vancouver Island, MWVANISL = middle west Vancouver Island, BARKLEYSD = Barkley Sound, NEGULF = northeast Strait of Georgia, and GULFISL = Gulf Islands.

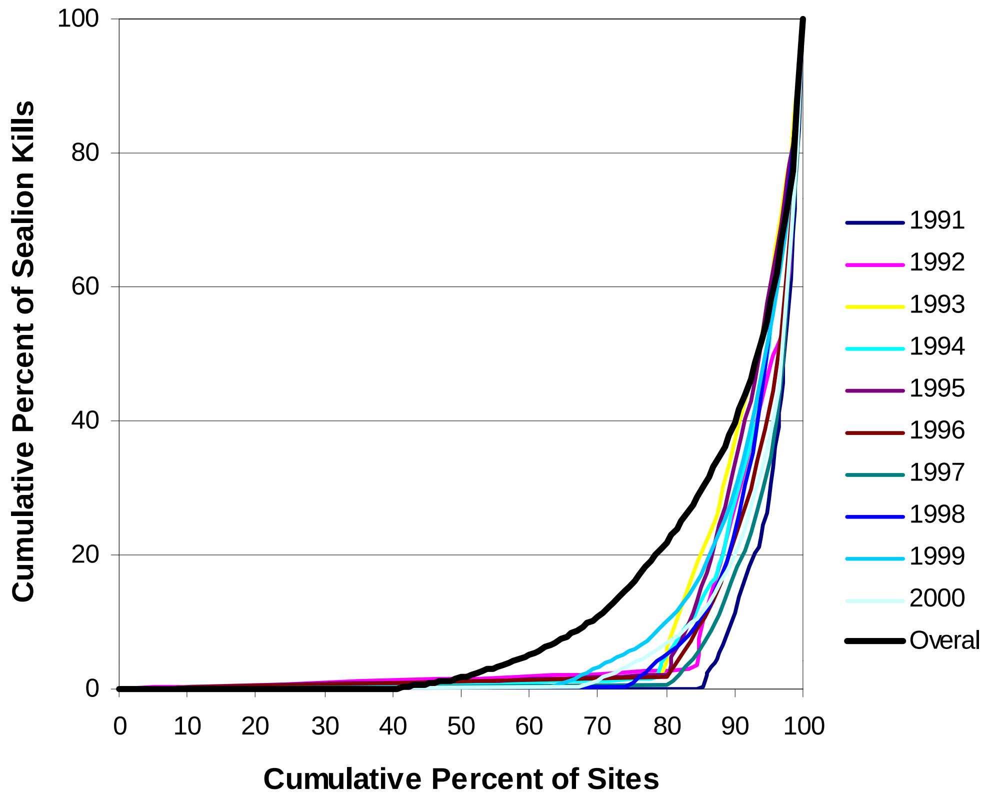



Figure 22. Relative distribution of sea lion kills among sites by year and for all years combined (overall, thick black line), showing the uneven distribution among sites. Trend lines were calculated by ranking the number of kills by site from lowest to highest, and taking the cumulative sum as a function as the percent of licensed sites. An even distribution of kills would be represented by a 1:1 line. The non-linear trends indicate that kills were not uniformly distributed, but rather concentrated at a few sites. For example, in any given year the 80% of sites reporting the lowest kills accounted for less than 10% of the total number of sea lions killed, whereas the 10% of sites reporting the highest kills accounted for 60-90% of the total number of sea lions killed. Over all years combined, the concentration of kills at a few sites was not quite as pronounced, since different sites had the greatest kills in different years.

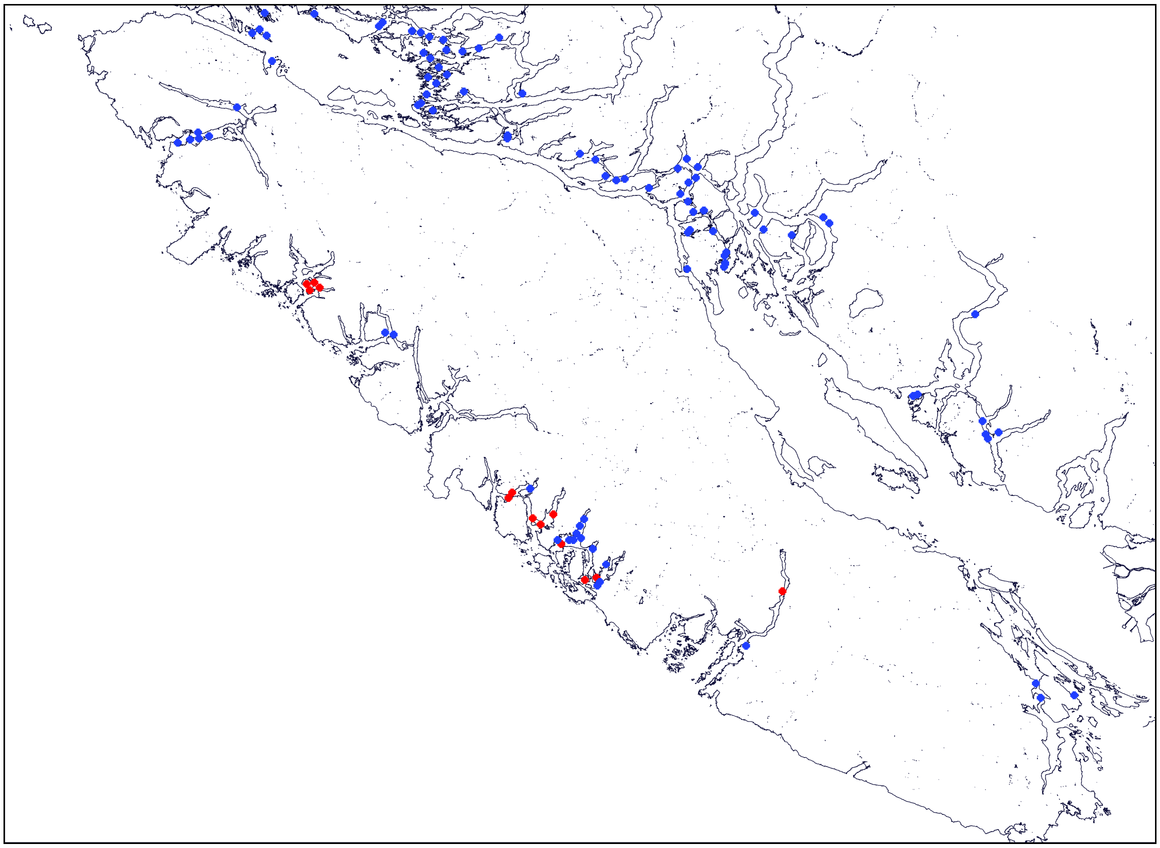


Figure 23. Map showing distribution of salmon farms, coloured to indicate the level of sea lion kills at each site. Blue denotes the site was in the bottom 90% of the sites that accounted for 40% of all kills (each site killed a total of less than 15 se a lions), and red denotes the site was in the top 10% of the sites, accounting for 60% of all kills (sites ranged from 16-105 kills each).

Appendix 1: The application form for a predator control licence. According to the DFO response to the BC EAO Salmon Aquaculture Review, prior to issuance of a license, applicants must demonstrate that all reasonable non-destructive predator control measures were employed. On the license application form, however, there is no place to document those alternative control measures.

# Fisheries and Oceans Canada

## Marine Mammal Predator Control Licence Application

*For the period January 1, 2001 to December 31, 2001*

- Annual fee of five dollars ($5.00) per licence
- Payable by cheque or money order to the Receiver General for Canada
- Forward payment to Fisheries and Oceans Canada, Regional Aquaculture Coordinator, 360 - 555 West Hastings Street, Vancouver, BC V6B 5G3 Tel: (604) 666-3152

Company: **NAME**

Contact: Name

Address:

Telephone: (250) Fax: (250)

| | *Name of Site* | *Location* | *BCAL File No.* | *Licence No.* | *Cost $* |
|---|---|---|---|---|---|
| 1. | Name | Name | XXXX | XXX | 5.00 |
| | | | 1 Site X $5.00 | **Total** | **5.00** |

Total amount paid: $___________

Date: ______________________

Company/Site details are correct ________ "yes"; _______ "no" (Indicate revisions)

Authorized Signature: ________________________________

Appendix 2: The format and conditions of DFO's predator control licence.

# Fisheries and Oceans Canada

## MARINE MAMMAL PREDATOR LICENCE
## No. XXX

PERMISSION IS HEREBY GIVEN by the Honourable Minister of Fisheries and Oceans Canada (hereinafter called the "LICENSOR") to:

**COMPANY**
**Street Address**
**City, British Columbia   Postal Code**

(hereinafter called the "LICENSEE") to kill, by means of firearms, seals and sea lions that are destroying fish being held or reared in sea cages of the "LICENSEE**" at (location), for the period of January 1, (year) to December 31, (year)**. This licence is issued pursuant to *subsection 4(1) of the Marine Mammal Regulations* and *subsection 22(1) of the Fishery (General) Regulations.*

Upon the following Terms and Conditions which the LICENSEE hereby agrees and accepts to perform and abide by:

1. For the permission hereby given, the LICENSEE shall pay to the LICENSOR, in advance an annual fee of five dollars ($5.00) or such other annual fee as the LICENSOR may in writing advise, made payable to the Receiver General for Canada and sent to the Regional Aquaculture Coordinator, Pacific Region.

2. Only Harbour Seals, California Sea Lions and Stellar Sea Lions are permitted to be killed under the authority of this Licence.

3. Only those seals or sea lions that are actually taking, or attempting to take fish being held or reared in sea cages may be killed.

4. The area of killing is restricted to the immediate site of the sea cages and shall not occur in waters outside the legal boundaries of the Lease or Licence of Occupation in which the sea cages and associated infrastructure reside.

5. Only employees of the LICENSEE who meet either of the following qualifications may kill seals or sea lions under the authority of this Licence:
    (a) Having a valid Federal Firearms Acquisition Certificate (FAC); or,
    (b) Having a valid Federal Possession and Acquisition Licence (FPAL).

6. Persons killing seals or sea lions under authority of this Licence must carry documentation confirming that they meet one of the criteria listed in subsection (5) and produce it on demand of a Fishery Officer, Conservation Officer or Constable.

7. Firearms used to kill seals or sea lions shall have a muzzle velocity of not less than 1,800 feet per second, and a muzzle energy of not less than 1,100 foot pounds; or a 12 gauge shotgun, utilizing a single rifled slug.

8. Every attempt shall be made to retrieve all seals or sea lions killed under authority of this Licence. These animals shall be retrieved from the water within 24 hours, biologically sampled according to instructions provided by the Pacific Biological Station (Marine Mammal Research), and then disposed of on shore by burial above the high water mark.

9. The LICENSEE shall submit quarterly written reports containing the following information:
   (a) The number of harbour seals killed;
   (b) The number and species of sea lions killed; and
   (c) The date each seal/sea lion was killed.

   The report should be sent to: The Regional Aquaculture Coordinator, Pacific Region
   Fisheries and Oceans Canada
   360 - 555 West Hastings Street
   Vancouver, British Columbia V6B 5G3

10. This Licence may be cancelled forthwith at any time by either party; by the LICENSEE by notice in writing and delivered to or mailed addressed to the Regional Aquaculture Coordinator's Office, Fisheries and Oceans Canada; by the LICENSOR by notice in writing and delivered to or mailed addressed to the LICENSEE.

DATED AT Vancouver, British Columbia, this (day) day of (Month), (Year) A.D.

LICENCEE: ______________________________________________
(Company)

______________________________________________
Regional Aquaculture Coordinator
for the Minister of Fisheries and Oceans

Appendix 3: Current Pinniped Deterrent Observations (summarised from Fraker et al. 1998)

**1. Primary Net Systems**

- mesh size exerts a significant influence, with small (1.7 – 2.2 cm) mesh nets being more resistant to predators than large (3.3 – 4.4 cm) mesh nets.
- mesh shape (square vs. diamond) is relevant because square hung nets are under more tension and thus billow less and present a flatter surface to predators
- age and strength of the net are related in that newer nets are stronger and less prone to damage by predators
- double bottom (shark guards) are useful adjuncts to primary nets. Dogfish are attracted to the dead salmon that accumulate at the bottom of the cages. The sharks are persistent and often create holes in the nets, which then provide opportunities for seals and sea lions to enter and for farmed salmon to escape.

**2. Secondary Predator Net System**

- the mesh size is too large to confine fish, but too small to permit seals and sea lions to pass through
- the most important requirement is for the predator net to be separated from the primary netcage by enough space to allow for movement of the netcage in the currents, and be weighted effectively to ensure that adequate separation is maintained in the strongest occurring currents.
- double bagging (placing one primary netcage into another) can be effective in frustrating seals, but because two relatively small mesh nets are next to each other, water flow to the fish is restricted.

**3. Visual Factors**

- white nets may interfere with the ability of predators to see fish.
- net fouling organisms may inhibit predation by blocking the view of the net contents and add weight, making it more difficult for billows to form in the nets
- lighting at night may help fish to orient inside the netcage and maintain positions away from the sides, where they are vunerable.

**4. Acoustic Deterrence**

- ADDs are only usually effective for periods of weeks or months, after which the animals began to ignore them.
- the newer high amplitude ADDs project a more powerful signal that may cause discomfort or pain at close range.
- individual animals that have learned to feed at a site may not be deterred, but newer ADDs appear to prevent new animals from becoming problem individuals.
- Airmar Technology Corp has a triggering device under development that would activate the ADDs only when the farm is under attack.

### *Evaluation of Options*

Seals and sea lions should be presented with an essentially rigid external primary netcage surface. This does not mean that the system has to be absolutely flat and stiff, but that the predators need to be presented with a netcage that lacks slack that may billow and that would allow fish to be confined or grasped. The absence of corners (i.e. circular) is also useful for the same reasons.

**Primary Nets**

There are several ways of achieving the desired rigid net surface (Arnold 1992).

a. Weighting and tensioning systems can be effective in increasing net rigidity. Extra horizontal lines and ribs add overall rigidity and reduce the tendency for pockets to develop. Nets are commonly treated with a red copper-based antifoulant, which hardens the fibres (Arnold 1992). In combination with tensioning systems, this adds to the rigid surface.
b. Extra horizontal lines and ribs appear to reduce the ease with which pockets are formed within the netcage.
c. Rigid collars on net bottoms can help maintain net shape, but folds may still develop in central parts of the net and the collars increase the difficulty of raising and lowering nets.
d. Semi-rigid netting is a strong durable material, which has inherent rigidity. Netcages made from semi-rigid netting are more expensive than those made from conventional material, but they may also have a significantly longer useful life.
e. Solid materials such as fiberglass and PVC laminates have been used in constructing prototype cages that appear to be resistant to predators. New materials (i.e. Spectra) may be stronger and more durable, and even if more expensive, the extended life and effectiveness against predators may cost-effectively compensate.
f. Larger netcages appear to be effective in reducing predation because the surface area/unit volume is much smaller.
g. Larger pens also use more, and therefore heavier, material that is more difficult to manipulate.
h. Ocean-Spar tension cage systems are stable in currents up to 3 knots. The spar tensioning system does not require complex weighting and has low stresses resulting in no complex deformations. The resultant semi-rigid cage does not billow and presents seals and sea lions with an essentially rigid flat surface.
i. Sargo and Future Sea Technologies Inc. have floating semi-enclosed and enclosed systems which exclude seals and sea lions. These systems require pumping water rather than natural currents and tidal action to circulate water.

**Predator Nets**

a. the effectiveness is a function of heavy weighting and net integrity
b. whole system or modular predator nets are usually effective
c. predator nets around each primary netpen are the most effective
d. a mesh size of 30 – 35 cm is appropriate

**Curtain Nets**

Curtain nets are considered a poorer option than other exclusion nets, and since they have a high entanglement rate, Scottish Salmon Farmers Association guidelines recommend they be phased out as soon as practicable. However, they are recognised as easier to deploy and maintain. The use of curtain nets as predator control is gradually being phased out and replaced with cage net tensioning (Arnold 1992).

Appendix 4: DFO instructions for reporting pinniped kills and obtaining biological samples from killed pinnipeds, and the quarterly kill statistics report form required to be submitted by fish farm operators quarterly on an annual basis.

## INSTRUCTIONS

### I. QUARTERLY KILL STATISTICS

A report indicating the date, species and certainty of all potential kills, and whether the carcass was recovered, should be submitted once every 4 months. The quarterly reporting periods are January-March, April-June, July-September, and October-December. Reports, including any nil reports, should be forwarded within 15 days of the end of each quarter to:

Aquaculture Division
Department of Fisheries and Oceans
Suite 400, 555 West Hastings St.
Vancouver, B.C. V6B 5G3

Attention: Ron Ginetz

The following information should be recorded on the kill statistics forms provided:

1) **Page number and total number of pages**
If there are too many kills in a quarterly period to fit on a single page the report should be continued on subsequent pages. The page sequence number as well as the total number of pages used should be indicated to insure that the pages received represent a complete report for the quarterly period.

2) **Site name and location**
The name and precise location of your site. Companies operating more than one facility should submit separate reports for each individual site.

3) **Quarterly period**
The 4-month period and year covered by the report. Reports should be submitted for each of the following quarterly periods: January-March, April-June, July-September, and October-December.

4) **Contact name, address and phone number**
The name, address and phone number of a contact person, such as the facility manager, who would best be contacted should additional information or clarification of the provided information be required.

5) **Date of each potential kill**
The date should be recorded for each predator potentially killed, including those cases where there is some doubt whether it was actually killed (e.g. predator was wounded - see item 7 below).

6) **Species potentially killed**
Insofar as possible, each predator potentially killed should be identified to species-level. Methods for identifying those species known to interfere with aquaculture facilities in B.C. are described in section II. Biological Measurements and Samples (see item 1). The descriptions and photographs in the enclosed brochure on seals and sea lions may also be useful.

7) **Certainty of kill**
In some cases, there may be some doubt as to whether a predator was actually killed (e.g. it was shot but then disappeared). You should record all instances in which there was even a possibility a predator was killed. You should also indicate, based on your best judgement, the certainty of each kill as being either positive, probable, or possible.

<u>Positive kills</u>: no doubt that predator was killed (e.g. carcass recovered).

<u>Probable kills</u>: quite sure predator was killed (e.g. hit and sank in a pool of blood, but no carcass recovered).

<u>Possible kills</u>: not sure whether predator was killed or not (e.g. shot at it and think it was hit, but it then disappeared).

In estimating the total number actually killed, it will be assumed that 100% of positive kills were killed, 75% of probable kills were killed, and 50% of the possible kills were killed.

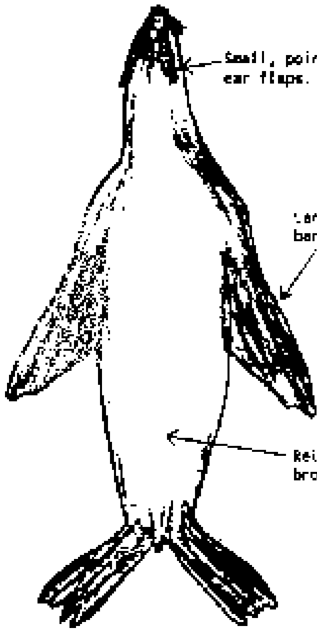
8) **Was carcass recovered and sampled?**
The conditions on your control permit stipulate that all predators killed must be retrieved, sampled, and disposed of on shore by burial. In some cases, however, carcasses may be lost (e.g. sink in deep water). For each kill, you should indicate whether the carcass was recovered and sampled and, if not, a brief explanation should be provided.

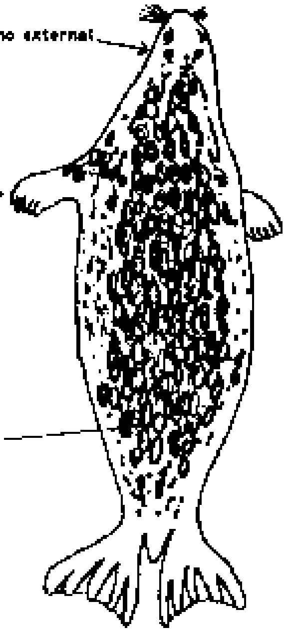
## II. BIOLOGICAL MEASUREMENTS AND SAMPLES

Several biological measurements must be taken and the lower jaw collected from all carcasses recovered. Data should be recorded on the tags provided and the tags affixed to the specimen's lower jaw. The data should be written with a soft lead pencil to insure that it remains legible while being stored. The following measurements and samples are required:

1) **Species**
Seals and sea lions belong to two families: the Otariidae, which in B.C. is represented by California and Steller sea lions and the northern fur seal; and the Phocidae, which in B.C. is represented by harbour and elephant seals. Since northern fur seals and elephant seals only occasionally occur in inshore waters and are not known to interfere with aquaculture operations, identification of the predator usually consists of one or two steps. First, you must establish whether the predator is a phocid (harbour seal) or an otariid (sea lion) and, if the latter, whether it is a California sea lion or a Steller sea lion. The illustrations on the following page show some differences between otariids and phocids, and between California and Steller sea lions. Note that the differences between the two species of sea lions pertain only to males, as only male California sea lions occur in B.C. and the vast majority of Steller sea lions in inside waters are also male. The descriptions and photographs in the enclosed brochure on seals and sea lions may also be useful in identifying the species. In cases where the predator cannot be postively identified, you should describe its distinctive features.

**Otariid (sea lion)** | **Phocid (harbour seal)**





| Otariid (sea lion) | | Phocid (harbour seal) |
|---|---|---|
| Small, pointed external ear flaps. | Ears | Openings but no external ear flaps. |
| Large, dark and bare-skinned. | Foreflippers | Small and fur-covered. |
| Relatively uniform brown in color. | Pelage | Mottled black-grey-white. |
| Up to 2,200 lbs and 10 ft in length. | Body size | Less than 250 lbs and 6 ft in length. |

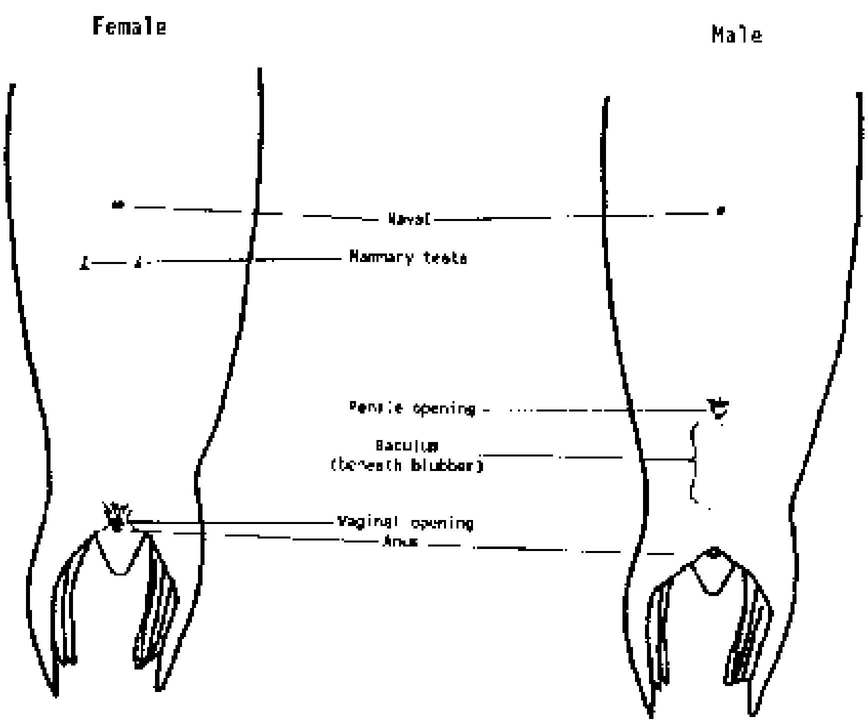
| California sea lion | | Steller sea lion |
|---|---|---|
| Slender snout and steep forehead. Dark brown-black in color though mature males develops light crest on top of the head. | Head | Robust snout and shallow forehead. Tan-light brown in color. |
| Darker, brown-black in color but sometimes bleached to a golden brown on the abdomen. | Pelage | Lighter, color ranges from blonde to medium brown; sometimes darker brown on the underside and around flippers. |
| Distinctive honking bark. | Volcalizations | Deep-throated bellowing roar. |
| Less than 800 lbs; typically 400-650 lbs. | Size | Up to 2,200 lbs; typically 500-1,600 lbs. |

Please note that river otters, martens, mink and other terrestrial mammals, which sometimes inhabit marine shorelines, are under provincial jurisdiction and are not covered by the DFO control permit. Sea otters, which generally occur only along the exposed coast of northwest Vancouver Island and central mainland, are an endangered species and are also excluded from the permit.

2) **Sex (female or male)**
Because the sex organs of seals and sea lions are internal and because the outward appearance of both sexes may be very similar, determining gender is not always straightforward.

The most reliable criterion for sexing both seals and sea lions is on the basis of the presence or absence of a penial opening. In females, the anal and vaginal openings are combined into a single opening on the underside of the animal immediately forward of the base of the tail. In males, there is an anal opening at the base of the tail and a second penial opening on the belly-side approximately 1/8th up the body (i.e. about 7 inches forward of the anus on an average-sized harbour seal). These differences become obvious after both sexes have been examined and compared.

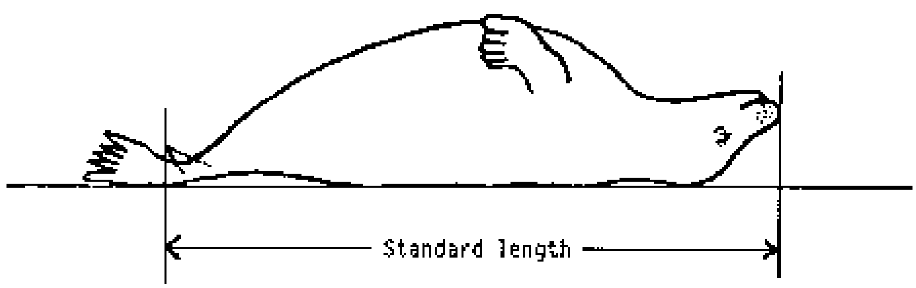
In adult males, it may be possible to feel or see the baculum (penial bone) which lies between the anus and penial opening beneath the blubber. It is important to note that the penial opening is an actual opening and should not be confused with the naval (umbilical) scar which is present on the belly-side of both males and females but further forward of the mlae penial opening (on males the penial opening lies approximately midway between the anus and naval). Also, animals should not be categorized as female based solely on the presence of mammary teats as rudimentary nipples are sometimes evident on males.



**3) Standard length**

Standard length is defined as the linear distance between the tip of the snout and tip of the tail with the animal lying on its back. When making this measurement, it is important that the animal be lying in as natural position as possible. Length should always be measured within a few hours of collection before rigor sets. Length should never be taken with the animal lying on its belly and should always be measured in a straight line rather than following the curvature of the body.

Standard length is best measured by laying the animal in a natural position on its back, marking the location of the tip of the snout (not including the vibrissae or whiskers) and the location of the tip of the tail (not including the hind flippers) and then measuring the linear (i.e. shortest) distance between the two marks. This approach is better than trying to line-up the snout or tail with a fixed mark as there is a tendency for the animal to be stretched or compacted in the process. While both units are acceptable, you should indicate whether the measurement is in centimeters or inches.




**4) Body mass**

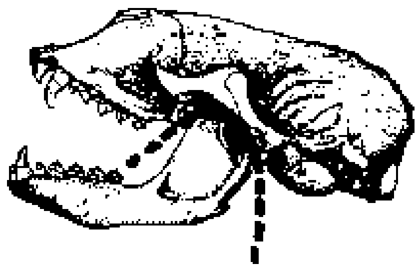
Total body mass should be weighed within an hour or so of recovery as animals lose mass rapidly as they dehydrate. While both units are acceptable, you should indicate whether measurement is in kilograms or pounds.

Larger individuals, particularly Steller sea lions, may have to be weighed piecemeal, in which case this should be noted on the space provided on the reverse side of the tag for additional comments.

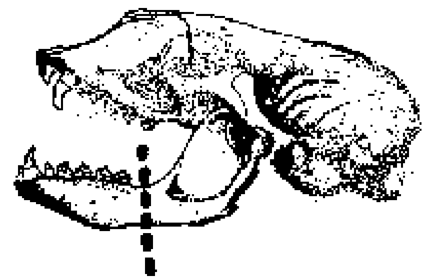
**5) Lower jaw**

A lower canine is required for age determination. Since teeth are extremely difficult to extract from the jaw without damaging them, it is much easier to remove the entire lower jaw.

The lower jaw can be removed by two methods. The easiest, once the technique is learned, is to cut through the cartilage and musculature between the joint where the jaw hinges on the upper skull. Alternatively, the tip of the lower jaw can be removed by sawing through the skin, muscle and bone with a coarse meat- or hack-saw or a small hatchet. When using the latter method, be sure to make the cut at least 3-4" behind the canine teeth as their roots curve backwards within the jaw.



Cut along joint



Cut through bone

The labels (on which the other data from the specimen have been recorded) should be firmly affixed to the lower jaw. The wire on the tag should be wrapped around both the right and left halves of the lower jaw to prevent them from becoming separated.

The lower jaws can be preserved until they are submitted at the end of each quarterly period by one of two methods. The preferred method, if sufficient freezer space is available, is to freeze them in plastic bags. Alternatively, the jaws can be salted and stored at ambient temperature in the bucket provided. When using the latter method, enough salt should be added to cover the jaws, the lid of the bucket sealed, and the bucket stored in as cool a location as possible away from any dogs, etc. Formalin or alcohol should not be used to preserve the jaws.

6) **Additional comments:**
Space is provided on the reverse side of the label for additional comments. Any deviations from normal sampling procedures should be noted along with any unusual observations.

7) **Reproductive tracts: (OPTIONAL)**
When combined with ages from teeth, reproductive tracts (i.e. the uterus and both ovaries) provide information on age of maturation and pregnancy rates, which are probably the two most important parameters in regulating natural populations. Data obtained from reproductive tracts are therefore of enormous value in projecting future population trends and in predicting how populations may respond to various forms of population control (e.g. culls, application of anti-fertility drugs).

Although not mandatory, the Department is soliciting volunteers to collect reproductive tracts. Tracts are required only from females taken in the Strait of Georgia (Campbell River-Victoria) during the months of December-August. A biologist will visit any facility interested in participating in the project to demonstrate the removal procedure, which requires about 15 minutes. In addition, DFO will provide formalin and containers for storing the samples, periodically pick-up the samples, and pay a recompense of $25.00 for each sample collected. Facilities interested in participating in this project should contact our research program (see below).

## III. SUMMARY

1) Complete the top portion of the quarterly kill statistics form at the beginning of each quarter (1st January, 1st April, 1st July, and 1st October).

2) Maintain a record of the dates, species and certainty of all potential kills, and whether carcasses were recovered, on the kill statistics form.

3) Determine the species and sex, measure the length and total body weight, and remove the lower jaw from each carcass recovered. Record these data on the labels provided, wire the labels to the lower jaw, and either freeze or salt the jaws (optionally, you could also remove the reproductive tract and preserve it in formalin).

4) Submit the quarterly kill statistics report and lower jaws within 15 days of the end of each quarterly period (15th April, 15th July, 15th October, and 15th January).

If you have any questions or comments concerning the sampling program, please contact:

Marine Mammal Research
Pacific Biological Station
Nanaimo, B.C.
V9R 5K6

Attention: Peter Olesiuk
Phone (604) 756-7254

If you have any questions or comments concerning your predator control permit, please contact:

Aquaculture Division
Department of Fisheries and Oceans
Suite 400, 555 West Hastings St.
Vancouver, B.C.
V6B 5G3

Attention: Ron Ginetz
Phone (604) 666-3152

PLEASE NOTE: Reports, including nil reports when no predators are killed, must be submitted every quarter.

License #: ___

Page ___ of ___

QUARTERLY KILL STATISTICS

Site name & location: ___ Quarterly period: ___, 19___

Contact name & address: ___ Phone number: ___

| Date | Species (check one or specify) | | | | Certainty of kill (check one) | | | Was the carcass recovered and sampled? | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Day & Month | Harbour seal | Calif. sea lion | Steller sea lion | Other species (specify) | Positive (100%) | Probable (75%) | Possible (50%) | Yes | No | If no, explain why |
| | | | | | | | | | | |
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