Review on utilization and research on harbour seal *(Phoca vitulina)* in Iceland

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ABSTRACT

Harbour seals *(Phoca vitulina)* have been harvested in Iceland since the first settlers arrived in the 9th century. Pups were generally netted, clubbed and harpooned until 1875 when general use of guns for hunting began. Seal-hunting has been traditional amongst the farms legal rights. Seal hunting was an important supplement to other economic resources. Harbour seal skins, salted or dried, were exported and large dataset of catch statistics is available from trading logbooks since the late 19th century. In the early 20th century catch was about 6,000. In the 'bounty' period 1982 – 1989, maximum catches were of 4,000 animals with about 350 hunters participated; in 2006 catches were only about 100 animals with 18 hunters. After 1989 the population continued to decline even though catches decreased markedly. Unreported by-catch in fishing gear, hunt for local consumption and shooting of seals swimming in salmon rivers estuaries may have kept the total removal from the stock above sustainable levels. A considerable Icelandic knowledge base had been compiled about the biology of the harbour seal since the late 16th century, with the first written reference in 1588-1589. In the last decades, research on various aspects of its biology and monitoring have been intensified, with focus on abundance, distribution, diet and nematode infestation. The main results show that the Icelandic harbour seal population - has declined annually about 5% in the period 1980-2006, - was most abundant on the NW-coast, - feeds mainly on sand-eels and gadoids, - and was less infected with anisakid nematodes than grey seals. Seal-watching, as a low-consumptive indirect utilization, may represent a new economical opportunity if properly regulated.

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INTRODUCTION

In the 9th century, when Iceland was settled there is indication of large abundance of seals and many locations are named after seals and sealing (Kristjánsson 1980, Hallgrímsson 1985). Sealing likely started right in the beginning of the settlement and seals were probably a quite important resource for the early settlers. Indications of this are reflected by clauses in the early laws and rules that relate to seals and sealing. Settlement locations were often chosen with regard to facilities for seal hunting and from early days landowners sold permissions for sealing at places where prospects for spotting seals were considered good (Kristjánsson 1980).

Seal-hunting has been traditional amongst the farms legal rights, no form of license or catch quotas have been introduced. All individuals holding Icelandic license for shooting weapon are allowed to hunt seals outside the jurisdictions of private land. All adult residents in Iceland can apply for this license and visitors may apply for temporary license.

Harbour seal *(Phoca vitulina)* skins were exported salted or dried and large dataset of catch statistics is available from

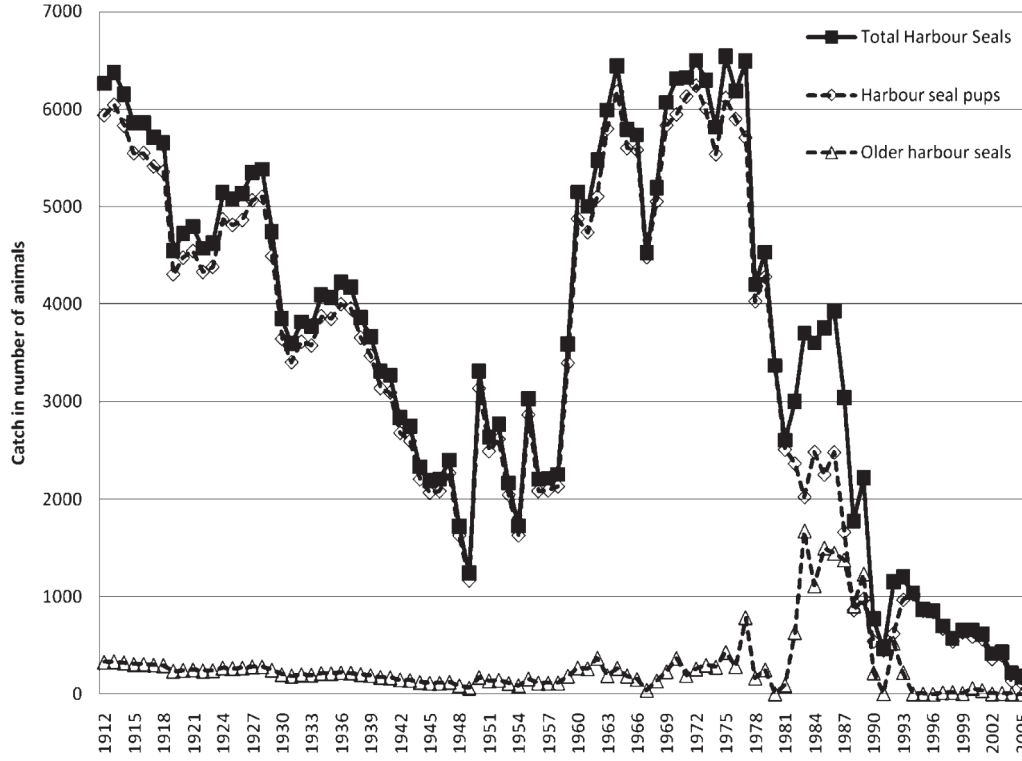

Fig. 1. *The catch of harbour seals* (Phoca vitulina) *from 1912 to 2006, in Icelandic waters, divided between pups and 1+ animals. Figures from the logs of commercial seal skin dealers in the period 1962-1971 indicate that about 90% of the catch was harbour seal pups and about 5% was 1+ harbour seals (Arnlaugsson 1973), with harbour seals representing 95% of the catch and the remainder being grey seal pups. This was used to estimate harbour seal pup catch and 1+ harbour seal catch from the total catch, for the years 1912 to 1961 and 1972 to 1977. Raw data is given in Appendix 1 in Hauksson and Einarsson (2010).*

trading logbooks, since year 1897 to present. Seal-hunting rights were considered highly profitable. Thirty-two churches and three monasteries are known to have held such rights, and the Episcopal see owned a number of seal-hunting farms. Seal hunting was regarded as an important supplement to other economic resources, and in certain regions it at times provided the only means of subsistence. In the beginning of the 17th century sealing (mainly harbour seals) was important for at least 395 farms, compared to 215 in the 18th century and 264 farms in year 1932 (Kristjánsson 1980). In this paper data on the utilization and biology of the Icelandic harbour seal is reviewed, for underlining the importance of the harbour seal for the Icelandic inhabitants and in the Icelandic nature, at present and in the past.

SEALING

As the harbour seal pups in the spring or early summer, it was referred to as spring seal. The way harbour seals have been harvested has not varied much with time until 1875. Pups were generally netted although clubbing was also practiced, and harpooning was used too. All harpooning was discontinued in 1875, when guns for sealing became more frequent.

Sealing statistics indicates that in the late 19th and early 20th century harbour seal catch was much higher than recently, about 6,000 individuals a year compared to about 100 in 2006, when only 18 hunters took part. Catches exceeded 6,500 animals annually, from 1901 to 1914 (Fig. 1 and five-year average from 1901- to 1912, see Appendix 1 in Hauksson

and Einarsson 2010). The catches showed a decreasing tendency and dropped of a thousand in 1919, just following an acute epizootic pneumonia in 1918 which is estimated to have caused at least about 1,000 animals reduction in about 29,000 animals population or about 3% (Skírnisson and Pétursson 1983). Overall, catches continued to decline after 1919 and reached a minimum during and post WWII, in the period 1939-1959. At this time more and more people were moving from the countryside to towns, giving up farming and getting jobs in industry and retail. The sealing effort may also have decreased after 1928 due to unfavourable prices for skins and skin export during the Great Depression and then WWII. The apparent decline during WWII might partly be due to less export rather than less catches. Arnlaugsson (1973) observed some correlation between annual harbour seal pup catches and the price of seal skins in the European market. Extrapolating hunting statistic from export statistics may be less reliable around the war years than in periods where the market situation was more stable and seal skins from catch of the year could be exported right away.

Catches stayed relatively low until 1960 when they dramatically increased and remained high, at the level of 5,000-7,000 animals per year until 1977 (Fig. 1). In this period, there were good markets and high prices for sealskin in Europe. The seal farmers got paid for the skins in Icelandic kroner from the exporters, and since the value of the Icelandic kr. decreased constantly compared with the USD, the prize for the sealskin in Icelandic kr. increased constantly. The sealskin market collapse in 1978 due to the anti-sealing propaganda directed at the Canadian seal industry. Seal farmers could not sell their skins, and the catches started declining, to less than 3,000 seals.

In the period 1982-1989, when a bounty was paid by the Icelandic Fishery Organisations, for hunting harbour seals, the total catch of harbour seals rose to about 4,000 animals and about 350 hunters took part. This bounty program was initiated by the Research Committee for Biological Seafood Quality [RCBSQ] in order to subsidize sealing in Icelandic after the decline in sealing due to the diminished demand for seal products (MRI 2008). Initially the program aimed at increasing the overall hunting of all s eal-species, but in 1990 to 1994 bounties for harbour seals became paid exclusively to seal farmers, as a compensation for the prospects on the seal skin markets at that time. The catch of older harbour seals which increased, while the catch of pups continued decreasing (Fig. 1), thus changing the age composition of the catch, with an increase in the proportion of adult animals compared too pups in the total catch (Hauksson 1992a).

Since 1990 harbour seal catch has mostly consisted of pups hunted by seal farmers or seals drowned in fishing gear, except in 1992/93 when adult harbour seals were taken, for an investigation on the diet and stomach nematodes (Hauksson and Bogason 1997, Olafsdóttir and Hauksson 1998). From 1993, the direct catch of harbour seal pups declined again due to the difficulties on seal skin markets. However, there are indications for considerable by-catch of harbour seals in the lumpsucker *(Cyclopterus lumpus)* fishery. This fishery has a long history in Iceland, although in recent decades the species has mainly been exploited for the roe. The fishing is therefore mainly conducted in the period from March to June in shallow waters and the fishing effort is quite variable and fluctuates inter-annually with the demand for roe on fishing markets. It peaked in mid 1980's and 1990's but has been relatively low since 1997 (MRI 2008), so the mortality inflicted by the lumpsucker fishery on the harbour seals has probably been reduced in the last decade. This may have led to the beginning of a recovery of the Icelandic harbour seal population, as indicated by the growth rate of 5% observed between 2003 and 2006 (Hauksson and Einarsson 2010).

HARBOUR SEAL KNOWLEDGE THROUGH HISTORY

In earlier times, Icelandic seal hunters and farmers accumulated knowledge about seals through observations and experience. Since the six-

teenth hundred, the considerable knowledge gathered has been kept in hand-written annals on vellum and parchment. The first reference on harbour seal in Iceland is made by the Bishop of Skálholt (see Fig. 2 for the location of the places mentioned), Oddur Einarsson (1588-1589 cited in Jónsson 1988). He did not refer to the species directly, but mentionned a coastal stationary seal caught in coarse nets in river mouths and being of great value, giving food and fur. He differentiated it from seals migrating from the ice in the North (harp seal *(Phoca groenlandica)*, hooded seals *(Cystophora cristata)* and ringed seal *(Phoca hispida))*. Jón Guðmundsson (1640-1644 cited in Jónsson 1988) mentioned six seal species and correctly noted that harbour seals give birth to pups at the same period as ewes have lambs (the month of May). Olavius (1780) mentioned three seal species in his report on the economy and natural resources of Iceland, one of which likely being the harbour seal. Seals were considered very important food for the Icelanders in those days and rewards were offered to promote seal hunting for fur and food by the local Danish government at the command of the Danish King, then the sovereign of Iceland. The Bishop of Hólar, North Iceland, organized sealing for gathering food for needy people during famines.

After 1800, the studies on harbour seals, as well as the other marine creatures, becomes more systematic and scientific. Thienemann (1824) made note of the general behaviour of harbour seals in the fiord Eyjafjörður, which must be considered the first scientific ethologic study on harbour seals in Iceland. Thienemann also described Icelandic harbour seals anatomy and life history (Thoroddsen 1904). Sæmundsson (1932, 1939) described harbour seal occurrence, distribution and biology more thoroughly and estimated the population size to 15-20 thousand. Arnlaugsson (1973) and Einarsson (1978) estimated the size of the population and reviewed information about the biology. Arnþór Garðarsson (unpublished) counted harbour seals from an aircraft on part of the Icelandic coast in the summer of 1973 and 1977. He found 2,500; 632 and 3,568 harbour seals in Faxaflói, Vestfjörðum and NW-NE-coast respectively

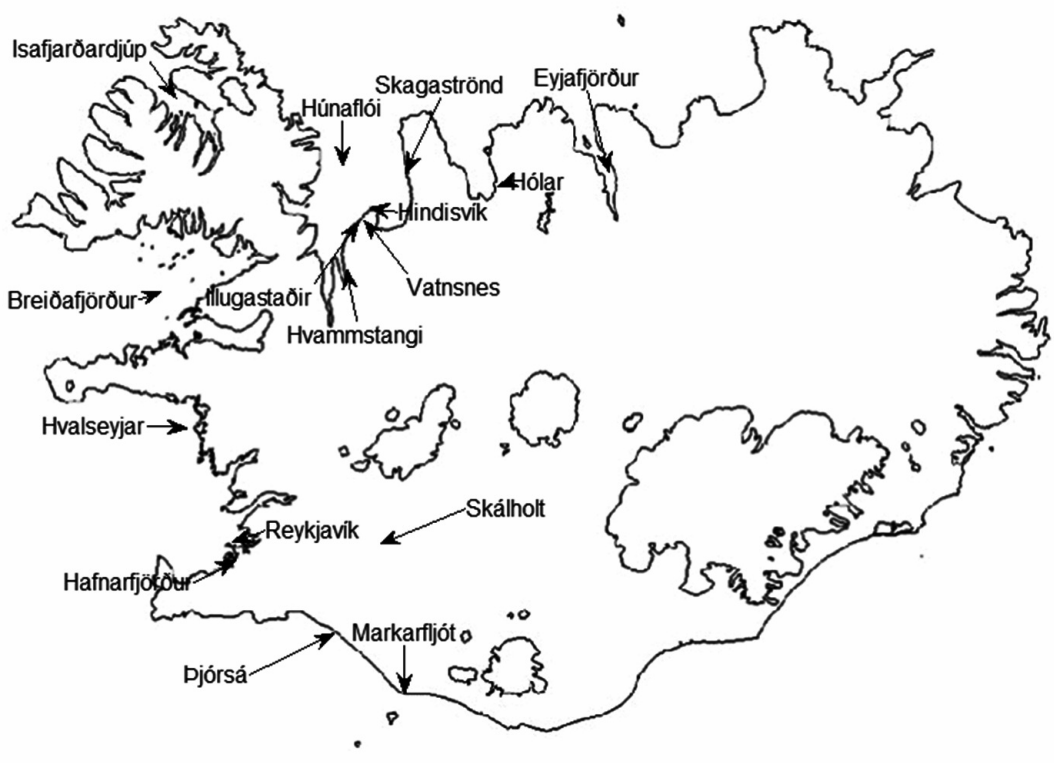

Fig. 2. *Map of Iceland with locations and names of places referred to in the text.*

(cited in Einarsson 1978). Pálsson (1976) did aerial counts on the South-coast of Iceland in 1976 and observed 5,800 harbour seals. Eldon (1977, cited in Jónsson 1990), studied the diet in Icelandic waters by collecting feces and found gadoids remains dominating in the river estuary of Þjórsá while sand-eels (*Ammodytes* spp.) remains dominating in Hvalseyjar. The Marine Research Institute [MRI] compiled the older catch data from 1962 and continue holding the catch statistics. It gives information on the abundance and advise on sustainable levels of removals in its annual report on the status of marine stocks in Icelandic waters (MRI 2008). In 1982 a program to collect standardized information on the seal catch was initiated, including ageing of animals in the catch in 1982-84 and 1990 and thereafter (Hauksson 1992a and unpublished). Regular monitoring of the population started in 1978 (Garðarsson unpublished, Pálsson 1976, Jónsson 1990, Hauksson 1992b, Hauksson 2010).

Economic value

The economic value of the harbour seal catch has been reduced in recent decades along with diminishing demands for skin products (Guðmundsson 1944, Þorsteinsson 1964, Þorleifsson 1982, Gíslason 1986). The interest has shifted from seals as a resource toward its potential economic effects on the fishing industry. Consequently, there has been an increase in investigation on the role of seals in the ecosystem and in the life cycles of fish parasites (Sæmundsson 1897, Sólmundsson 1952, Þorláksson 1952, Dagbjartsson 1982, Hannesson 1982, Gunnarsson 1988, Hauksson and Bogason 1997, Olafsdóttir 2001, Olafsdóttir and Hauksson 1998).

In recent years, eco-tourism has increased in Iceland, and seal watching has already gained much popularity since the first firm was established in 2005. Some harbour seals' rookeries are now protected by landowners not for harvesting pups as was usually the case, but for seal watching. Stakeholders in eco-tourism fear that uncontrolled encounters between tourists and harbour seals during seal-watching may negatively affect the seal-herds and thereby weaken the financial foundation of the business.

DISTRIBUTION AND MOVEMENTS

The harbour seal is the most abundant coastal seal in Icelandic waters, occurring all around the coast, but with highest density in the bay of Húnaflói, NW-Iceland. It mainly inhabits two habitat types, rocky shores and river estuaries. Totally, 98 haulout sites have been identified and monitored "semi regularly" since 1980. Majority of the haulout sites were on the NW-coast (Hauksson 2010).

The Icelandic harbour seal population is one of the six populations which have been described in the NE-Atlantic (Goodman 1998). More recent investigations based on DNA investigated with new techniques have clarified its relationship to the other harbour seal populations. It seems to be more related to harbour seals in northern Norway than Greenland (Andersen and Olsen 2010).

In 1976 ten harbour seal pups were tagged in the estuary of glacial river Markarfljót, S-Iceland. Four recaptures occurred in the vicinity of the tagging site shortly after the tagging. One harbour seal was entangled in lumpsucker nets in Isafjarðardjúp, NW-Iceland nine months later (Einarsson 1977).

As reviewed in Hauksson and Einarsson (2010), the early estimates of the size of the population were mostly based on harvest data, then from 1978 on counting and surveying the seals on the coast (Jónsson 1990), and since 1980 harbour seal abundance has been estimated regularly every 3 to 5 years, by aerial surveys along the entire coastline (Hauksson 2010).

LIFE HISTORY PARAMETERS

Investigations of the life history parameters were carried out in 1980-85 and in 1990-93 (Hauksson 2006). The maximum observed age was 36 years for females and 30 years for males. The asymptotic lengths and body masses for females and males were estimated to 161 cm and 93 kg and 174 cm and 97 kg, respectively.

Males reached sexual maturity between five and seven years of age, whereas 50% of females became mature at the age of 4 years. The mean birthing period for the Icelandic harbour seal was found to be in early June. No significant differences in life history parameters were observed between the two periods.

Estimate of the average rate of exponential increase (r_{est}) for the period 1980-2006 was -0.05 (Hauksson 2010). The r_{est} has not been calculated for other periods, but was most likely negative in the years following an epizootic outbreak in 1918 (Skírnisson and Pétursson 1983).

ROLE IN THE ECOSYSTEM

Pálsson (1977) collected diet samples from 49 harbour seals in 1975. The samples were mainly collected during wintertime and capelin (*Mallotus villosus*) was found to be most abundant prey followed by sand eels and gadoids. A more intensive study in 1992 – 1993 (Hauksson and Bogason 1997), with a sample size of 799, showed that the main food items, measured in percentage by weight, was cod *(Gadus morhua),* redfish *(Sebastes* sp.*)*, sand eels, saithe *(Pollachius virens)*, herring *(Clupea harengus)*, catfish *(Anarhichas lupus)* and capelin. Geographic and seasonal differences were observed. Off the south coast, sand eel occurred more frequently during spring and summer, while capelin and herring were more important in the diet in autumn and winter. Off the other coastal areas, cod was the major prey item, and no seasonal variation was observed. The estimated prey sizes ranged mainly between 10-40 cm and the maximum estimated fish size observed was about 70 cm. Age-groups of cod in the diet were 0-5 years. Bogason (1995) concluded that 20% of the natural mortality of 2-3 year old cod in 1992 and 1993 could be explained by the predation of harbour seals. Low cod and sand-eel recruitment in recent years raises the question, whether the Icelandic harbour seal population could be food-limited or whether shifts have occurred in the diet towards species such as haddock *(Melanogrammus aeglefinus)* and herring, which are much more abundant in Icelandic waters now than in the years 1992/93 (MRI 2008). A new study on the diet of the Icelandic harbour seal was initiated in 2008 by BioPol Inc. marine biotechnology-science hotel Skagaströnd NW-Iceland, for investigating potential changes in the diet as a consequent to the changes in prey availability in the last decade. Harbour seals appear to be opportunistic fish eating top-predators in Icelandic coastal waters. They may compete with grey seals *(Halichoerus grypus)* and cormorants *(Phalacrocorax* spp.*)*, since these two species have been shown to feed on similar prey species (Hauksson and Bogason 1997, Hauksson 2005, Lilliendahl and Sólmundsson 2006).

Arctic fox *(Alopex lagopus)* and gulls have been observed killing harbour seal pups and are known to devour dead pups and older seals (anecdotal information). A group of killer whales *(Orcinus orca)* have been seen throwing a young dead grey seal between each other, behaviour that probably ended by eating it (Karl Gunnarsson pers. comm.). Killer whales probably predate on harbour seals too and harbour seals have been observed fleeing high up on the shore in the presence of killer whales close to haulout sites (anecdotal information). Sharks are known to kill seals in Canadian waters (Ainley *et al.* 1981, Le Boeuf *et al.* 1982), and seals have also been found in the stomach of Greenland sharks *(Somniousus microcephalus)* in Icelandic waters (Sæmundsson 1926).

Young grey seals have been observed harassing harbour seals at rookeries and fully grown grey seal males have been observed killing harbour seal pups (anecdotal information).This behaviour may indicate inter-species competition for space. In earlier times when harbour seal skin prizes were high, farmers in the fiord Breiðafjörður drove grey seals away from the most important harbour seal haulout sites, by shooting them. Prizes for skins of grey seal pup were always lower, and the farmers had experienced that grey seals could take over the rocks and spoil the opportunities for catching harbour seal pups (local farmers pers. comm).

Harbour seals are regarded as nuisance in salmon *(Salmo salar)* rivers and are driven away by shooting and harassing individual seals that

are seen. Usually, this does not lead to large number of killed seals, sine the seals usually dive and disappear quickly from the estuaries. The aim of the owner of the river is usually not to kill the seals, but to keep the river and estuary clear of seals during the salmon run season (anecdotal information).

POLLUTANTS, DISEASES AND PARASITES

Pollutants accumulate in the blubber and tissue of top predators like harbour seals through consumption of fish diet. Concentrations of organochlorines in harbour seal blubber from Icelandic waters in the period 1988 - 1990, were found to be at relatively low levels, much lower than observed in the North Sea (Germany) and northwestern Ireland (Vetter *et al.* 1995, Klobes *et al.* 1998), but in similar concentrations that Wolkers *et al.* (2004) observed in harbour seals from Svalbard. There is no evidence for pollution having influence on the reproduction of Icelandic harbour seals, although this has been shown elsewhere (Helle 1976, Reijnders 1982).

Early in the spring of 1918, the first sign of an epizootic of acute pneumonia was observed among harbour seals along the coast of Iceland. The seals exhibited signs of respiratory distress, were reluctant to dive and crawled ashore, even in the presence of people (Skírnisson and Pétursson 1983). Epizootic diseases have not been observed in Icelandic harbour seals since the 1918 epidemic and the morbillivirus outbreak in European populations in 1988 and 2002 did not reach Iceland (Harding *et al.* 2002). Mortality estimated for the Icelandic harbour seal in 1918 (3.4%) was much lower than the one reported from the morbillivirus outbreak in northwestern European waters in 1988 and 2002 (about 60% each time, Lonergan and Harwood 2003).

Skírnisson and Ólafsson (1990) collected a total of 12 parasite species from 15 harbour seals from Icelandic waters. Three of them had previously not been recorded from Iceland, the nematodes *Otostrongylus circumlitus*, *Dipetalonema spirocauda* (hearthworm) and the acanthocephalan *Corynosoma semerme*. Skírnisson and Ólafsson (1990) especially described the biology and life-cycle of the sea louse (*Echinopthirius horridus*) in Icelandic waters. Pálsson (1977) investigated 36 stomachs and 26 intestines from Icelandic harbour seals and found four species of ascaridoid nematodes, *Phocanema decipiens, Phocascaris cystophorae, Contracaecum osculatum* and *Anisakis* sp. larvae. Prevalence and abundance of adult worms were 72% of seals infected and 30.1 worms/seal, 17% and 0.4, 33% and 2.6, and 0% and 0.0 respectively. Distribution and abundance of stomach and intestinal nematodes in harbour seals have since been investigated by Olafsdóttir and Hauksson (1998). The most abundant adult species was *Pseudoterranova* (=*Phocanema*) *decipiens*, with *Contracaecum osculatum* and *Phocascaris cystophorae* being less frequent. The prevalence and abundance of *P. decipiens* showed marked geographic variations, with higher numbers in harbour seals from the west and the northwestern coast. Olafsdóttir (2001) discussed the lower infestations of sealworms in harbour seals than in grey seals, and hence the lesser importance of harbour seals in the dynamics of the worm in Icelandic waters at the current levels of seal abundances. A different picture was however reported elsewhere, with Wiles (1968) suspecting harbour seals to uphold high infestations of sealworms in cod in the Gulf of St. Lawrence, the Strait of Belle Isle and the Labrador Sea, while Andersen *et al.* (1995) related sealworm infestations in shallow water fish-species to harbour seal densities off the Norwegian coast.

EXPLOITATION OTHER THAN HUNTING

Harbour seals are frequently entangled in fishing gear, especially gill nets and lumpsucker nets. Icelandic regulations demand reporting of all catch in fishing logbooks including by-catch of marine mammals, although there are strong indications that this demand may not be followed by all fishermen (NAMMCO 2007). Some sport-hunting for harbour seals is practiced and fur and meat may or may not be utilized.

In a small and narrow bight, Hindisvík Vatnsnes, NW-Iceland, harbour seals have been protected from seal-hunting since 1940, by the decision of the landowner at that time, pastor Sigurður Norland. There has been since then an open access for tourists and local people to view seals on the spot, with no limitation for approaching the animals for watching and photographing. Total number of harbour seals in this area has decreased markedly since then, and was in the summer of 2008 several orders of magnitude lower than when the protection was established in 1940 (Tómas Þorvaldsson pers. comm.). The decrease in the number of harbour seals in the bight of Hindisvík seems far greater than in adjacent areas where traditional sealing has been performed, although reliable counts are not available for 1940. Hindisvík is a part of Vatnsnes haulout site no 53 (see in Hauksson (2010)), which has not shown a significant change in harbour seal numbers in the period 1980-2006. Results from a special study on haulout behaviour of harbour seals in Hindisvík gave a maximum of 78 harbour seals the 5 May 1980, 190 the 10 June 1989, 287 the 10 July 1990, 380 the 22 July 1991, 56 the 3 June 1998, 154 the 7 July 1999, 121 the 7 June 2002 and 234 the 14 July 2003 (Hauksson 1985, 1992b, 1993, unpublished). This suggest an increasing abundance of harbour seals in Hindisvik in the period 1980-1991, an overall movement out of Hindisvik between 1991 and 1998, and then an increasing movement into Hindisvik from 1998 to 2003. It is, however, difficult to establish whether there exists a connection between the potential harassment of tourists and the changes in abundance of harbour seals at Hindisvík, since data on tourist traffic only started being collected in 2006. In 2008 the protection of eiderduck (*Somateria mollissima*) nests and harbour seals in Hindisvík was reinforced and the area was closed for tourists and local people. This action seems to have led to increasing harbour seal numbers (Tómas Þorvaldsson pers. comm.). In 2008 a monitoring program of harbour seals in the southwest part of Húnaflói was initiated by the Seal Center at Hvammstangi, which incorporates Hindisvík as well. An ongoing study on the behaviour of the seal watchers and the harbour seals on the rocks at the farm Illugastaðir, close to Hindisvík, has been initiated for detecting the potential effects of human disturbance on seals. The results from this study will be used for establishing guidelines for the management of seal watching operations.

PRESENT CONSERVATION AND UTILIZATION OF THE ICELANDIC HARBOUR SEAL POPULATION

The population size was estimated to be about 60,000 animals in 1912, then about 10,000 animals in the year 2003 and 12,000 in the year 2006 (Hauksson and Einarsson 2010). In the last decade, the harvest rates have been very low, but even so the population continue declining up to 2003. It is quite probable that unreported catches are still quite high. Unreported catches includes by-catch in lumpsucker nets and other fishing gear and shooting of seals for local consumption or attempts to prevent salmon disturbance in estuaries. Four of the ten tagged harbour seal pups were recovered from lumpsucker nets. Mortality caused by fishing gear could then be about 4/10 (40%, range 15% - 71%) for pups (Einarsson 1977). The lumpsucker fishery has been considered as the most harmful by-catch agent for the harbour seal population in Icelandic waters (NAMMCO 2005). The more marked decline in harbour seal numbers have occurred in coastal areas were the efforts of the lumpsucker fisheries were the highest (Hauksson 2010 , Hauksson and Einarsson 2010, MRI 2008 for fishing effort of lumpsuckers). The only exception to this has been off the south-coast, with considerable decline in number of harbour seals but little lumpsucker fishery. Reduced levels of direct takes may therefore not be sufficient to prevent takes above sustainable levels if by-catch rates are and remain, high.

The misreporting of by-catch prevents a responsible management of the stock that requires detailed monitoring of all removals together with abundance data. The fishermen have no interest in the seals getting caught in their nets, since they cannot utilize the seal products in any way to increases their income and the seals

cause damage to the fishing-gear. Some form for dialog is needed between harbour seals researchers, lumpsucker fishermen and other harbour seal hunters, based on confident trust, for working out a plan for decreasing the by-catch and the unreported catch of harbour seals.

Harbour seal numbers also have been reduced off the south-coast where lumpsucker fishery has been little practiced and sealing was very difficult from the exposed sandy beach cut with glacial rivers estuaries. Therefore, it is also possible that some other unknown factors are causing the decline in harbour seals there, such as the frequent debacle with violent rush of water from glaciers flooding off the shore. Food shortage could also be an explanatory factor, since both the sand-eel and the cod stocks are presently at historical low levels in Icelandic waters, and especially off the south coast for the sand-eel (MRI 2008, Valur Bogason pers. comm.). Young harbour seals may also be dispersing to the fishing grounds for lumpsuckers and by-caught there. Marking-recapture experiments have shown that harbour seals can undertake extensive journeys along the coast (Einarsson 1977).

Could harbour seal watching turn out to be a new opportunity in cultural tourism? Such low-consumptive uses of the harbour seal resource could yield substantial net economic benefits in relation to the scale of utilization. Net economic benefits would here be measured as the value of the recreational or educational opportunities enjoyed by users minus the necessary economic costs of producing these opportunities. It is useful to consider that the low-consumptive indirect utilization of marine mammal resources usually can be achieved with little or no conflict with the direct utilization of stocks through commercial harvesting. Particularly if commercial harvest is kept within the limits of MSY, plenty of individuals will remain for low-consumptive uses. The demands of the latter usually are trivial in their effect on stock abundance for commercial harvesting (Copes 1981). Such harbour seal herds on display could be used as conservation hot spots for maintaining the Icelandic harbour seal population. Seal-watching must, however, be properly regulated for not turning into seal-harassment, as it may have been the case in the bight of Hindisvík. The protected seal herds could make a stronghold for the population in general, making one patch of the 98 patches of the Icelandic harbour seal population, in a meta-population context. From these herds, surplus harbour seals could colonize other patches or new ones (see Hauksson 2010).

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REFERENCES

Ainley, D.G., Strong, C.S., Huber, H.R., Lewis, T.J. and Morell, S.H. 1981. Predation by sharks on pinnipeds at the Farallon Islands. *Fish. Bul.* 78(4):941-945.

Andersen, K., des Clers S. and Jensen T. 1995. Aspects of the Sealworm *Pseudoterranova descipiens* life-cycle and seal-fisheries interactions along the Norwegian coast. In Blix, A.S., Walløe L. and Ulltang Ø. (eds.); *Whales, Seals, fish and man.* Elsevier Science B.V., Amsterdam, 557-564.

Andersen, L.W. and Olsen, M.T. 2010. Distribution and population structure of North Atlantic harbour seals *(Phoca vitulina)*. *NAMMCO Sci. Publ.* 8:15-36

Arnlaugsson, T. 1973. *Selir við Ísland* (Biology of Icelandic seals). Research report. Icelandic Fisheries Laboratories. Reykjavík, 26 pp. In Icelandic.

Bogason, V. 1995. Fæða landsels *(Phoca vitulina)* við Ísland (Food of harbour seals in Icelandic waters). Hafrannsóknastofnun (MRI). *Fjölrit* 57:319-330. In Icelandic.

Copes, P. 1981. Some aspects of evaluating low-consumptive uses of marine mammal stocks. In: Clark, J.G., Goodman, J. and Soave, G.A. (eds.); *Mammals in the Seas,* FAO Fisheries Series 5*, vol 3*, Food and Agricultural Organization of the UN, Rome, 67-71.

Dagbjartsson, B. 1982. Um selveiðar 1982 (About sealing in 1982). *Ægir 82:625-627.* In Icelandic.

Einarsson, S.T. 1977. Tagging of Icelandic Seals. *ICES C.M.* 1977/N:22. 3 pp.

Einarsson, S.T. 1978. Selarannsóknir og selveiðar (Seal research and sealing). *Náttúrufræðingurinn* 48:129-141. In Icelandic with a summary in English.

Gíslason, E.G. 1986. Selveiðar eru hefðbundin hlunnindi bænda (Sealing was the traditional subsidiary of farmers). *Freyr* 12:458-459. In Icelandic.

Goodman, S.J. 1998. Patterns of extensive genetic differentiation and variation among European harbour seals *(Phoca vitulina vitulina)* revealed using microsatellite DNA polymorphisms. *Mol. Biol. Evol.* 15:104-118.

Guðmundsson, B. 1944. Nokkur orð um selveiði á Íslandi fyrrum og nú (Sealing in Iceland at earlier times and now). *Náttúrufræðingurinn* 14(3-4):150-169. In Icelandic.

Gunnarsson, S. 1988. Selurinn var mikil nytjaskepna, en… (Once seal was an important commercial harvest). *Sextant* 1(1):22-24. In Icelandic.

Hallgrímsson, H. 1985. Örnefni í Eyjafirði, kennd við seli og hvali (Places in Eyjafjörður named after seals and whales). *Týli* 15(1-2):61-62. In Icelandic.

Hannesson, E. 1982. Veldur veiðivargur umtalsverðu tjóni á laxi? (Do varmints cause great damage to salmon) *Veiðimaðurinn* 109:29-32. In Icelandic.

Harding, K.C., Härkönen, T. and Caswell, H. 2002. The 2002 European seal plague: epidemiology and population consequences. *Ecology Letters* 5:727-732.

Hauksson, E. 1985. Fylgst með landselum í látrum (Haul-out behaviour of common seal *(Phoca vitulina* L.*)* on selected hauling-out sites at the coast of Iceland). *Náttúrufræðingurinn* 55(3):119-131. In Icelandic with a summary in English.

Hauksson, E. 1992a. Selveiðar 1982 til 1989 (Sealing in Iceland 1982 to 1989). *Hafrannsóknir* 43(1):59-70. In Icelandic with a summary in English.

Hauksson, E. 1992b. Talningar á landsel og útsel og ástand þessara stofna við strendur Íslands (Counting of common seals *(Phoca vitulina* L.*)* and grey seals *(Halichoerus grypus* Fabr.*)* in 1980-1990, and the state of the seal population at the coast of Iceland). *Hafrannsóknir* 43(1):5-22. In Icelandic with a summary in English.

Hauksson, E. 1993. Árstíðabreytingar á fjölda sela í látrum á Vatnsnesi í Vestur-Húnavatnssýslu (Seasonal pattern of hauling-out of common seals *(Phoca vitulina* L.*)* on Vatnsnes, NW-Iceland). *Náttúrufræðingurinn* 62(1.-2.):37-41. In Icelandic with a summary in English.

Hauksson, E. 2005. Hringormar og fæða fisks, dílaskarfs og landsels við Melrakkanes í Hamarsfirði (Nematode infestation and diet of fish, cormorants *(Phalacrocorax carbo)* and common seals *(Phoca vitulina)* at Melrakkanes, Hamarsfjörður, Eastern Iceland). In Hauksson, E. (ed.); *Sníkjuormar og fæða fisks, skarfs og sels* (Nematodes and diet of fish, cormorant and seal). Hafrannsóknastofnunin (MRI). Fjölrit 115:21-30. In Icelandic with a summary in English.

Hauksson, E. 2006. Growth and reproduction in the Icelandic common seal *(Phoca vitulina* L.*, 1758)*. *Mar. Biol. Res.* 2:59-73.

Hauksson, E. 2010. Monitoring trends in the abundance of harbour seals *(Phoca vitulina)* in Icelandic waters. *NAMMCO Sci. Publ.* 8:227-244

Hauksson, E. and Bogason, V. 1997. Comparative Feeding of Grey (*Halichoerus grypus*) and Common Seals *(Phoca vitulina)* in Coastal Waters of Iceland, with a Note on the Diet of Hooded *(Cystophora cristata)* and Harp Seals *(Phoca groenlandica)*. *J. Northw. Atl. Fish. Sci.* 22:125-135.

Hauksson E. and Einarsson, S.T. 2010. Historical trend in harbour seal *(Phoca vitulina)* abundance in Iceland back to the year 1912. *NAMMCO Sci. Publ*. 8:147-160.

Helle, E. 1976. PCB levels correlated with pathological changes in seal uteri. *Ambio* 5(5-6):261-263.

Jónsson J. 1988. *Hafrannsóknir við Ísland. I. Frá öndverðu til 1937* (Icelandic oceanic research. I. From the beginning to year 1937). Bókaútgáfa Menningarsjóðs, Reykjavík, 340 pp. In Icelandic.

Jónsson J. 1990. *Hafrannsóknir við Ísland. II. Eftir 1937* (Icelandic oceanic research. II. Later than 1937). Bókaútgáfa Menningarsjóðs, Reykjavík, 447 pp. In Icelandic.

Klobes, U., Vetter, W., Luckas, B., Skírnissson, K. and Plötz, J. 1998. Levels and enantiomeric ratios of α-HCH, Oxychlordane, and PCB 149 in blubber of harbour seals *(Phoca vitulina)* and grey seals *(Halichoerus grypus)* from Iceland and further species. *Chemosphere* 37:2501-2512.

Kristjánsson, L. 1980. *Íslenskir sjávarhættir 1* (Icelandic sea habits). *Menningarsjóður*, Reykjavík, 472 pp. In Icelandic with an English summary.

Le Boeuf, B.J., Riedman, M. and Keyes, R.S. 1982. White shark predation on pinnipeds in California Coastal Waters. *Fish. Bull*. 80(4):891-895.

Lilliendahl, K. and Sólmundsson, J. 2006. Feeding ecology of sympatric shags *Phalacrocorax aristotelis* and great cormorants *P. carbo* in Iceland. *Marine Biology* 149:979-990.

Lonergan, M. and Harwood, J. 2003. The potential effects of repeated outbreaks of phocine distemper among harbour seals: a response to Harding *et al.* (2002). *Ecology Letters* 6:889-893.

[MRI] Marine Research Institute. 2008. Nytjastofnar sjávar 2007/2008. Aflahorfur fiskveiðiárið 2008/2009 (State of Marine Stocks in Icelandic Waters 2007/2008. Prospects for the Quota year 2008/2009). Reykjavík, Hafrannsóknastofnun. *Fjölrit.* 138:1-180. In Icelandic with an abstract in English.

NAMMCO. 2005 Report of the twelfth meeting of the Scientific Committee. In: *NAMMCO, Annual Report 2004*. NAMMCO, Tromsø, pp. 207-278.

NAMMCO 2007. Management Committee Working Group on By-Catch. In: *NAMMCO, Annual report 2006, vol 1*. NAMMCO, Tromsø, 249-255.

Olafsdóttir, D. 2001. Review of the ecology of sealworm, *Pseudoterranova sp(p) (Nematoda: Ascaridoidea)* in Icelandic waters. *NAMMCO Sci. Publ*. 3:95-112.

Olafsdóttir, D. and Hauksson, E. 1998. Anisakid nematodes in the common seal *(Phoca vitulina* L.*)* in Icelandic waters. *Sarsia* 83:309-316.

Olavius, Ó. 1780. *Oeconomisk Reise igennem de nordvestlige, nordlige og nordöstlige Kanter af Island* (Study of the resources of N-Iceland)(Ferðabók I-II, 1964 þýð. Steindór Steindórsson frá Hlöðum). Reykjavík. In Danish.

Pálsson, J. 1976. Ítarleg könnun á stærð selastofnsins (Investigating the sizes of seal populations). *Sjávarfréttir* 10:50-53. In Icelandic.

Pálsson, J. 1977. Nematode infestation and feeding habits of Icelandic seals. *ICES C.M.* 1977/N:20. 12 pp.

Reijnders, P.J.H. 1982. On the ecology of the harbour seal *Phoca vitulina* in the Wadden Sea: population dynamics, residue levels, and management.*Vet. Quart.* 4(1):36-42.

Skírnisson, K. and Ólafsson, E. 1990. Sníkjudýr í selum við Ísland (Parasites of seals in Icelandic waters). *Náttúrufræðingurinn* 60(2):93-102. In Icelandic with a summary in English.

Skírnisson, K. and Pétursson, G. 1983. Selafárið 1918 (Acute epizootic pneumonia of seals in Iceland 1918). *Náttúrufræðingurinn* 52(1-4):105-116. In Icelandic with a summary in English.

Sólmundsson, K. 1952. Selir og syndaselir (Seals and sinners). *Veiðimaðurinn* 19:24-29. In Icelandic.

Sæmundsson, B. 1897. Um fiskirannsóknir 1896, skýrsla til landshöfðingja (Fish research 1896, report to the Governor). *Andvari* 22:96-172. In Icelandic.

Sæmundsson, B. 1926. *Íslensk dýr I. Fiskarnir* (Pisces Islandiæ). Bókaverslun Sigfúsar Eymundssonar. Reykjavík, 583 pp. In Icelandic.

Sæmundsson, B. 1932. *Íslensk dýr II. Spendýrin (Mammalia Islandiæ)*. Reykjavík, 437 pp. In Icelandic.

Sæmundsson, B. 1939. *Mammalia. The Zoology of Iceland IV*(Part 76). Ejnar Munksgaard. Copenhagen and Reykjavik. 38 pp.

Thienemann, F.A.L. 1824. *Naturhistorische Bemerkungen gesammelt auf eine Reise im Norden von Europa vorzüglich in Island in den Jahren 1820 bis 1821* (Observations in natural history while travelling in N-Europe and Iceland, years 1820 and 1821). I. Abtheilung Säugethiere. Leigzig. In German.

Thoroddsen, Þ. 1904. *Landfræðissaga Íslands IV* (The Geography and Natural History of Iceland volume IV). Hið íslenska bókmenntafélag. Kaupmannahöfn (reprinted and modernized in 2006 by Ormstunga ehf, Reykjavík), 242 pp. In Icelandic.

Vetter, W., Hummert, K., Luckas, B. and Skírnisson, K. 1995. Organochlorine residues in two seal species from Western Iceland. *Sci. Tot. Environ*. 170:159-164.

Wiles, M. 1968. Possible effects of the harbour seal bounty on codworm infestations of Atlantic cod in the Gulf of St. Lawrence, the Strait of Belle Isle, and the Labrador Sea. *J. Fish. Res. Bd. Canada* 25(12):2749-2753.

Wolkers, H., Lydersen, C. and Kovacs, K.M. 2004. Accumulation and lactational transfer of PCBs and pesticides in harbour seals (*Phoca vitulina*) from Svalbard, Norway. *Sci. Tot. Environ.* 319:137-146.

Þorláksson, Ó. 1952. "Veiðivargar"(Varmints). *Veiðimaðurinn* 19:4-11. In Icelandic.

Þorleifsson, Ö. 1982. Selveiðar sem hlunnindi (Sealing as a advantage of farms). *Freyr* 78(15):621-623. In Icelandic.

Þorsteinsson, G. 1964. Selaróðrar. (Sealing by boat) *Árbók Þingeyinga* 7:92-110. In Icelandic.