Historical trend in harbour seal *(Phoca vitulina)* abundance in Iceland back to the year 1912

Erlingur Hauksson[1] and Sólmundur T. Einarsson[2]

[1] Fornistekkur 14, IS-109 Reykjavík, Iceland
[2] Breiðvangi 71, IS-220 Hafnarfjörður, Iceland

ABSTRACT

The harbour seal *(Phoca vitulina)* is Iceland's most abundant seal and has likely been exploited since the settlement of the country. Detailed information on skin exports is available as far back as 1912, and suggests that the catch, consisting mainly of pups, was far higher in the early 20th century than now. Assuming that skin exports were proportional to catches, these data were used to back-calculate the size of the Icelandic harbour seal population to the year 1912. The results indicate that the harbour seal population was considerably larger in the early 19th century than at present, about 60,000 (90% CI:40-100) animals. Aerial surveys conducted since 1980 indicate that the population has declined from 33,000 (90% CI:26,000-44,000) animals in 1980 to about 12,000 (90% CI:9,000-16,000) animals in 2006. The population time series suggests that the stock began to decline rapidly around 1960 and continued to decrease until 2003. In the period 1980 - 2003, the population declined even though reported catches were relatively low. Harvest rate had probably been about 10% before 1960. Between 1960 and 1980 the reported harvest rate increased to about 13%, but unknown numbers of adult seals were also taken as by-catch and shot in defence of salmon rivers. Since 2003, total removals have decreased and the population decline appears to have ceased. Entanglements in fishing gear and other incidental unreported hunting could increase again in the future. Therefore, the population must be monitored on a regular basis, and better information on by-catch and other unreported harvest is needed.

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INTRODUCTION

The harbour seal *(Phoca vitulina)* has been, according to anecdotal information the most common coastal seal in Iceland for centuries. Its exploitation probably started immediately upon settlement of the country in the 9th century (Hauksson and Einarsson 2010). The hunt was based on exploiting harbour seal herds breeding on privately own land. Further, this information also suggests that harbour seal skins, salted or dried, were exported in earlier times as they are today. A large dataset of catch statistics is available from trading logbooks as far back as 1897(Appendix 1). Information on exports of seal skins from 1897 to 1972 was compiled by Arnlaugsson (1973).

The pre-exploitation size of the population size is not known, as systematic monitoring of the Icelandic harbour seal population was initiated in 1980 (Hauksson 2010). Based on the catch statistics it is apparent that the Icelandic harbour seal population must have been considerably

larger in the early nineteenth century than at present (Fig. 1 in Hauksson and Einarsson 2010). The Marine Research Institute in Reykjavík has compiled seal catch data from 1962 to the present (MRI 2008), providing much better information about the identity of seal species in the catch. The MRI data indicates that the proportion of harbour seal pups in the catch was about 90%, with unspecified adult seals (probably mostly juvenile harbour seals) accounting for about 4%, the rest being grey seals *(Halichoerus grypus)*.

In 1982 the Research Committee of Biological Seafood Quality [RCBSQ] initiated bounty payments for seals caught in Icelandic waters, which for the harbour seal lasted until 1989 (Hauksson and Einarsson 2010).

The long-term harvest data may provide some information on trends in the Icelandic harbour seal population in the 20th century. In this paper we estimate the size of the Icelandic harbour seal population over time, back-calculated using Latin hypercube simulation from the annual catch in the 20th century (skin export data until 1977, then direct catch data since 1978). The sustainability of the Icelandic seal harvest, past and present, is then discussed.

MATERIALS AND METHODS

Back-calculation of population size

Population size was back-calculated by using a discrete formula for population growth rearranged to give the population size the year before:

(1)

$$P_{(t-1)} = (P_t + H)/(1 + b_t + m_t)$$

Where:
P_t is the population size in year t;
H the harvest;
b_t the birth rate in year t;
m_t the mortality rate in year t.

We assume that the carrying capacity of the environment for the harbour seal population did not influence population growth significantly. The initial value of P_t was the year 1980 (Table 1) and assumed to have a lognormal distribution. Harvest data were compiled by Arnlaugsson (1973) for the period 1897-1972 and MRI from 1962 to 2007. Birth rate and natural mortality for the Icelandic harbour seal population were not exactly known, but Arnlaugsson (1973) and Einarsson (1978) assumed them to be 0.3 and 66% respectively for the first 4 years of life, as for the pre-epizootic European harbour seal, using data from Lockley (1966), Bonner (1972) and Bigg (1981). Natural mortality of 10%, (95% CI:1-44.6%) for harbour seal pups in Icelandic waters, were obtained from tagging data (Einarsson 1977). Hauksson (unpublished) estimated the natural mortality for harbour seals aged 3 and older from the catch in 1982 as 0.15 (95% CI:0.20 - 0.11) and 0.14 (95% CI:0.16 - 0.11) for females and males respectively. Here we assume that b = 1/3.5 (on the interval 1/3.0 – 1/4.0 for the triangular distribution), where 3.5 represent total number of 1+ harbour seals for each pup born in the population, and m = 0.20 (0.15 and 0.25 as min. and max.) for the triangular distribution. In the year 1918 a seal epidemic occurred, so 0.03 was added to the natural mortality to simulate the minimum effect on the population as estimated by Skírnisson and Pétursson (1983). The calculations were started in year 1980 and carried backward to the year 1912 - the last year for which the harvest is reported on an annual basis. Earlier, back to 1897, the harvest data is only reported as 5-year annual means (Arnlaugsson 1973).

Estimating population size from the aerial counts

Since 1980 aerial surveys have been flown to count harbour seals 9 times (Hauksson 2010). The harbour seal counts *(C)* were transformed into population size *(P)* by multiplying with - a conversion factor β for seals missed by observers because they were hidden on the shore or in the water close to the haulout sites, which was log-normally distributed with mean 1.06 (min 1.03 and max 1.09); - a factor β, the reciprocal probability of harbour seals hauling out during a survey, from Ries *et al.* (1998) with a triangular distribution with mean 1.48 (min 1.18 and max 2.12); - and a factor γ, the proportion of the seasonal maximum of seals

hauling out, dependent on when the survey was carried out, which was sat to 1.0 because no data was available for this conversion factor for the Icelandic harbour seal population. The conversion factor α was estimated by counting harbour seals from the shore with binoculars and estimating the ratio of seals usually in the water, about 1%. To this ratio was added the likely ratio of seals hauled out, missed by the observers in the airplane, about 5% (Hauksson 1986). The distribution of 1,000 population sizes from the simulation using the method of Latin-Hypercube sampling (Stein 1987) was used in subsequent calculations. The standard deviation (SD), 5% and 95% limits (90% of the values lie on this interval) or minimum and maximum of values are presented in Table 1.

Estimating the proportion of unreported catch

Exponential growth rate (r_{est}) was estimated to be about -5%, in the period 1980-2003 by Hauksson (2010). This was subdivided into birth rate *(b)* and death rate *(d)*, and death rate was further subdivided into harvest *(H)*, natural mortality *(m)* and unreported catch *(c)* rates. Assuming the finite rate of increase $\lambda \cong 1 + r_{est}$(which is usually the case for rest close to 0 and applicable here for r_{est} = -0.05), gives rest = $b - h - m - c$. The same birth and natural mortality rates were used as in the back-calculation of population size. By rearranging the formula for r_{est} in respect to c, the unreported catch was estimated for each survey year assuming that harvest rate and natural mortalities were additive (Table 1).

Estimation of catch per sealer in relation to the total number of sealers

Log_e - transformed harbour seal catch per sealer (log_e(H/*f*) for the period 1982-2006, was fitted against the total number of sealers (*f*) taken from MRI (2008), using robust linear regression and the regression coefficients k_1 and k_2

Table 1. The population size of the Icelandic harbour seal (*Phoca vitulina*) estimated from aerial surveys, harvest compiled by MRI (2008), harvest rate and probable unreported removal rate (see methods). The mean, (SD) standard deviation and (90% CI), minimum and maximum of the 1,000 simulation cases

Year	Population size (SD) (90% CI)	Harvest	Harvest rate mean (SD) (min – max)	Probable unreported removal rate mean (SD) (min – max)
1980	33,327 (5,918) (25,492 – 43,779)	3,364	0.10 (0.017) (0.05 – 0.15)	0.04 (0.036) (0.00 – 0.16)
1985	27,871(4,718) (21,241 – 36,988)	3,752	0.14 (0.023) (0.07 – 0.20)	0.00 (0.036) (0.00 – 0.14)
1989	15,298 (2,794) (11,696 – 20,050)	2,214	0.15 (0.024) (0.06 – 0.22)	0.00 (0.036) (0.00 – 0.12)
1990	17,026 (3,085) (13,079 – 21,718)	767	0.05 (0.008) (0.02 – 0.07)	0.10 (0.029) (0.02 – 0.19)
1992	15,731 (2,810) (11,902 – 20,567)	1,149	0.08 (0.012) (0.04 – 0.12)	0.07 (0.031) (0.00 – 0.16)
1995	13,578 (2,320) (10,484 – 18,135)	865	0.06 (0.011) (0.03 – 0.10)	0.08 (0.030) (0.00 – 0.17)
1998	13,887(2,489) (10,670 – 18,477)	566	0.04 (0.007) (0.02 – 0.06)	0.10 (0.029) (0.02 – 0.20)
2003	9,972(1,773) (7,559 – 13,336)	416	0.04 (0.007) (0.02 – 0.06)	0.10 (0.028) (0.02 – 0.18)
2006	12,122 (2,151) (9,187 – 15,867)	192	0.02 (0.003) (0.01 – 0.02)	-Omitted

estimated, in order to estimate sustainable yield (MSY) and the total number of sealers giving MSY (f_{MSY}) (King 1995):
(2)

$MSY = (-1/k_2 \exp(k_1 - 1)$ and f_{MSY} equals $-1/k_2$.

Estimation r_{est} in time periods
In time periods 1919-1940, 1940-1960, 1960 - 1979, 1980-2003 and 2003-2006, rest was estimated as:
(3)

$$r_{est} = \log_e (P_t + _i / P_t)/(\Delta_t)$$

where:
i and Δ_t are years between the first and last year in respective periods.

Statistical software
Estimation of population size from aerial surveys, the estimation of proportional harvest *(h)* and unreported catch *(c)*, and the back-calculation of the population size *(P_t)* were estimated with @RISK 5.0 Professional for Microsoft Excel®, Palisade Corporation. The MSY analyses were performed using the "robustfit" and "corrcoef" routines of MATLAB version R2008b for Windows®, The MathWorks™.

RESULTS

Historical trends in population size
The back-calculation simulation (Fig. 1) indicates that population size was about 60,000 animals (90% CI:40,527-97,927) in 1912. The population shows a steady decline to about 40,000 (90% CI:20,851-70,114) animals in about 1940, followed by a steady increase to about 60,000 (90% CI:41,485-88,200) animals again in 1960. After 1960 seal numbers steadily declined to a population size of about 35,000 (90% CI:25,429-43,567) in 1979 and further declined to a population about 1/6 that of the early 20th century in the early 21st century. Counts obtained in aerial surveys corrected with conversion factors indicate that the population size in 1980 was about 35,000 and was declined to about 10,000 animals (90% CI:7,559-3,336) in 2003 (Table 1). In the period 2003-2006, the Icelandic harbour seal population increased again reaching 12,000 animals (90% CI:9,187-15,867) (Table 1).

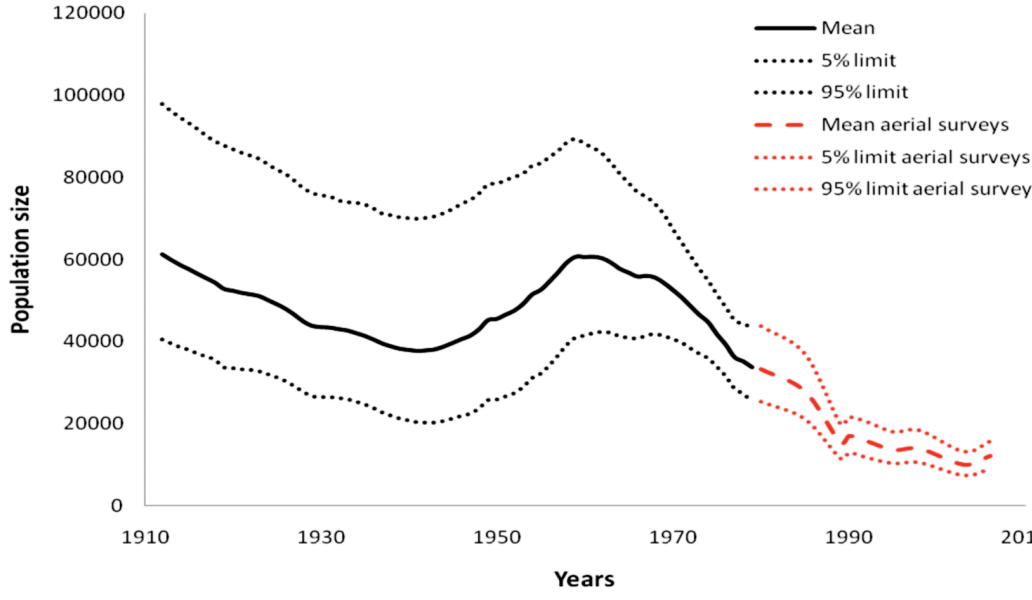

Fig. 1. *Historical trend of the abundance of the Icelandic harbour seal (*Phoca vitulina*) population: 1912 – 1979, as back-calculated from export data of skins, and 1980 – 2006 as estimated from aerial surveys. The means of simulated values of the population (black line) and 90% CI 5% and 95% limits (black dotted lines) and the means of estimated values of the population (red broken line) and 90% CI 5% and 95% limits (red dotted lines) are shown.*

Collected evidence indicates that in 1918 the exponential growth rate (r_{est}) was -0.03 (Skírnisson and Pétursson 1983). In the period 1919 – 1940 it was negative (r_{est} = -0.02 SD = 0.004, 90% CI:0.02 - 0.01), in the period 1940 - 1960 positive (r_{est} = 0.02 90% CI:0.01-0.03 SD = 0.007), and in the period 1960-1979 the exponential growth rate was negative, (r_{est} = -0.03 SD = 0.013, 90% CI:0.05-0.01). It was also negative in the period 1980-2003 (r_{est} = -0.05, SD = 0.0105, 90% CI:0.09-0.01), but become positive again (r_{est} = 0.06, SD = 0.079, 90% CI:0.057-0.197, $r_{est} \geq 0.00$ in 80% of simulation cases) between the years 2003 and 2006.

Sustainable harvest and unreported catch

There was a significant positive correlation between population size and harvest in the period 1980-2003 (data from Table 1); Pearson R = 0.89 (P = 0.003). The robust linear regression of $\log_e$ (catch per sealer) with the total number of sealers resulted in a poor fit (Fig. 2, robust s = 0.24, df = 23). MSY can therefore not be estimated. The mean number of harbour seals caught by each sealer was 10.5.

Before 1960 the harvest rate for the population was about 0.10. In the period 1960-1980 it rose to 0.12, but since 1980 it has been in the range of 0.02-0.15 (Table 1). Unreported catch rate was much higher after 1990 than before (Table 1). Adding estimated unreported harvest rate to the observed harvest rate to obtain the rate of total removals indicates that the harvest rate of the Icelandic harbour seal population was about 0.15 in the period 1980-2003. In this period the population declined about 5% annually, indicating that the harvest rate was not sustainable. This suggests that the Icelandic harbour seal population might tolerate harvest rate up to 0.1 (10%).

DISCUSSION

Methodological considerations

Estimation of the total population size of harbour seals from aerial survey counts requires correction for the number of seals that are not hauled-out when the survey is flown (β), the number of visible seals that are missed by observers (α) and the proportion of the seasonal

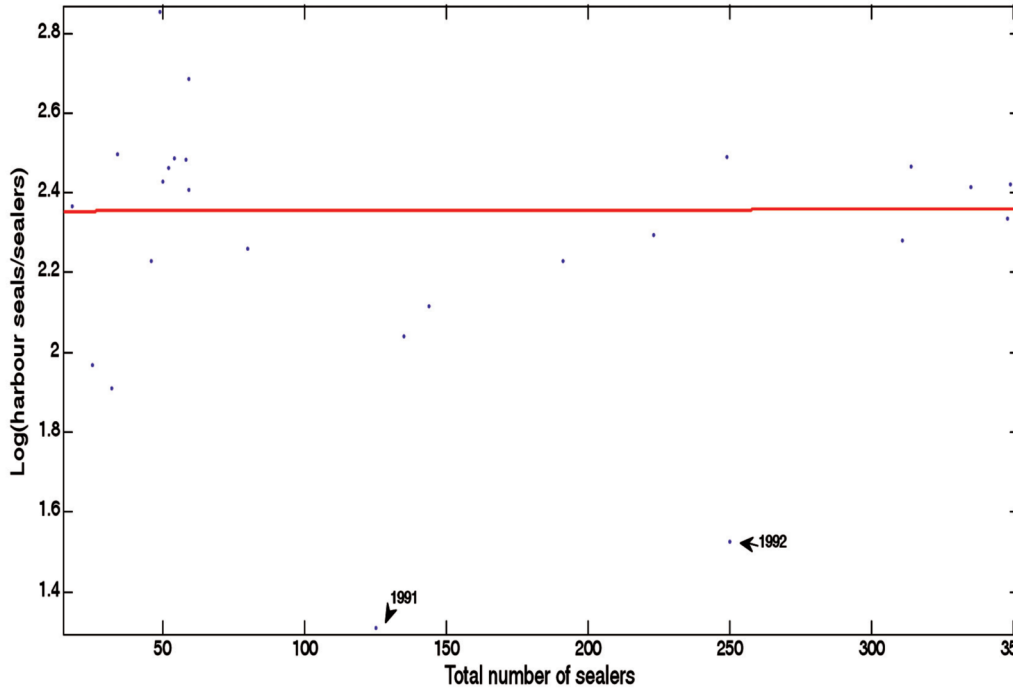

Fig. 2. *Catch per sealer versus total number of sealers (sealing effort). The years 1991 and 1992 were treated as outliers by the linear robust regression analyses. The slope was not significantly different from zero. The Y – intersect is the mean $\log_e$ catch per sealer.*

maximum of seals hauling out, dependent on when the survey was carried out (γ). No data were available to estimate α, β and γ for the Icelandic population.

A range of values for the correction factor β have been applied by workers in other areas: *e.g.* 1,48 in the Wadden Sea (Ries *et al.* 1998); 1.20 in Alaska (Boveng *et al.* 2003); 1.25 (range 1.13 - 1.41) in the United Kingdom (Thompson and Harwood 1990). According to Pitcher and McAllister (1981), 41% (36% – 46%) of harbour seals were hauled-out in August in Alaska, which would mean a conversion factor about 2.2 (range 1.8 – 2.8). Thompson *et al.* (1997) found a 50-70% utilization of haulout sites in the UK, yielding a conversion factor of 1.4 – 2.0, and on San Miguel Island, California, about 41% radio-tagged harbour seals hauled out each day (Yochem *et al.* 1987), giving a conversion factor of value 2.4. In the Wash, UK, a total of 1,722 harbour seals were seen during surveys of a population of about 3,915 harbour seal, suggesting a conversion factor 2.3 (Summers and Mountford 1975). However Everitt and Braham (1980) observed an 11% difference between a minimum abundance estimate and the highest count for any one year, which gives conversion factor of only 1.1. We estimated the correction factor (β) from Ries *et al.* (1998) - mean 1.48 (min 1.18 and max 2.12) with a triangular distribution – to be the most appropriate to convert Icelandic survey counts to total numbers.The size of 2 was set at 1.0 each survey year, because aerial surveys were performed at similar times each year, during August and September.

The number of visible seals that are missed by observers (α), possibly 6% (SE 2%) - conversion factor 1.06 (SE 0.02) was estimated empirically, but based on Hauksson (1986).

It is important in the future to obtain values for these conversion factors specific to the Icelandic harbour seal population,

Reijnders (1994) in his back-calculation model for harbour seals in the Delta area of the Netherlands corrected for adult females giving birth before being shot, because there was a bounty system operational at the time and adult seals were included in the catch. A similar bounty system operated in Iceland in the period 1982 to 1989. However, no consideration could be given to the age of caught animals in the back-calculation of the population trend, because no reliable data were available on the age distribution of the catch. Historically mainly pups have been taken by Icelandic hunters.

It was assumed that the Icelandic harbour seal population follows exponential changes in population size, and that density dependence did not influence its population dynamics. The authors are not aware of any study indicating density dependence in harbour seal populations.

Recent versus historical status of the population

The back-calculated estimates of the seal population show a steady decline from the beginning of the series in 1912 until about 1940, from about 60,000 to about 40,000 harbour seals. From the 1940s to the early 1960s the population increased again to around 60,000 animals, then declined rapidly to 35,000 in 1979 (Fig. 1).

There were reports of a harbour seal epidemic in 1918, followed by drastic decline in seal catches in the following years (See Fig. 1 in Hauksson and Einarsson (2010). The epidemic was incorporated into the back-calculations by increasing the natural mortality that year by 0.03.

Skírnisson and Pétursson (1983) estimated that the minimum size of the Icelandic harbour seal population was around 29,000 in 1918, about half that estimated by back-calculation. They considered that the epidemic likely killed about 3% of the harbour seals, so the effect of the epidemic was not as severe as experienced in the North Sea and adjacent waters in recent years (Harding *et al.* 2002). Sæmundsson (1932) estimated it at 15,000 - 20,000 around 1930, which is lower than the 5% lower limit of the 90% CI for the estimated population, and would represent 3 to 5 times the seal catch in the years around 1930. Lockley's (1966) estimate of 12,000 (excluding pups) in the 1960's (the exact year not given in the reference) is about 1/5 our estimate and must

be considered an absolute minimum. A harbour seal population as small as 12,000 (age 1+ animals) would be very unlikely to produce the number of pups harvested in the sixties - the pup-catches in 1963, 1964 and 1965, were 5,795, 6,176 and 5,598 respectively. Arnlaugsson (1973) estimated the minimum size of the Icelandic harbour seal population as 30,000 -35,000 animals in the period 1966-1971 from catch information, and similarly Einarsson (1978) estimated the population was 43,000 animals in the period 1962-1978. The estimate of Arnlaugsson (1973) is significantly less than that from our simulation for the same period, but that of Einarsson (1978) is within our confidence interval for the period.

The population trend between 1912 and 1978 was back calculated from skin export data, as opposed to direct catch data. The annual seal catch information, as deduced from the skin export data may not, however, only reflect changes in the seal population. The decline in catches is partly caused by overexploitation, as indicated by the simultaneous decline in population and catches. However, the decline in catches and effort may also be due to changes in life style and occupation of the Icelandic people combined with unfavorable prices for skins and difficulties in the sealskin market during the Great Depression and the Second World War (WW II). Further, skin exports may have been delayed in some years to later years due to unfavourable market conditions. For more details see Hauksson and Einarsson (2010). Therefore, the rate of the decline in the estimated population size between 1927 - 1940 may have been overestimated. Likewise, the decrease observed in the population, as well as the minimum observed about 1940 and subsequent increase, may also be exaggerated (Fig. 1). Catches remained relatively low until 1960 (over 2,000 in average) and the population recovered. The 3 fold increase in catches from the beginning of the 1960s was followed by stable high catches until 1978, due to a flourishing skin market in Europe and good prizes for the seal farmers in Icelandic kroner (Hauksson and Einarsson 2010). This led to a steep decline in the population over this ~20-year period, from around 60,000 to 35,000 animals.

In summary, the most probable description of the Icelandic harbour seal population in the period 1912-2006 is presented in Fig. 1. A relatively large population of over 60,000 animals in the early 20th century declined to about 40,000 in 1940, due to an epidemic in 1918 combined with overharvesting. The population then increased to its 1912 size in 1960, due to reduction in the harvest in the years during WWII and in the fifties. From 1960 to 2003, the population exhibited a substantial decline to about 16% of its 1912 size, because of overharvesting due to a dramatic increase in reported and unreported catches. The population increased between 2003 and 2006, probably due to decreased harvesting and by-catch mortality.

Harvesting and unreported catch

Harvest rate in the early 20th century was about 10%. Unreported catch was likely low in this period compared to subsequent periods (Table 1). Unreported catch rate was deduced from the observed decline in the estimated population size over different years, and was therefore estimated with large uncertainty. In the early 20th century market prices for seal skins were high, so every harbour seal skin was collected, even if it was not obtained in traditional sealing operations. In later years, due to lower market prices, skins were not collected if caught in fishing operations, because their quality was usually poor. Skins of harbour seals caught in the lumpsucker *(Cyclopterus lumpus)* fisheries were rejected by the organization of the Icelandic seal farmers which works as a cooperative in organizing the export of the sealskins. Unreported catch was estimated to have a rate of 0 to 0.1 in the period 1982 - 2003, making the total harvest rate in many years about 0.15, or 50% higher than in the early 20th century. Mortality of pups caused by fishing gear could be of the order of 40% (range 15% - 71%) (Hauksson and Einarsson 2010).

In 2007 and 2008, efforts were made to obtain information about the number of harbour seals taken as by-catch in the lumpsucker fisheries by direct observation and a sample collection program. In 2007 and 2008, respectively, 32 and 73 harbour seals were collected, about an order of magnitude less than expected given

the rates estimated above. Einarsson (unpublished) investigated seal by-catch in the fishery in the period 1979 - 1981, and recorded a by-catch of 168, 253, 7 and 94 in those years. It is possible by-catch was underestimated in recent years and that natural mortality has increased, the latter would positively bias our estimate of unreported catch. Increased natural mortality could explain the reduction in the total number of harbour seals on the south coast, where there has been negligible seal harvesting in recent years, no lumpsucker fishery, and very limited by-catch of harbour seals in the gill-net fisheries for cod *(Gadus morhua)* (see also Hauksson 2010, Hauksson and Einarsson 2010).

Management of the Icelandic harbour seal population

The linear regression between effort and catch per unit effort renders almost a flat line (*b* close to 0), and this relationship therefore does not give reliable information on MSY. Variation in the level of unreported removals and error in reporting the number of participating hunters might partially explain this lack of fit. The years 1991 and 1992 appear to be outliers, with very low reported catch per hunter (Fig. 2). However it seems more likely that Icelandic seal hunters simply do not compete with one another for seals. The hunt is based on owning private land and exploiting the seal herd breeding there. Therefore the number of hunters exploiting a particular breeding colony is limited.

There are indications that the Icelandic harbour seal population has been depleted by over-harvesting (reported and unreported catch combined), although with a temporary recovery, and is now only a fraction of the size it was100 years ago. For the most part harvesting has been very selective for pups and young animals, and such a harvest scheme is prone to make a population unstable (Harwood 1981). In a paper on growth and reproduction of the Icelandic harbour seal, Hauksson (2006) speculated that the reason for the observed decline of the population was a decrease in the survival of young seals, because no significant difference was observed in the reproductive material between the periods 1979 - 1983 and 1990 - 2000. However, the changes in the exploitation rate since 1982 may bring a supplementary explanation for the later period of decline. In the period 1982 - 1989 exploitation of all age groups was very high because of the bounty hunting (Hauksson 1992), but after 1989 the exploitation was much reduced with mostly pups caught from 1994 (MRI 2008). Theoretical models indicate that marine mammal populations are extremely sensitive to increases in adult mortality (DeMaster 1981). The dramatic decline in the Icelandic harbour seal population, which started after 1980, may therefore be mainly caused by the lower adult survival due to the bounty hunting. This may have reduced the population substantially to a new lower level from which it has been slow to recover even after adult hunting decreased. In addition by-catch and unreported catch of mainly pups has continued over this period. The increase in the population in the period 2003 - 2006 may be due to the higher survival of all age groups, combined to the proportionally very low catch of adult harbour seals.

It is important to reduce total removals to a sustainable level and to report all killed animals to have an effective management program. Management objectives for the Icelandic harbour seal stock have not been explicitly defined, however an immediate objective should be to arrest the population decline (which may already have been achieved) and to keep the population at a level no lower than at present. To achieve this, unreported catch due to by-catch and unreported shooting, particularly of adult seals, should be reduced. The strategy of harvesting only pups for their valuable skins has been historically effective in maintaining the population. Regulation of hunting effort may be more effective than maintaining a constant quota (Beddington and May 1977). A pup quota proportional to population size could produce a stable equilibrium, but a constant pup quota is potentially destabilizing unless relatively very low (Harwood 1978). In the present situation, even if traditional sealing (taking only pups) was discontinued, the population might decline because of the probably high but unreported by-catch in the fisheries as well as shooting. The future development of the harbour seal population could depend on the development of the lumpsucker fisheries off the Icelandic

coast. Increased fishing effort for lumpsucker might result in a decline in the seal population due to increased by-catch. However the actual extent of seal by-catch in Icelandic waters is not known, and should be assessed.

Conservation of the Icelandic harbour seal population is essential to the continued utilization of the stock. For over a century the skins from the pups have been valuable to the seal farmer, in some cases making up 25% of the farm's annual income (Örn Þorleifsson pers. com.). Seal watching could also, in the future, be profitable for landowners and sealfarmers. Fisheries interests might object to the unrestricted growth of the seal population because of perceived competition for fish, increased incidence of sealworm, and gear interactions, but a moderately sized and stable population, as at present, is probably acceptable to all parties.

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Appendix 1. Catch statistics of seals caught in Icelandic waters in the period 1897-2008. and lumpsucker fishermen who report seal by-catch.

a) Seal catch in the period 1897 to 1961, as deduced from the export of seal skin.

Years	Total catch	Years	Total catch	Years	Total catch	Years	Total catch
1897-1900	6,039[1]	1922	4,811	1936	4,443	1950	3,486
1901-1905	6,728[1]	1923	4,868	1937	4,395	1951	2,770
1906-1910	6,615[1]	1924	5,410	1938	4,062	1952	2,909
1908-1912	6,698[1]	1925	5,345	1939	3,857	1953	2,275
1912	6,593	1926	5,401	1940	3,488	1954	1,812
1913	6,711	1927	5,627	1941	3,439	1955	3,186
1914	6,475	1928	5,666	1942	2,980	1956	2,318
1915	6,162	1929	4,992	1943	2,888	1957	2,326
1916	6,164	1930	4,050	1944	2,453	1958	2,370
1917	6,012	1931	3,783	1945	2,299	1959	3,773
1918	5,950	1932	4,016	1946	2,317	1960	5,415
1919	4,784	1933	3,973	1947	2,522	1961	5,262
1920	4,972	1934	4,307	1948	1,809		
1921	5,048	1935	4,277	1949	1,300		

[1] Annual mean for the period.

b) Seal and harbour seal catch from 1962 onwards (MRI 2008). The catch includes also the reported by-cath from 1982 onwards. The total catch also includes grey seals and other seals. The detailed seal catch statistics can be seen at http://www.hafro.is/Astand/2009/34-AFLATOFLUR.pdf

Years	Total catch	Harbour seal pups	Older harbour seals	Harbour seals age unknown	Unspecified	Older harbour or grey seals	Total number of harbour seals' hunters
1962	5,786	5,101 [1]				392 [1]	
1963	6,573	5,795 [1]				210 [1]	
1964	7,063	6,176 [1]				294 [1]	
1965	6,581	5,598 [1]				216 [1]	
1966	6,148	5,578 [1]				166 [1]	
1967	4,977	4,481 [1]				47 [1]	
1968	5,726	5,049 [1]				153 [1]	
1969	6,666	5,831 [1]				256 [1]	
1970	6,740	5,942 [1]				394 [1]	
1971	6,894	6,126 [1]				211 [1]	
1972	6,930	6,237 [1]				278 [1]	
1973	6,803	5,996 [1]				324 [1]	
1974	6,240	5,534 [1]				300 [1]	
1975	6,673	6,111 [1]				440 [1]	
1976	6,470	5,895 [1]				301 [1]	
1977	6,601	5,705 [1]			533 [2]	267 [2]	

Years	Total catch	Harbour seal pups	Older harbour seals	Harbour seals age unknown	Unspecified	Older harbour or grey seals	Total number of harbour seals' hunters
1978	4,623	4,030 [1]	168 [2]		174 [2]	87 [2]	
1979	4,978	4,278 [1]	253 [2]			0	100 [2]
1980	3,648	3,357 [1]	7 [2]			191 [2]	0
1981	2,974	2,510 [1]	94 [2]			115 [2]	219 [2]
1982	4,656	2,367 [2]	634 [2]				249
1983	5,110	2,025 [2]	1,672 [2]				314
1984	5,512	2,485 [2]	1,114 [2]				348
1985	6,094	2,254 [2]	1,498 [2]				335
1986	6,450	2,48 [1]	1,446 [2]				349
1987	5,166	1,664 [2]	1,376 [2]				311
1988	3,422	867 [2]	905 [2]				191
1989	4,863	982 [2]	1,232 [2]				223
1990	2,462	546 [2]	221 [2]				358
1991	1,866	454 [2]	9 [2]				374
1992	3,181	624 [2]	525 [2]				400
1993	3,068	971 [2]	225 [2]				144
1994	2,814	1,032 [2]	7 [2]				135
1995	2,216	860 [2]	5 [2]				59
1996	1,825	848 [2]	2 [2]				49
1997	1,979	676 [2]	18 [2]				58
1998	1,197	545 [2]	21 [2]				50
1999	1,409	638 [2]	11 [2]				54
2000	1,188	595 [2]	61 [2]				59
2001	1,062	571 [2]	40 [2]				52
2002	773	364 [2]	7 [2]	42 [3]			34(10) [4]
2003	938	405 [2]	11 [2]	12 [3]			46 (5) [4]
2004	524	140 [2]	6 [2]	70 [3]			32(17) [4]
2005	395	120 [2]	1 [2]	58 [3]			25(17) [4]
2006	482	100 [2]	0	92 [3]			18(11) [4]
2007	384	72 [2]	0	32 [3]			16(12) [4]

[1] Based on trade and export statistics on seal skin.
[2] Based on catch statistics on direct hunting and by-catch in lumpsucker and gillnet fisheries.
[3] Based on by-catch statistics in lumpsucker and gillnet fisheries.
[4] Number of seal hunters and lumpsucker fishermen (who report seal by-catch).