Landselur
Phoca vitulina

SUMMARY

Censuses of the Icelandic harbour seal population have been conducted regularly since 1980. The total number of observed seals in the survey of 2020 was 4,559 individuals, which yielded an estimated population size of 10,319 (CI 95%= 6,733-13,906) animals. This estimate is 14.00% below the governmentally issued management objective for the minimum population size of harbour seals in Iceland of 12,000 animals. The estimated population size was 9.38% larger than in 2018, when the last complete population census was conducted, but 69.04% smaller than when first estimated in 1980. Trend analyses indicate that the population is currently fluctuating around a stable minimum level. Considering the sensitive conservation status of the Icelandic harbour seal population, it is important to assess and sustainably manage factors affecting the status of the population, including direct and indirect seal removals, environmental changes, changes in prey availability and anthropogenic impacts. In addition, increased monitoring of population demographic factors is urgent.

INTRODUCTION

Population estimates of the Icelandic harbour seal population have been conducted regularly by aerial surveys since 1980. In 1980, the population was estimated to be 33,327 animals (Hauksson and Einarsson 2010). Trend analysis based on previous complete surveys has shown a declining trend in the harbour seal population since then. Most of the decline occurred between 1980 and 1990, when the population decreased by about half. Thereafter, the population decrease continued at a slower rate. The Icelandic government introduced a management objective in 2006, stating that the harbour seal population should not decrease below 12,000 animals and if that occurs, actions should be taken to prevent further declines (oral statement, NAMMCO 2006). The estimated population size in 2006 was close to the issued management objective. However, the population estimate prior to 2006, conducted in 2003, and all the population estimates following the 2006 estimate have been below the threshold of 12,000 animals. In 2014, a partial census was carried out (only the largest harbour seal haul-out sites surveyed), which indicated an annual decline of 28.55% in the period from 2011–2014 (Granquist et al. 2014). The decline was confirmed in the next full census which was completed in 2016, when the population size was estimated to be

7,700 animals (Þorbjörnsson et al. 2017). The census in 2018 resulted in an estimated population size of 9434 animals, which is 71.69% smaller than when the population was first estimated in 1980, and 21.38% below the set threshold of 12,000 animals.

In 2020, the size of the Icelandic harbour seal population was estimated for the 13th time, and general and local trends in the population size were estimated. Sufficient knowledge on the status of the population is an important foundation to facilitate evidence-based management of the Icelandic harbour seal population. Such knowledge is also a crucial base for other research undertaken on the Icelandic seal population.

POPULATION ESTIMATE

METHODS

AERIAL SURVEY

The aerial survey was conducted between 27 July and 24 August 2020, to coincide with the moulting season of Icelandic harbour seals. Previous studies have suggested that the peak of the moulting season of the seal population occurs between the end of July and the end of August (Granquist and Hauksson 2016a). The coastline of Iceland was surveyed from a small airplane. The entire coastline was covered at least once, while some important haul-out areas (Vatnsnes, Heggstaðanes, Sigríðastaðaós and part of South Iceland) were covered twice.

Previous research has shown that several factors, beside time of the year, may affect haul-out patterns of harbour seals, such as weather and tidal state (Granquist and Hauksson 2016a). To minimise the effects of these factors, conditions when the flights were carried out were standardized in the following way. All flights were conducted in clear weather without precipitation, with wind <10 m/s and +/- 3 h from low tide. During the survey, the observer was seated in the front of the airplane with a good view to be able to detect and count all smaller groups (<30 seals) of harbour seals and to photograph larger groups (>30 seals) through an open window. A Canon 5DS full-frame digital camera mounted with a Canon 70-200 mm f/2.8L II USM lens with image stabilization was used to photograph the seal groups. The camera was equipped with a Global Positioning System (GPS), which assigns positional coordinates to each image. If grey seals were spotted during the survey, they were also recorded. For further methodology description, see Granquist (2021).

PHOTOGRAPHIC ANALYSIS AND STATISTICAL ANALYSIS

When photographs were available, the number of harbour seals in the images was counted by two individuals separately, and if the results differed between observers,

the average number was used for the area. For smaller groups (<30 seals) the direct count value was used. In the areas that were covered twice the average of the two observations was used. To facilitate an exact site comparison to results from previous censuses, the definitions of sub-areas and counting areas were identical to those used in previous censuses (Hauksson 2010, Granquist and Hauksson 2019), meaning that the coastline is divided into seven sub-areas (Figure1) and each sub-area is divided into several counting areas (in total for the whole coast= 98 counting areas, see Granquist 2021).

The estimate of the Icelandic harbour seal population in 2020 was based on the total number of observed animals, corrected for submerged animals and animals missed by the observer, by applying a correction factor of 2.26 (SD=0.41) (see Hauksson and Einarsson 2010). To generate the estimated population size, the total number of observed animals was bootstrapped by normally distributed correction factors (10,000 resamples). A 95% Confidence Interval (95% CI) was then estimated as the 2.5 and 97.5 percentiles of the bootstrapped distributions.

Changes in the population size between 2020 and all previous estimates were examined by applying the following equations (Table 1):

The estimated exponential growth rate (R_{est}) was calculated as Mills (2012):

$$R_{est} = \frac{\ln\left(\frac{Nlast}{Nfirst}\right)}{\Delta T}$$

Linear percent change (Δ) was calculated as:

$$\Delta = \frac{(Nlast - Nfirst)}{Nfirst} * 100$$

Discrete time per capita growth rate (λ) was calculated as Mills (2012):

$$\lambda = exp(R_{est})$$

Where N_{last} was the most recent value; N_{first} was the earlier value which N_{last} was compared to; ΔT was the total time interval (in years) in which a change is examined ($T_{last} - T_{first}$).

Normal cumulative distribution (CDF) (Sokal and Rohlf 1997) was used to calculate the probability of a population estimate being lower than previous estimates. All analysis was carried out in R 3.3.1 (R Core Team 2021).

Figure 1. The seven sub-areas of the Icelandic coastline: Faxaflói, Breiðafjörður, Westfjords, Northwest Iceland, Northeast Iceland, Eastfjords and South Iceland

1. mynd. *Strandlengja Íslands skipt í sjö undirsvæði: Faxaflói, Breiðafjörður, Vestfirðir, Norðvesturland, Norðausturland, Austfirðir og Suðurland.*

RESULTS

ESTIMATED POPULATION SIZE

The number of observed harbour seals was in total 4558.5 seals, which after application of the correction factor resulted in a population size of 10,319 (SD=1830.0; CI 95%= 6,733-13,906) animals (Figure 2). The current estimate is 14.00% lower (Table 1) than the government-issued management objective for the minimum population size of harbour seals in Iceland of 12,000 animals (oral statement, NAMMCO 2006). Based on the estimate of the population size for 2020, there is an 82% chance that the population is below the management objective. The importance of improving the status of the population should therefore be emphasized. On the Icelandic national red list for threatened populations, the Icelandic harbour seal population is defined as critically endangered based on the estimate from 2018. The current status should be re-evaluated based on the results from 2020, presented in this report. The population status is clearly sensitive, which underlines the necessity of further conservation actions.

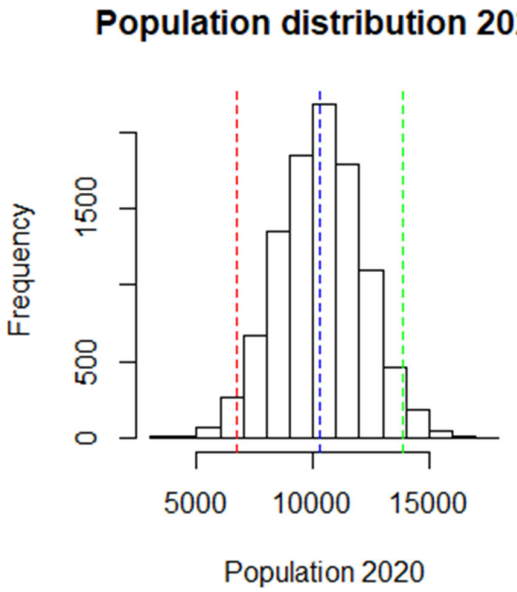

Figure 2. A normal distribution of the estimated number of harbour seals on the coast of Iceland in 2020 of 10,319 seals (mean value; blue line) and the 95% confidence interval (red and green lines).

2. mynd. *Normaldreifing yfir mat á fjölda landsela á strandlengju Íslands árið 2020 upp á 10,319 seli (meðaltalsgildi; blá lína) ásamt 95% öryggismörkum (rauð og græn lína).*

STATUS OF THE POPULATION AND TRENDS

METHODS

A linear regression model on *ln* transformed numbers was applied to examine the population trend based on all previous population estimates and the new estimate from 2020 (1980–2020). Secondly, the recent trend (2011-2020) based on estimates from the censuses in 2011 (Granquist et al 2011), 2014 (a partial census, Granquist et al 2014), 2016 (Þórbjörnsson et al. 2017), 2018 (Granquist and Hauksson 2019) and the current census (2020) was calculated. Further, linear regression models on *ln* transformed counts were also applied to estimate recent local trends in the seven different sub-areas (Figure 1, Table 2). The period of 2011–2020 was then compared to trends in the previous period of 1980–2006, (published by Hauksson 2010). Local trends in the 98 different counting areas were examined in Granquist (2021).

RESULTS

POPULATION TRENDS 1980–2020

The temporal population trend from 1980 to 2020 shows a total decline of 69.04%. During this period, the annual discrete time per capita growth rate (λ) was -2.89% (Table

1). A linear regression model revealed a significant decline of 3% annually between 1980 and 2020 (R_{est} = -0.03 (SE= 0.004); R^2_{ad} = 0.77, RSE=0.20, p < 0.001). When compared to the census of 2018, an increase of 9.38% was observed, which corresponds to an annual discrete time per capita growth rate of 4.59% between 2018 and 2020 (Table 1).

The trend analysis suggested that the four decades that have passed since regular censuses commenced, can be divided into a period of decline from 1980 to 2006 and a period of stability at a minimal population level from 2006 to 2020. As indicated in Figure 3, the main decline in the Icelandic harbour seal population occurred during the period of 1980 to 1990. Nevertheless, the decline continued after that point at a slower rate. The negative trend between 1980 and 2006 was significant; R_{est} = -0.04 (SE = 0.01), p>0.001 (Hauksson, 2010), while no significant trend was detected for the period 2011 to 2020; R_{est} =-0.01 (SE = 0.03), ns.

In the population estimate from 2016 the population was estimated to be 7652 animals, which is the smallest the population has ever been estimated (Granquist et al. 2014, Þórbjörnsson et al. 2017). However, since the slight increase observed between 2016 and 2018 has continued between 2018 and 2020, the steep declining trend did not seem continue, which suggests that the population is currently fluctuating around a historical minimum population size.

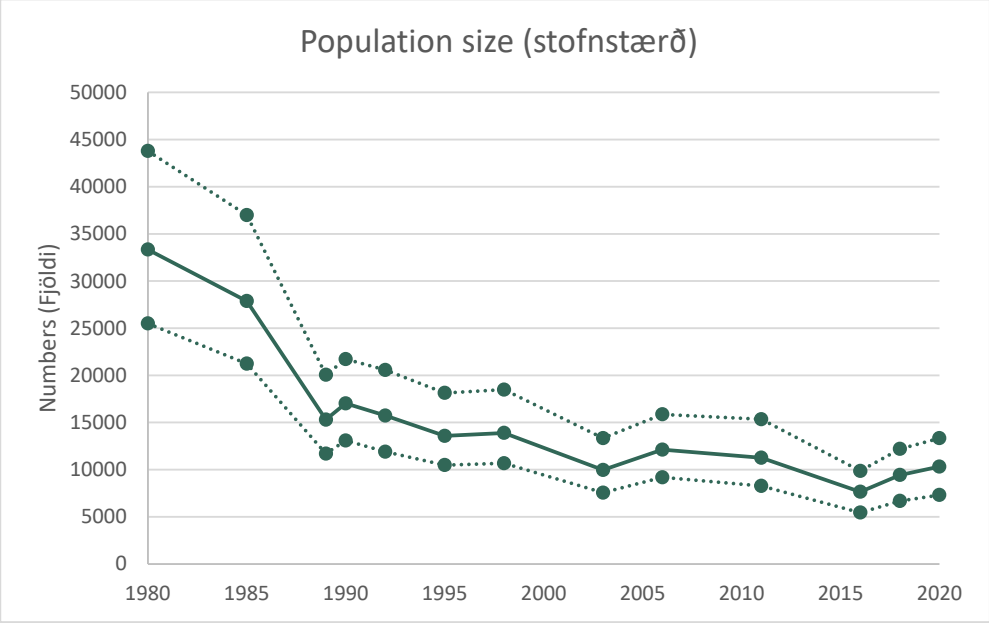

Figure 3. Changes in the Icelandic harbour seal population size from 1980–2020 (solid blue line) and the 90% confidence intervals (dotted line).

3. mynd. *Breytingar í stærð íslenska landselsstofnsins á árunum 1980 til 2020 (heil lína) ásamt 90% öryggismörk (brotnar línur).*

Table 1. Estimated population size from 1980 to 2020 and the governmentally issued management objective (M.o). The probability of the current population size being lower than previous estimates $P_{(pop2020<popyearX)}$. Exponential growth rate (R_{est}), with the linear percent change (Δ (%)) and annual discrete time per capita growth rate (λ (%)) from the relevant year compared to 2020.

Tafla 1. *Áætluð stofnstærð landsels við Ísland tímabilið 1980–2020, ásamt stjórnunarmarkmið stjórnvalda (M.o.). Líkur þess að núverandi stofnstærðin sé minni en árin á undan ($P_{(pop2020<popyearX)}$) með veldisvaxtarstuðull (R_{est}), prósentu breyting (Δ (%)) og ársvöxtur λ (%), miðað við ár 2020.*

Survey year	Est. pop.	$P(pop_{2020}<pop_{yearX})$	R_{est}	Δ (%)	λ (%)
1980	33,327[1]	100%	-0.03	-69.04%	-2.89%
1985	27,871[1]	100%	-0.03	-62.98%	-2.80%
1989	15,298[1]	100%	-0.01	-32.55%	-1.26%
1990	17,026[1]	100%	-0.02	-39.39%	-1.66%
1992	15,731[1]	100%	-0.02	-34.40%	-1.49%
1995	13,578[1]	96%	-0.01	-24.00%	-1.09%
1998	13,887[1]	97%	-0.01	-25.69%	-1.34%
2003	9,972[1]	42%	0.002	3.48%	0.20%
2006	12,122[1]	84%	-0.01	-14.87%	-1.14%
2011	11,272[2]	70%	-0.01	-8.45%	-0.98%
2016	7,652[3]	7%	0.08	34.85%	7.76%
2018	9,434[4]	31%	0.05	9.38%	4.59%
2020	10,319	-			
M.o.	12,000	82%			

[1]Hauksson 2010, [2]Granquist et al. 2011, [3]Þorbjörnsson et al. 2016, [4]Granquist and Hauksson 2019

TRENDS IN THE SEVEN SUB-AREAS AND IN THE INDIVIDUAL COUNTING AREAS

The highest number of harbour seals in 2020 was found in Northwest Iceland (907 seals), followed by the Eastfjords (861 seals) and the Westfjords (814 seals), while the lowest number of harbour seals was found in Northeast Iceland (138 seals). A higher number of seals were observed in all sub-areas in 2020 compared to 2018, except for South Iceland. Breiðafjörður had similar numbers of seals both years. When trend estimates based on the most recent population estimates (2011–2020) were calculated, significant trends were not found for any of the seven sub-areas. Nevertheless, during the period 1980–2006, a negative significant trend was found for three of the seven areas: Faxaflói, Eastfjords and South Iceland (Hauksson, 2010) (Table 2). The absence of detectable trends is most likely due to the drop in numbers in most areas between 2011 and 2018 being balanced by the higher numbers prior to 2016 and the increase of seal numbers in all areas, except South Iceland, between 2018 and 2020. The distribution of harbour seals around the coastal areas of Iceland seems to be rather stable and follows the general national trend (Granquist 2021). In Iceland, many of the haul-out sites have been occupied almost every survey year, supporting the earlier findings that harbour seals are loyal to their breeding, resting and moulting-sites, showing strong site fidelity (Yochem et al. 1987, Thompson 1989).

Table 2. Number of counted animals in each sub-area from censuses in the period 2011–2020. Trends in abundance of harbour seals for the periods 1980–2006 (Hauksson 2010) and 2011–2020, described by exponential growth rate (R_{est} (SE; standard error and p-value[a]). Adjusted coefficient of determination (R_{ad}^2) and residual standard error (RSE) are shown for the recent trends.

Tafla 2. *Fjöldi taldra landsela á mismunandi svæðum á tímabilinu 2011–2020. Árlegur veldisvöxtur fjölda landsela fyrir tímabilunum 1980–2006 (Hauksson 2010), og 2011–2020 (R_{est} (SE; staðalskekkja og marktækni[a])). Aðhvarfsgreiningarstuðull (R_{ad}^2) og staðalskekkja leifa aðhvarfsgreiningarinnar (RSE) er sýnt fyrir seinna tímabilið.*

Coastal area	2011	2016	2018	2020	1980-2006 R_{est} (SE)$^{p\text{-value}}$	2011-2020 R_{est} (SE)$^{p\text{-value}}$	R_{ad}^2	RSE
Faxaflói	554.5	556	325	602	-0.07 (0.01)*	-0.01 (0.05)^{ns}	-0.45	0.34
Breiðafjörður	621	463	489	495	-0.06 (0.01)^{ns}	-0.03 (0.01)^{ns}	0.45	0.10
Westfjords	796.5	685	683	813.5	-0.02 (0.01)^{ns}	-0.003 (0.02)^{ns}	-0.47	0.12
Northwest Iceland	1461.5	615.75	867	906.5	-0.02 (0.01)^{ns}	-0.06 (0.05)^{ns}	0.05	0.35
Northeast Iceland	209	89.5	96	138	-0.04 (0.01)^{ns}	-0.06 (0.06)^{ns}	0.04	0.38
Eastfjords	530.5	530	624	860.5	-0.01 (0.01)*	0.05 (0.03)^{ns}	0.44	0.17
South Iceland	709	443.5	1084	743	-0.07 (0.01)*	0.02 (0.07)^{ns}	-0.41	0.43

[a]Significance levels: ns = not significant, * significant at the 5%, ** 1 % and *** 0.1%, levels respectively.

REMOVALS

HUNTING

Historically in Iceland, harbour seal skins and meat were considered fairly important resources. However, during recent decades this subsistence hunt had declined to very low numbers. Nevertheless, in the 1980s, a bounty system for harbour seals was initiated with the purpose of decreasing the seal population to reduce interactions with the fishing industry and to limit the abundance of the seal worm (*Pseudoterranova decipiens*). The data presented in the current report shows that the largest decline in the harbour seal population occurred in the first decade (1980–1989), coinciding with the period when seals were culled to a large extent. In recent years prior to the implementation of the hunting ban, over 80% of the reported hunting of harbour seals was due to culling in the estuaries of salmonid rivers to reduce the potential effect that harbour seal predation was believed to have on the economically valuable salmon, trout and Arctic charr populations (Granquist 2016, Granquist and Hauksson 2016c). Notably, research on the interaction between seals and salmonids in Iceland indicated that such hunting was ineffective in terms of increasing human salmonid harvest (Granquist et al. 2016).

In 2019, new regulation regarding seal hunting in Iceland was enacted (Atvinnuvega- og nýsköpunarráðuneytið 2019). Seal hunting was banned, although it is possible for landowners to apply for exemptions to carry out so-called “traditional hunt”, referring to utilization of seals by landowners where there had been a tradition of seal hunting and utilization. Prior to the ban, no quota or compulsory registration system pertaining to seal hunting/culling was in effect, which complicated not only hunting management

in general, but also data collection on hunting statistics (Granquist and Hauksson 2016b).

Since the new regulation was enacted, seal hunters have been able to apply for exemptions to hunt harbour seals twice (2020 and 2021). In 2020, exemptions to hunt in total 67 harbour seals were given, while the total number of hunted seals was only 4 seals. This year, exemptions were given to hunt in total 43 harbour seals. Hunting statistics for 2021 are not at hand yet.

BY-CATCH

While the hunting ban has prohibited culling and direct exploitation, the largest mortality risk, by far, for the Icelandic harbour seal population is considered to be drowning in fishing gear. Seal bycatch occurs mainly in the lumpsucker fisheries but also in other gillnet fisheries and demersal trawls at smaller magnitudes. The annual average over the period 2014-2018 is 1389 (CV=35) harbour seals in lumpfish gillnets (Marine and Freshwater Institute 2019) (Table 3). Further, the MFRI estimates that 18 harbour seals (CV=102) were by-caught in other gillnets during 2015-2019 (cod and Greenland halibut fisheries mainly). Harbour seals have also been observed in bottom trawl fisheries but by-catch in these fisheries has not been investigated since before 2015. No observations have been made in other fisheries. Data used to quantify the magnitude of affected animals in the lumpsucker fisheries comes from inspectors, who are only able to cover a small proportion of the fishing effort, or 1.7% in the lumpfish fishery and 3.7% in other gillnets (Table 3). Increased data collection to facilitate more exact marine mammal bycatch estimates and to generate more information on the animals that get caught is advised.

Table 3. Bycatch estimates of harbour seals by gear type based on data from 2014-2018 (lumpfish gillnets) and 2015-2019 (Other gillnets). The estimate from the lumpfish fishery is stratified by lumpfish management area which roughly correspond to the seal counting areas (Figure 1). Number of observed animals is the total number of animals observed by onboard inspectors or MFRI scientists. Raised estimate is those observed animals raised by total fishing effort in that fishery.

Tafla 3. *Áætlaður meðafli á landsel eftir veiðarfærum samkvæmt gögnum frá 2014-2018 (grásleppuveiðar) og 2015-2019 (aðrir netaveiðar). Matið er unnið eftir skilgreindum grásleppuveiðisvæðum sem eru sambærileg við selatalningarsvæðin (1. mynd). Fjöldinn sýnir fjölda sela sem hafa verið skráðir af eftirlitsmönnum eða sérfræðingum Hafrannsóknarstofnunnunar og uppreiknaður fjöldi er ákvarðaður miðað við heildarfjölda veiðiferða í þessum veiðum.*

ishery	Observed animals	Raised estimate	CV	Average inspector coverage
Lumpfish gillnets	138	1389	35	1.7%
Other gillnets	2	18	102	3.7%
Total	140	1407		

OTHER FACTORS AFFECTING POPULATION STATUS

Apart from human induced removals (hunting, culling and by-catch) there are many other factors that may potentially affect trends in the harbour seal populations, such

as prey availability, environmental changes, diseases and anthropogenic disturbance (Granquist et al. 2014, Lowry 2016). Many of these relationships are poorly understood and require more research, both internationally and for Icelandic conditions.

ENVIRONMENTAL CHANGES AND PREY AVAILABILITY

Environmental changes, including climate change, are likely to affect seal populations in various ways. Currently, knowledge on how factors such as increasing sea temperatures, and changes in weather and prey availability due to climate change are affecting population trends is scarce. Harbour seals are considered generalist predators, and hence may not be as vulnerable to changes in stocks of particular prey species as specialist predators. However, further research on how variation in prey availability can affect the Icelandic harbour seal population is needed (Granquist 2021b).

DISTURBANCE

To facilitate sustainable management for pinniped populations, it's crucial to consider anthropogenic activities not only at sea, but also on land at important haul-out sites. Periods spent on land are essential for the viability of pinniped populations, especially during periods that are biologically important such as the pupping, nursing, mating and moulting periods. This applies not only to implementation of constructions near important haul-out sites, but also to human presence in these areas. Due to increasing tourism in Iceland, harbour seal haul-outs are frequently visited, including more remote areas. Anthropogenic disturbance can impact seals physiologically and affect their behaviour and distribution, which in turn may reduce fitness, both at an individual and at a population level (Granquist and Sigurjónsdóttir 2014). Therefore, it is important to study and subsequently minimise impacts due to disturbance as part of seal management strategies.

In addition to the human induced factors that can have effects on harbour seal population trends described above, it´s important to monitor population identity, population demographics, fecundity and pup production around Iceland. There is a pressing need to increase knowledge of these components, to facilitate sustainable management of the population.

ADVICE

MFRI advises that direct hunt should be limited and that actions must be taken to reduce by-catch of seals in commercial fisheries to enable the population size to reach management objective. MFRI further advises that attempts to minimize anthropogenic

disturbance of harbour seal colonies are initiated, in particular during breeding and moulting seasons between May and August.

METHODOLOGICAL CONSIDERATIONS

The estimates presented in this report are all, except for one (2011) based on a single over-flight survey of the entire Icelandic coastline. The exception is the census from 2011, when three overflights were possible (Granquist et al. 2011). One single overflight, combined with a low census frequency with sometimes up to several years between censuses, impedes highly accurate population estimates and trend analyses. To increase accuracy and better be able to detect population trends, a higher census frequency combined with three replicates each year has been suggested as a way forward since that would increase statistical power (Teilmann et al. 2010, Granquist et al. 2011). One overflight presents a potential bias of seals being missed by observers, for example due to local visibility difficulties (such as sunshine or fog). In addition, disturbance of a colony prior to the survey, can cause seals to move into the water and be totally submerged, which reduces the possibility of detecting the seals from the air.

The accuracy of the population estimate is partly based on the validity of the correction factor applied to counts in the calculation of an estimate (see Methods). Correction factors have not yet been optimized for Icelandic conditions (but see Hauksson and Einarsson 2010). However, the correction factor used in the present estimate has been used since 2006 and the current estimate is therefore directly comparable to all estimates made since 2006.

CONCLUSION AND FUTURE PROSPECTIVE

Despite the slight increase that has been observed in the harbour seal population since 2016, there is an 82% probability that the population remains under the management objective threshold level. Moreover, the population stays on the Icelandic red list for threatened populations. The sensitive conservation status of the Icelandic harbour seal population underlines the need to augment evidence-based seal management in Iceland. For example, it is important to continue regular censuses, but also to increase knowledge regarding what factors affect population trends and how these factors can be regulated. Increased monitoring for more precise assessments of indirect removals (bycatch in fishing gear), is an important step in this work. Further, it is important to note that management of seal populations is not only related to human induced mortality (hunting, culling and by-catch). It is also important to increase research regarding other factors that potentially affect seals both at the individual and population level, many of which are poorly understood. For example, the effects of

environmental change, fluctuation in prey availability, and anthropogenic disturbance, such as due to increasing tourism pressure, should be researched thoroughly. Moreover, increased monitoring of population demographic factors such as recruitment to the population (fecundity, pup production and survival) and age distribution in the population is urgent.

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