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Abstract

Censuses of the Icelandic grey seal population have been conducted regularly since 1982. The population size is estimated based on pup production. Pups are counted three to five times during the pupping period from the end of September to beginning of November in all known grey seal pupping areas through aerial surveys. In the most recent census, conducted in 2022, the total pup production was estimated to be 1551 pups (95% CI= 1486-1613).

The most important pupping area was Breiðafjörður, with a total of 963 (95% CI = 927-995) pups, corresponding to 62% of the total estimated pup production in 2022. Other important pupping areas were the northwest coast (Strandir and Skagafjörður) and the south coast (Öræfi and Surtsey).

Based on the pup production, the total grey seal population size in 2022 was estimated to be 6697 animals (95% CI = 5576-7841). The population was approximately 27% smaller than when the first census was conducted in 1982 and corresponds to an increase of 6.8% since the census in 2017. However, trend analysis for the period 2005–2022 revealed no statistically significant trend for the total population size.

The population size was larger than the governmental management objective for the size of the grey seal population of 4100 animals. The management objective will be re-evaluated as part of work aimed to establish a formal management plan for grey seals. According to the Icelandic red list for threatened populations, which is based on criteria put forward by IUCN, the grey seal population is defined as "Vulnerable".

***Keywords**: Grey seal, population estimate, pups, counting*.

Ágrip

Stærð íslenska útselsstofnsins hefur verið metin reglulega frá 1982. Stofnstærðin er metin út frá kópaframleiðslu. Á kæpingartímabilinu frá lok september fram í byrjun nóvember er flogið þrisvar til fjórum sinnum yfir helstu kæpingarsvæðin. Í síðustu talningu sem fór fram árið 2022 var heildarkópaframleiðslan 1551 kópar (95% CI = 1486-1613). Mikilvægasta kæpingarsvæðið var líkt og áður Breiðafjörður, en þar var áætluð kópaframleiðsla 963 (CI 95% = 927-995) kópar, sem svarar til 62% af heildarkópaframleiðslu við Ísland árið 2022. Önnur mikilvæg kæpingarsvæði voru norðvesturland (Strandir og Skagafjörður) og suðurland (Öræfi og Surtsey).

Stofnstærð útsels árið 2022 sem metin er frá kópaframleiðslunni var 6697 dýr (95% CI = 5576-7841). Það þýðir um 27% fækkun í stofninum frá fyrstu talningu sem fór fram árið 1982, en jafnframt um 6,8% fjölgun frá árinu 2017 þegar talning fór síðast fram. Breytingin á heildarstofnstærð milli 2005 og 2022 var þó ekki tölfræðilega marktæk. Stofnstærðin árið 2022 var metinn yfir viðmiðunarmörkum stjórnvalda, sem eru 4100 dýr. Viðmiðunarmörkin verða endurmetin við gerð stjórnunarmarkmiða fyrir íslensku selastofnana. Hafa ber í huga að á válista íslenskra spendýra sem er gerður samkvæmt viðmiðum Alþjóðlegu náttúruverndarsamtakanna (IUCN) lendir íslenski útselsstofninn í áhættuflokknum „í nokkurri hættu" (e. vulnerable).

Lykilorð: Útselur, stofnmat, kópar, talningar.

Efnisyfirlit

1 Introduction

Regular monitoring of the status of the population is an important foundation to facilitate evidence-based management of the Icelandic grey seal population, including regulation of seal hunting. Such knowledge is also a crucial basis for other research undertaken on seal populations. The first aerial grey seal census in Iceland was conducted in 1982, resulting in a population estimate of 9,200 animals. Since then, 11 censuses have been carried out. The highest population estimate was found in 1990 (10,600 animals), after which the population decreased substantially. The lowest estimate was observed in 2012 (4,200 animals, 95% CI= 3,400 – 5,000) (Hauksson et al. 2014). The latest census from 2017, however, indicated an increase (6,269 animals, 95% CI= 5,375-7,181). In 2022, a census of the Icelandic grey seal population was carried out with the aim to estimate the population size for the 12th time and to calculate population trends.

2 Material and methods

The estimated population size for the grey seal population is based on pup production and therefore the census is carried out during the pupping period ranging from the end of September to the beginning of November. Before 2005, the grey seal population estimates were based on only one count at each pupping site and subsequently correction factors were applied (Hauksson 2007). However, to increase the significance of results (see Duck and Thompson 2007), pups have been counted three to five times in all known grey seal pupping areas since 2005 (in total four surveys; 2005, 2008/2009, 2012 and 2017). No large pupping sites are found in the Westfjords and in NE Iceland and these areas were therefore covered only once in 2022.

The census of 2022 was carried out by aerial survey from 22 September to 9 November. Known pupping sites in all seven coastal areas of Iceland were surveyed (Figure 1). In each fly-over, pups were either counted directly, or photographs taken. Newborn grey seal pups can be assumed to stay in the pupping site until they are 15-30 days old, when they have finished moulting their white lanugo fur. To obtain the total pup production for each area, it is important to determine the number of newborn pups in each fly-over. Consequently, the probability of pups still being present in the area since the last fly-over (non-moulted pups which had not left the area yet) needs to be estimated. Therefore, the following assumptions were made: a) pups which are less than 15 days old are all still present at the breeding site, b) half of the 22-day-old pups have left the pupping site, and c) all pups more than 30 days old have left the pupping site. These data are assumed to follow a normal density distribution with a mean of 22 days and standard deviation of about 3 days (Bowen et al. 2003; Hauksson 2010).

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

1. mynd. Strandlengju Íslands skipt í sjö strandsvæði: Faxaflói, Breiðafjörður, Vestfirðir, Norðvesturland, Norðausturland, Austfirðir og Suðurland.

Various statistical distributions (normal, Weibull, gamma, log-normal and logistic) were fitted to the pupping data for each site. The number of pups born outside of the survey period (born either after the last fly-over or born so long before the first fly-over that they had moulted and left before the first count—and hence missed), was estimated based on the best fitted distribution and added to the total pup production of each site.

The estimated total pup production was used as an index for the total population size of grey seals by assuming that the ratio between pup production and the total number of grey seals (one year old and older) was 4 (SD=3-5), as applied by Hauksson (2007a). Correction factors for undercounting (pups that are at the pupping site but missed by the observers) and for a natural mortality (estimated to 2% by Hauksson 2007) were combined into one conversion factor (q) of 1.08 (95% CI= 1.07-1.10) (Hauksson 2007) and applied to the estimated pup production. After applying the correction factor q, and an extrapolation of 4 (3-5) times the pup production, the distribution of 1,000,000 population sizes replicates was calculated to yield an average population size.

The following equations were used to calculate changes in pup production (Mills, 2012) for the total population size between the years 2005 and 2022 and for the different coastal areas:

The estimated exponential growth rate, (R_{est}): $\frac{\ln\left(\frac{Nlast}{Nfirst}\right)}{\Delta T}$

Linear percent change: $\frac{(Nlast-Nfirst)}{Nfirst} * 100$

Discrete time per capita growth rate, (λ): $\lambda = exp$ (R_{est})

Where *Nlast* is the most recent value, *Nfirst* is the earlier value, which *Nlast* is compared to and ΔT represent the total duration of survey.

To assess trends in the population size, a robust linear regression was used (rlm and method = "MM") from the MASS package in R (Venables and Ripley 2002). All analysis was conducted in R (RStudio. Version 3.3.1. 2016).

3 Results

3.1 Estimated pup production

In the census conducted in 2022, the total pup production was estimated to be 1,551 (95% CI= 1,486-1,613). The most productive pupping area was Breiðafjörður, with a total of 963 pups (CI 95%= 927-995), corresponding to 62% of the total estimated pup production in 2022. Other important pupping areas were the northwest coast (Strandir and Skagafjörður) and the south coast (Öræfi and Surtsey). No pups were found in the Westfjords and only one pup was observed in NE Iceland. When the development for the coastal areas over the period 2005-2022 (when the new method of counting pups 3-4 times was applied) was investigated, the largest difference occurred in East Iceland where the number of pups has been increasing, R_{est} 0.16 (Table 1).

Table 1. Pup production in the coastal areas for the survey years 2005-2022. Change in pup production for the years 2005-2022 (Δn), total percent change (Δ(%)), discrete time per capita growth rate (λ) and the exponential growth rate (R_{est}), are shown for each coastal area.

Tafla 1. Kópafjöldi á strandsvæðum árin 2005 til 2022. Breyting á kópafjölda milli áranna 2005 og 2022 (Δn), hlutfallsleg breyting (Δ(%)), meðalársvöxtur (λ) og veldisvöxtur (R_{est}).

	Pup production / *Kópafjöldi*					Period / *Tímabil* 2005-2022			
Coastal area	2005	2008/9	2012	2017	2022	R_{est}	Δ (%)	λ (%)	Δn
Faxaflói	40	18	12	37	57	0.02	42.5	1.02	17
Breiðafjörður	645	859	525	845	963	0.02	49.30	1.02	318
West Iceland	2	0	0	0	0	(-)	-100	(-)	-2
NW Iceland	471	424	322	262	284	-0.03	-39.70	0.97	-187
NE Iceland	6	0	0	4	1	-0.11	-83.33	0.90	-5
East Iceland	5	13	1	37	74	0.16	1380	1.17	69
South Iceland	223	225	133	267	172	-0.02	-22.87	0.98	-51

3.2 Population estimate and trends

Based on the pup production in 2022, the total grey seal population size was estimated to 6,697 animals (95% CI= 5,576-7,841). The population estimate for 2022 corresponds to an increase of 6.8%

since the last census in 2017 (Table 2, Figure 2 and 3). The population was 27% smaller than when the first census was conducted in 1982 with an approximate total exponential growth rate (r_{est}) of -0.008 between 1982 and 2022.

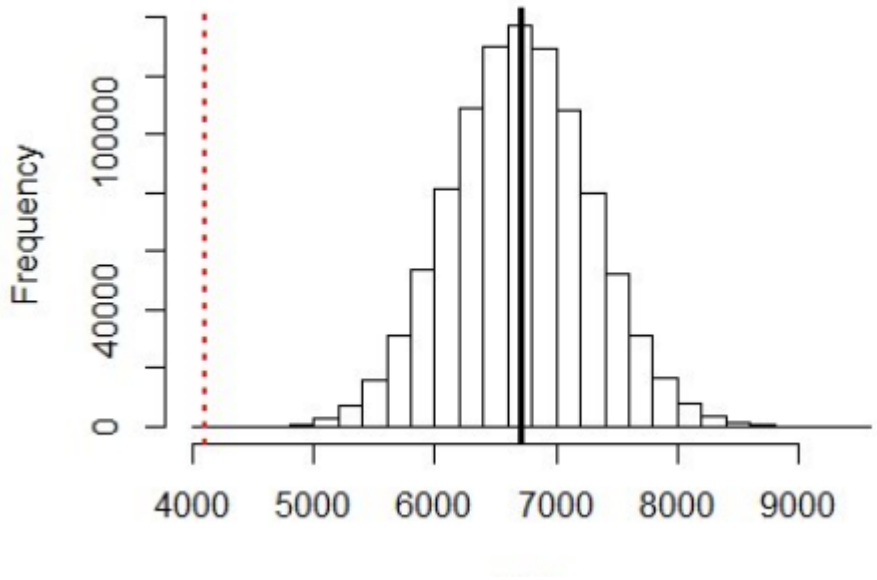

Figure 2. Distribution of the population sizes of Icelandic grey seal for the year of 2012, when calculated from 1,000,000 replicates using pup data and correction coefficients. The bold line corresponds to the average population size of 6697 animals. The red line corresponds to the current management objective for the grey seal population (4,100 animals).

2. mynd. Dreifing á 1.000.000 endurteknum útreikningum á stofnstærða útsels árið 2022, reiknað út frá kópafjölda og leiðréttingarstuðlum. Feitletraða lóðrétta línan er meðalstofnstærðin 6.697 dýr og lóðrétta rauða punktalínan er núverandi viðmiðunarmörk stjórnvalda um stofnstærð útsels hér við land (4.100 dýr).

Trend analysis (*rlm*) showed no significant trend for the total population size between 2005 and 2022 ($p>0.05$). The population size was larger than the governmental management objective for the size of the grey seal population of 4100 animals. The calculated probability of the population being smaller than 4,100 is negligible (p = 0.0003%) (Table 2, Figure 2).

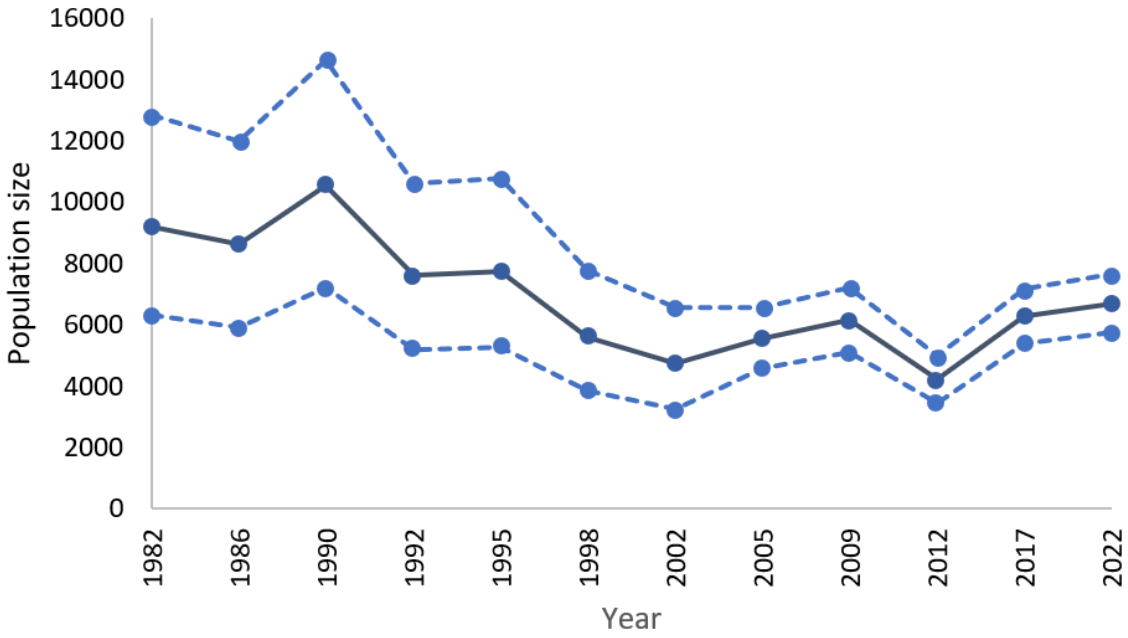

Figure 3. Estimated population sizes of Icelandic grey seal from 1982 to 2022 (solid line), with 90% CI (dashed line). The population sizes for 1982-2002 were estimated based on only one pup count (see Methodology section regarding the difference between the new and the previous methods).

3. mynd. Stofnstærðir útsels 1982 til 2022 (heildregin lína) með 90% öryggismörkum (brotalína). Stofnstærðir 1982-2002 voru metnar með eldri aðferð sem byggðist á einni flugtalningu á hverjum kæpingarstað að hausti (sjá aðferðakafla um mun á eldri og nýrri aðferð).

Table 2. Population estimates for the Icelandic grey seal population based on surveys between 1982 and 2022. Probability of the 2022 population estimate being lower than previous estimates ($P(pop_{2022}<pop_{yr.x})$), exponential growth rate (R_{est}) with the total percent change ($\Delta(\%)$), discrete time per capita growth rate (λ) and change in size (Δn) for each year compared to 2022. The governmental management objective is 4,100 animals.

Tafla 2. Stofnstærðarmöt útsels fyrir árin 1982 til 2022. Líkur þess að stofnstærðarmatið árið 2022 sé lægra en stofnstærðarmöt árin á undan ($P(pop_{2022}<pop_{yr.x})$)*, veldisvöxtur (R_{est}), prósentvís breyting ($\Delta(\%)$), ársvöxtur (λ) og breyting í fjölda* (Δn) *hvert ár miðað við árið 2022. Management objective er núverandi viðmiðunarmörk stjórnvalda fyrir útselsstofninn, sem er 4.100 dýr.*

Survey year*	Est. pop.	$P(pop_{2022}<pop_{yearX})$	R_{est}	Δ (%)	λ (%)	Δn
1982	9,216	100.00%	-0.008	-27.33	0.99	-2519
1985/6	8,632	99.96%	-0.007	-22.42	0.99	-1935
1990	10,557	100	-0.014	-36.56	0.99	-3860
1992	7,624	94.60%	-0.004	-12.16	1.00	-927
1995	7,758	96.71%	-0.005	-13.68	0.99	-1061
1998	5,612	3.00%	0.007	19.33	1.01	1085
2002	4,731	0.033%	0.017	41.56	1.02	1966
2005	5,568	2.51%	0.011	20.28	1.01	1129
2008/9	6,156	17.41%	0.006	8.79	1.01	541
2012	4,206	0.0008%	0.047	59.22	1.05	2491
2017	6,269	23.00%	0.013	6.83	1.01	428
2022	6,697	(-)	(-)	(-)	(-)	(-)
Management objective	4,100	0.0003%				

**The population sizes for 1982-2002 were estimated based on one count (older method, see Method section).*

4 Discussion

4.1 Methodological considerations

Although grey seal population estimates have always been based on pup production in Iceland, it is of importance to note that between 1982 and 2002 the pup production was calculated based on only over-flight, while the new method applied between 2005 and 2022 considered 3-4 counts of the pupping areas. The new method therefore provides a more precise estimate of pup production. As previously reported, analysis have shown that the new method gives about 11% higher average population size compared to the older method. Hence, the older estimates should possibly be multiplied by 1.11 (1.09–1.13) (see Granquist and Hauksson 2019) to increase their comparability to the updated method. This involves an even larger downward trend in stock size since 1990 than presented in this report.

4.2 Future prospective

Breiðafjörður, NW Iceland and the South coast are the most important pupping areas for grey seals in Iceland and should be considered important in terms of management.

Knowledge on behaviour and distribution of the Icelandic grey seal population outside of the pupping period is almost nonexciting. It is crucial to gain knowledge on important haul-out sites of the population throughout the year, specifically during biologically sensitive periods, such as the moulting period. Further, since by-catch is the largest treat to the population (MFRI 2019), it is of great importance to investigate and monitor at sea distribution, and co-use with the fishing industry of key grey seal areas to facilitate evidence-based management.

According to the Icelandic red list for threatened populations, which is based on criteria put forward by IUCN, the grey seal population is defined as “Vulnerable” due to the observed decrease in the population over three generations where a generation is considered 16.5 years (Icelandic Institute of Natural History. 2018, 2018).

4.3 Conclusion

The estimated population size of the Icelandic grey seal in 2022 was similar to the previous survey in 2017 and the population size between 2005 and 2022 seems stable with no significant trend. The population estimate from 2012 was lower than the rest of the estimates during the period, which explains why no clear trend was obtained for the period. Although, the population is above the management objective for grey seals in Iceland, the population is defined as “vulnerable” on the National Read List for Threatened Populations (Icelandic Institute of Natural History, 2018) due to the observed decline in the population over 3 generations (definition used by IUCN). A new management plan for grey seals is underway where the management objective of 4,100 animals for the Icelandic population will be re-evaluated based on biological criteria.

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