Population dynamics and demography of reindeer (*Rangifer tarandus* L.) on the East Iceland highland plateau

1940–2015

A comparative study of two herds

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Population dynamics and demography of reindeer (*Rangifer tarandus* L.) on the East Iceland highland plateau 1940–2015
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Declaration of the author

I hereby declare that the collection of data and writing of this thesis is my work under the supervision and assistance of my advisors Tomas Willebrand, Auður Magnúsdóttir and Anna Guðrún Þórhallsdóttir. I did all statistical analysis except for home ranges, movements and utilization of different habitats done by Kristín Ágústsdóttir.

Egilsstaðir 21. May 2018

________________________________
Skarphéðinn G. Þórisson
Abstract

In 1787, 35 domestic reindeer (*Rangifer tarandus*) were introduced to northeast Iceland from Norway and have roamed wild since then. They increased and dispersed in the 19th century but in 1939 only few persisted in East Iceland. Thereafter the herd increased and dispersed all over East Iceland. The herd, Snæfellsherd, broke up into two herds in two separate areas corresponding to two hunting management areas 1 and 2, in the sixties, with limited immigration between the herds. Because of the hunting value of this species and their potential ecological role in Icelandic ecosystems, more knowledge is crucial. The main aim of this thesis is to assess the status of Icelandic reindeer, evaluate their probability of persistence in the future and compare the two herds with regards to population dynamics and demography. I compiled information from reindeer counts, data collected from hunters and data from GPS-collared reindeer. Positions from three females in area 1 and five in area 2 in 2009–2011 were used to define home ranges, analyse movements and utilization of different habitats. Monitoring of population dynamics with various annual counts and data on physical condition collected by hunters were used to compare the herds. Apart from hunting, car accidents were the most common cause of mortality in both herds. Reindeer were significantly heavier in area 1 than 2. Home and core range were different in size and shape and varied over time; home ranges were smallest during the calving season, and largest during the hunting season for both herds. Travelling speed was higher in area 1 than area 2, but in general the two herds travelled shorter distances in summer than reindeer herds in Norway, most likely related to the absence of warble flies and mosquitoes in Iceland. Dwarf shrub heath rich in willow and lichens constituted the main habitat of the reindeer in area 1 while dwarf shrub heath poor of lichens and willow but rich in sedges are dominant in area 2. Both herds showed changes in summer distribution that are thought to reflect grazing competition and anthropogenic disturbance. Now the status of reindeer in Iceland is good but the future is uncertain in a changing word both climatically and with increased human activity in East Iceland. Both herds are strong, but more studies of grazing are needed. The results of this study will hopefully help guide sustainable management of the populations in the future.

Key words: Reindeer, *Rangifer tarandus*, Snæfellsherd, habitat use, demography, home range, movement, recruitment, physical condition, wildlife management
Ágrip


Lykilorð: Hreiðyr, Snæfellshjörð, Fljótsdalshjörð, Norðurheiðahjörð, gróðurlendi, lýðheilsa, heimasvæði, ferðir, talningar, nýliðun, líkamlegt atgervi, fæða, umhverfi.
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# Table of contents

Declaration of the author ........................................................................................................... i
Abstract ....................................................................................................................................... ii
Ágrip ............................................................................................................................................... iii
Acknowledgements ...................................................................................................................... iv
Table of contents .......................................................................................................................... v
List of Tables ...................................................................................................................................... ix
List of Figures ............................................................................................................................... xii
1 Introduction ................................................................................................................................. 1
2 A brief introduction of the species Rangifer tarandus L ....................................................... 5
3 Reindeer in Iceland ...................................................................................................................... 8
   3.1 Management of reindeer in Iceland ..................................................................................... 11
   3.2 Reindeer in Iceland 1787–1977 ........................................................................................ 14
      3.2.1 Reindeer in East Iceland 1787–1939 ........................................................................ 14
      3.2.2 Reindeer in East Iceland 1939–1944 ....................................................................... 14
      3.2.3 Number and distribution of reindeer in Iceland 1940–1977 ................................... 15
      3.2.4 Reindeer in area 1 1965–1978 ................................................................................. 18
      3.2.5 Reindeer in area 2 1965–1978 ................................................................................. 19
   3.3 Grazing in the reindeer pastures ......................................................................................... 20
4 Aims of study .............................................................................................................................. 22
5 Material and methods ................................................................................................................ 23
   5.1 The study area ....................................................................................................................... 23
      5.1.1 Vegetation mapping ................................................................................................. 25
   5.2 Climate ................................................................................................................................. 29
   5.3 Reindeer data ....................................................................................................................... 32
      5.3.1 Winter counts ........................................................................................................... 33
      5.3.2 Counts to assess pregnancy rates ............................................................................. 34
      5.3.3 Calving ....................................................................................................................... 34
5.3.4 Annual summer counts and recruitment .............................................. 35
5.3.5 Counts at rutting time ................................................................. 36
5.3.6 Mortality ....................................................................................... 36

5.4 Data from hunted reindeer ..................................................................... 36
5.4.1 Collection of reindeer for scientific purposes ........................................ 36
5.4.2 Age determination ............................................................................. 37
5.4.3 Collection of mandibles ..................................................................... 38
5.4.4 Carcass weight and backfat thickness .................................................. 38

5.5 Sheep in area 1 and 2 ........................................................................ 38
5.5.1 Slaughter weights of lambs ............................................................... 39

5.6 GPS collars .......................................................................................... 40
5.6.1 Proportion of Snæfellsherd represented by GPS-collared reindeer ......... 43
5.6.2 Home range estimation ..................................................................... 44
5.6.3 Analysis of habitat use of GPS-collared reindeer ................................. 45
5.6.4 Analysis of seasonal movements ......................................................... 45

5.7 Data analyses ....................................................................................... 46

6 Results ..................................................................................................... 47

6.1 The reindeer population in East Iceland 1978–2015 ............................... 47
6.2 Number and distribution of reindeer in Snæfellsherd 1978–2015 .............. 49
6.2.1 Snæfellsherd 1979–1999 ................................................................. 49
6.2.2 Snæfellsherd 2000–2015 ................................................................. 50
6.2.3 Reindeer in area 1 from 1979 to 2015 ............................................... 52
6.2.4 Reindeer in area 2 from 1978 to 2015 ............................................... 55
6.2.5 Winter counts ................................................................................ 58
6.2.6 What is known about migration between area 1 and 2 ....................... 59

6.3 Hunting in Snæfellsherd 1978–2015 ....................................................... 60
6.4 The demography of Snæfellsherd .......................................................... 64
6.4.1 Pregnancy rates ................................................................. 64
6.4.2 Timing of calving ............................................................... 65
6.4.3 Recruitment ................................................................. 66
6.4.4 Mortality ................................................................. 67
6.4.5 Age and sex composition at rut ........................................ 69
6.4.6 Data from harvest .......................................................... 71
6.4.7 Comparison of autumn carcass weight in sheep and reindeer .... 78

6.5 GPS-collars ........................................................................... 80
6.5.1 Comparison of herd sizes in area 1 and 2 ......................... 81
6.5.2 Time and place of calving based on GPS-collared females 2009–2011 ...... 82
6.5.3 Home range ................................................................. 86
6.5.4 Movements ................................................................. 88
6.5.5 Comparison of movements and home ranges ......................... 91
6.5.6 Vegetation mapping of area 1 and 2 .................................. 92
6.5.7 Habitats used by reindeer based on GPS-collared reindeer females .... 96

6.6 Comparison of food intake by different herbivores .................. 101

7 Discussion .............................................................................. 102
7.1 The reindeer as an introduced species .................................. 102
7.2 Abundance and density ....................................................... 103
7.3 Shifting ranges of both herds ............................................... 104
7.4 Physical condition and recruitment ....................................... 106
  7.4.1 Comparison of calving in Iceland and Norway ................ 109
  7.4.2 Comparison of body weight in Icelandic and Norwegian reindeers .... 110

7.5 Vegetation and grazing ....................................................... 112
  7.5.1 Summer grazing of sheep and reindeer .......................... 113

7.6 Factors that could affect reindeer populations in the future ........ 115
  7.6.1 Pink-footed Goose in East Iceland and reindeer ................ 115
  7.6.2 Greening ........................................................................ 116
7.7 The use of GPS technology in wildlife studies ........................................ 117
   7.7.1 Home range .................................................................................. 117
   7.7.2 Movement analysis ........................................................................ 118

7.8 The future ............................................................................................... 122

8 Conclusions ............................................................................................... 123

9 References .................................................................................................. 124

10 Appendices ................................................................................................. 141
   10.1 Predicted calving date based on GPS-collared females .................... 141
   10.2 Home range of GPS collared females in Snæfellsherd at different times... 145
   10.3 Used habitat at different times based on GPS-collared females .......... 153
   10.4 Grazing by reindeer and sheep .......................................................... 155
      10.4.1 Reindeer food in area 1 and 2 ...................................................... 155
      10.4.2 Comparison of food intake by reindeer in area 1 and area 2 ......... 159
      10.4.3 Plant species grazed ................................................................. 160
      10.4.4 Comparison of sheep and reindeer grazing ............................... 161
      10.4.5 References ............................................................................... 163

   10.5 Icelandic moss (*Cetraria islandica*) .................................................. 164
      10.5.1 References ............................................................................... 167
List of Tables

Table 1. Subspecies of the genus Rangifer (Banfield, 1961), distribution and estimated population size of wild reindeer/caribou (Gunn, 2016). ................................................................. 5
Table 2. Subspecies, distribution and population size of wild reindeer in Russia (Grubb, 2005; Gunn 2016)................................................................................................................................. 5
Table 3. The year, origin, embarkation and number of reindeer introduced to Iceland and their destiny................................................................................................................................. 8
Table 4. Major events in monitoring and management of reindeer in Iceland 1940–2015. 13
Table 5. CORINE 2012 classes in Iceland, in area 1 and area 2, actual (km²) and proportional size........................................................................................................................................... 25
Table 6. Classification and descriptions of the four most common ecotypes in Brúardalr and Vesturöræfi in INH mapping 1999–2002 (Magnússon et al., 2009)............................... 27
Table 7. Aeroplanes used at midsummer reindeer counts 1979–2015 (unpubl. reports)... 32
Table 8. Overview of aerial counts of reindeer in East Iceland.................................................................................. 33
Table 9. Mean number of sheep in area 1 and area 2 in 2013–2015 (The Icelandic Agricultural Advisory Centre (RML homepage))........................................................... 39
Table 10. Three different programs of the GPS-collars. Collars recorded locations every three hours, and each collar was programmed to switch between time plans for recording every eight days, so that for each individual information on every hour over a 24-hour cycle would be recorded.................................................................................................................. 41
Table 11. The usage of GPS-collars on females in area 1 and 2 and their durability........ 42
Table 12. Number of locations of the herds that included the GPS collared females in each month from 15th of February 2009 to 2nd of June 2011................................................................. 43
Table 13. Herds of reindeer in East Iceland in winter 2015–2016, their numbers and density (Pórisson & Pórarinsdóttir, 2016; Arnalds, 2002)................................................................. 47
Table 14. Crossing of GPS-collared females in spring and summer 2010 of two rivers delineating calving and summer grazing areas of reindeer in area 1. ......................... 53
Table 15. Result of the annual summer count on 11th of July 2010 in different parts of area 1................................................................................................................................................. 54
Table 17. Comparison of hunting pressure (number of reindeer shot as a proportion of herd size) in four periods in area 1 and 2; average hunting pressure for the whole period 2000–2015 is included for comparison between the two areas. 63

Table 18. Proportion of reindeer females born without antlers in area 1 and 2, for different time periods. 64

Table 19. Proportion of calves per females/yearlings in July counts in area 1 and area 2 in the period 1999–2012 (except 2001 and 2011). 66

Table 20. Comparison of time of death in area 1 and 2 at different time periods based on carcass analysis 1991–2013. 68

Table 21. Age groups of reindeer carcasses in hunting area 1 and 2 found in 1991–2013. 69

Table 22. Comparison of sex composition in area 1 and 2 in three time periods. Values in bold indicate significant differences (p<0.05). 70

Table 23. Sex composition (one year and older) in area 2 in four periods. Sample size in brackets. Values in bold indicate significant differences (p<0.05). 70

Table 24. Mean mandible length (mm) in area 1 and 2 in two time periods (significant P<0.05). 71

Table 25. Mean mandible length (mm) in two time periods in area 1 and 2 in adult females and 3–5 years old males (significant P<0.05). 71

Table 26. Mean carcass weight (kg) and mean back fat thickness (mm) in >2-year-old females in area 1 and area 2 in the year 1990 (significant p<0.05). 72

Table 27. Mean carcass weight and mean back fat thickness in >2 years old males in area 1 and area 2 in 2015 (significant p<0.05). 72

Table 28. Mean carcass weight with 95% confident limit of 3–5 years old lactating females in two areas in September-May in 1980–1981, August 1990 and August-September 2003 and 2005 (significant p<0.05). 73

Table 29. Mean carcass weight (with 95% confidence limits) of 4 months old reindeer compared between area 1 and 2 in two time periods (significant P<0.05). 77

Table 30. Mean carcass weight (with 95% confidence limits) of 4 months old reindeer compared between two time periods in area 1 and 2 (significant P<0.05). 77

Table 31. Comparison of carcass weight of ram lambs in area 1 and area 2 from 2000 to 2015. 78

Table 32. Time of calving of eight GPS-collared females 2009 to 2011. Antlered females in May are regarded pregnant. 83
Table 33. Total distance between positions over a year in area 1 and 2. Total distance calculated with 2900 positions (8 positions for 365 days).

Table 34. Changes of CORINE classes (km$^2$) in Iceland 2006–2012 (LMÍ, 2015).

Table 35. Proportion of home range (HR=95%) and core range (CR=50%) of all GPS-collared females inside INH mapped area at different time of year.


Table 37. Average travelling speed (m/hour) in area 1 and 2 and two herds in Norway, one with domestic ancestry the other wild ancestry (Pórisson & Ágústdóttir, 2014 and the Norwegian information's adjusted from Reimers et al., 2013b: table 1. p. 28).
List of Figures

Figure 1. Kárahnjúkar hydropower project. Asphalt road (Kárahnjúkavegur): black line, tracks: broken black lines, dams red, tunnel pink, open ditches green. The power plant being at the end of the tunnel in Fljótshalur valley (Þórisson & Ágústsdóttir 2014). .......... 3

Figure 2. Distribution of wild reindeer/caribou (yellow) and introduced domesticated reindeer to four islands: Iceland, South Georgia, Kerguelen and Falkland Islands (blue) (Gunn 2016). ................................................................. 6

Figure 3. Introduction of reindeer to Iceland in 1771–1787 (dates of introduction are indicated for the different areas). III Past distribution /// Main past distribution range = Current distribution (updated from Þórisson, 1983). ................................................................. 9

Figure 4. Nine hunting areas of reindeer in Iceland in 2015. The red line delimits the highland plateau where Snæfellsherd roam (areas 1 and 2) and the East fjords (areas 3 to 9). The blue line shows the northern border of area 1 in the years 1992–2014. Vatnajökull National Park is delimited by a yellow unbroken line. The two uncoloured areas around and west of Mt. Snæfell are the only protected areas for reindeer in East Iceland, where hunting is not permitted. (Þórisson & Þórarinsdóttir, 2015). ...................................................... 10

Figure 5. Reindeer population size of Snæfellsherd (purple line) and total reindeer population (green line) in summer. Hunting quotas (red open bars) and number of shot reindeer (black bars) during the hunting seasons 1940–1977. Sources: Thorlacius (1960); Böðvarsson (1967–1969, 1971, 1973); Böðvarsson & Pálsson (1965, 1966, 1970, 1972); Guðmundsson & Þorsteinsson, (1974, 1976) and Þorsteinsson, (1975). ........................................ 12

Figure 6. Growth of the reindeer population 1939–1950. Given an annual natural mortality of females 5% and 10% of males, and a proportion of calves in summer 60% of females/ yearlings. Summer counts from Thorlacius (1960). ...................................................... 15


Figure 8. The principal summer grazing areas of Snæfellsherd in area 1 and area 2 (Þórisson & Ágústsdóttir, 2014). ................................................................. 17

Figure 9. Result of reindeer summer counts between 1965–1978 in area 1, in Kringilsárrani area (blue) and Norðurheiðar (pink). Source: Thorlacíus (1960, 1972); Böðvarsson (1967–

xii


Figure 11. Total number of winterfed sheep in Iceland compared with East Iceland (Hagstofa Íslands 2018).

Figure 12. Condition of vegetation in area 1 and area 2 (Arnalds, 2002).

Figure 13. CORINE 2006 mapping and classification in the study area (Þórisson & Ágústsdóttir, 2014).

Figure 14. Vegetation mapping of the Icelandic Institute of Natural History, covering the main summer grazing areas and 42% of the home range of the Snæfellsherd. Area 1 is delineated with a red line and area 2 with a blue line (Þórisson & Ágústsdóttir, 2014)....

Figure 15. Annual mean precipitation (mm) in Iceland in the years 1971–2000 (Icelandic Meteorological Office, 2007).


Figure 17. The durability of GPS collars (number of days) on different females (see Table 11) from 15th of February 2009 to 2nd of June 2011, blue in area 1 and red in area 2. ... Figure 18. Division of the year in seven periods. Day-of-year is shown in the x-axis, and the numbers of days are indicated for each period. Winter is divided in early and late winter.

Figure 19. Proportion of Snæfellsherd (black area) represented by GPS collared reindeer females over the study period (838 days). The proportion varies over time, as the number of GPS-collared females and reindeer group size differed between months.


Figure 21. Proportion of reindeer in areas 1 and 2 (Snæfellsherd) and 3 (the East Fjords) in the total reindeer population in the years 1978–2015.
Figure 37. Proportion of barren (dark colour) and lactating (light colour) females in different age classes in area 1 (blue) and 2 (red), as estimated from combined hunting data 1992–2015. 65
Figure 38. Correlation between recruitment and North Atlantic oscillation index (NAO) in winter (NCAR, 2018). 67
Figure 39. Cause of death of reindeer (except hunting) based on carcass analysis 1991–2013 (Þórisson & Ágústsdóttir, 2014). 67
Figure 40. Time of death of reindeer from carcass analysis of reindeer found dead in 1991–2013. 68
Figure 42. Mean carcass weight (kg) (with standard error) of 3–5-year-old lactating females at the hunting time in area 1, 2 and 3–8 (Eastern fjords) in 2008 to 2015. 73
Figure 43. Comparison of carcass weight (kg) (with standard error) of 3–5 years old males in area 1 and area 2 in the 2004–2015 hunt. 74
Figure 44. Size and distribution of reindeer in area 2 in July compared with mean carcass weight of 3–5 years old lactating females in hunt 2000–2015. 74
Figure 45. Number of reindeer in Brúaröræfi (including Kringilsárrani and Sauðárrani area (dark blue columns) and in Norðurheiðar (light blue columns) in July 2008–2015 compared with the average carcass weight of 3–5-years old lactating females (green line and trendline black straight line) shot in August-September. 75
Figure 46. Mean carcass weight (kg) of 3–5-year-old lactating females in area 1 2008–2015 correlated with the herd size in July. 76
Figure 47. Mean carcass weight (kg) of 3–5-year-old lactating females in area 2 2002–2009 correlated with the herd size in July. 76
Figure 48. Mean carcass weight (kg) of 3–5-year-old lactating females in area 2 2010–2015 correlated with the herd size in July. 77
Figure 49. Mean carcass weight of adult reindeer females in area 2 and ram lambs in area 1 and area 2 in 2000–2015. 79
Figure 50. Tracks of three GPS-collared reindeer females 2010–2011 in area 1 (Google Earth map). 80
Figure 51. Tracks of five GPS-collared reindeer females 2009–2010 in area 2 (Google Earth map). ................................................................. 81
Figure 52. Mean herd size of GPS-collared females in area 1 and 2 in 2009–2011........ 81
Figure 53. Herd size in Snaefells herd 1980–1981 in different months, number of herds in parenthesis (Þórisson, 1983). ........................................................................................................... 82
Figure 54. Calving places based on minimum movements in May (Strand et al., 2011). GPS-collared females in different years. T: positioned from aeroplane (Þórarinsdóttir & Ágústsdóttir, 2015)........................................ 84
Figure 55. Positions of three GPS-collared females in area 1 from 8th to 31st of May 2009–2012: Ána 2011 (15th of May) and Ranga 2012 (19th of May) spotted after the GPS-collars stopped transmitting and Gríma in area 2. (Þórarinsdóttir & Ágústsdóttir, 2015)........ 85
Figure 56. Home and core range sizes (km²) of three females in area 1 and five females in area 2 in different periods of the year. ........................................................................................................... 87
Figure 57. Comparison of home range between area 1 and area 2 at different times of year. ................................................................................................................................. 88
Figure 58. Average speed (m/hour) by different females and time periods in area 1 (Þórisson & Ásgústsdóttir, 2014)......................................................................................... 89
Figure 59. Average speed (m/hour) by different females and time periods in area 2 (Þórisson & Ásgústsdóttir, 2014)......................................................................................... 89
Figure 60. Average movements (m/hour) with standard error in area 1 and 2 at different time of year..................................................................................................................... 90
Figure 61. Number of step length >5 km per 3 hours at different time of year of all three GPS-collared females in area 1 and five in 2 ................................................................. 90
Figure 62. Comparison of average movements, home and core range between area 1 and 2 at different periods. ........................................................................................................... 91
Figure 63. Proportional size of CORINE land classes (CORINE class codes are indicated by numbers in brackets) in area 1 and area 2. ................................................................. 93
Figure 64. Comparison of actual CORINE land classes in area 1 and area 2.............. 93
Figure 65. Proportional division of habitats according to the INH vegetation map in area 1 and area 2, and specifically for the combined home range and core range in areas 1 and 2. ........................................................................................................... 94
Figure 66. Habitats inside INH mapped home range of reindeer in area 1 and 2........ 94
Figure 67. Habitats inside INH mapped core range of reindeer in area 1 and 2........... 95
Figure 68. Proportion of INH vegetation mapping of home range (HR=95%) and core range (CR=50%) of GPS-collared females in area 1 (Ána, Hlenda, Ranga) and in area 2 (Ása, Gríma, Hnefla, Heiða, Stína) (Þórisson & Ágústdóttir, 2014).

Figure 69. Proportional average annual habitat uses in home (HR; 95%) and core (CR; 50%) range of GPS-collared females in area 1 and 2.

Figure 70. Area size of the four most common habitats utilized by reindeer in home range in area 1 and 2.

Figure 71. Reindeer utilization of four of the most common habitats in core range in area 1 and 2.

Figure 72. Habitat use in home and core ranges of all GPS-collared females in area 1 and area 2.

Figure 73. Average proportional annual habitat uses in home and core range of GPS-collared females in area 1 and 2, gravel excluded.

Figure 74. Comparison of estimated annual food intake of four grazers in pastures in area 1 and area 2 in East Iceland in 2015. Data based on Garðarsson (1987).

Figure 75. Correlation between carcass weight of females age 2+ years and mid-calving in May in Norway and area 1 and area 2 in Iceland (Reimers, 1983b; Reimers et al., 1983; Þórarinsdóttir & Ágústsdóttir, 2015).

Figure 76. Comparison of pre-rut mean total body weight (pre-rutTBW) of 2+ year old reindeer females with different ancestry in Norway: wild (green), mixed (violet), domestic (blue) (Reimers, 1997; 2013) and Icelandic (area 1; dark blue, area 2; red).

Figure 77. Sheep number in Fljótsdalur community 1990–2011 (Sæmundsen et al., 2014 (Picture1-5, p. 7)).

Figure 78. Average speed (m/hour) in different time periods on Hardangervidda in Norway (Fallsdorf, 2013) and in two herds in Iceland (Þórisson & Ásgústsdóttir, 2014). The Icelandic data adjusted to the Norwegian time periods.

Figure 79. Average travelling speed (m/hour) in Iceland (area 1 and 2) and two herds in Norway, one with domestic ancestry the other wild ancestry (adjusted from Reimers et al., 2013b): table 1. p. 28.)
For

word

In this master thesis I analyse the life history of reindeer in East Iceland focusing on the herds roaming the highland plateau in the past, present and future. The emphasis is on the population dynamics and demography of Snæfellsherd based on my monitoring after 1978 and especially after 2000. Most of these monitoring efforts have been published as internal reports, but are compiled and synthesized here, adding a new perspective to the status and dynamics of reindeer populations in East Iceland. The main lines in the monitoring of the population are counts at different times of year and data on physical condition of the reindeer based on hunting reports. I analyse behaviour and habitat use of reindeer females, based on eight GPS-collared reindeer females in 2009–2011. That research was done with Kristín Ágústsdóttir for the Icelandic National Power Company to evaluate the impact of a hydropower project on Snæfellsherd. In the end, I discuss the status of the population in the light of management and climate change. In the appendices, I include maps of the home ranges of all the females at different times of year and detailed information about grazing and food species.
1 Introduction

The reindeer (*Rangifer tarandus*) has lived feral in Iceland for almost two and a half centuries, since its first introduction to Iceland from Norway in 1771. Today reindeer are confined to East Iceland where they live in separate herds, the largest one being Snæfellsherd. Conditions for reindeer in Iceland are favourable, given that the only predator is the Arctic fox (*Vulpes lagopus*) and the absence of warble flies (*Hypoderma tarandi* and *Cephenemyia trompe*) and mosquitoes (*Aedes nigripes*) which harass reindeer populations in their native range (Þórisson 1993; Skjenneberg & Slagsvold, 1968).

The main studies concerning the life history of reindeer in Iceland are Valtýsson (1945), Þorvaldsson (1960) and Thorlacíus (1960) and ecological writings in Þorsteinsson et al. (1970) and Þórisson (1983, 1993, 2004). Information is scarce before 1939 but that year the Ministry of Education and Culture hired Helgi Valtýsson to visit what was left of the Icelandic reindeer. He did so in 1939–1943. He proposed in his report to hire a local person to monitor the herd and the authority hired Friðrik Stefánsson, a local farmer and hunter. His main task was to conduct annual summer counts that started in 1943. In 1956 Egill Gunnarsson took over and the counting "vehicle" changed from a horse to an aeroplane. From 1965 to 1976 the National Land Service of Iceland (Landmælingar) conducted the annual summer counts of reindeer and Ingvi Þorsteinsson in 1978; thereafter I have overseen the counts on behalf of institutions monitoring the population. From 1991–1999 The Wildlife Management Unit took over the monitoring. Since 2000 the East Iceland Nature Research Centre (EINRC) has been in charge of monitoring and studies of the reindeer population responsible deemed necessary to maintain a sustainable population. (Þórisson, 1983; Þórisson & Karlsdóttir, 2001; Þórisson & Ágústsdóttir, 2014; Þórisson & Þórarinsdóttir, 2015, 2016).

Studies on disease, parasites and health of Icelandic reindeer can be found in Sigurðarson, 1993; Guðmundsdóttir, 2006; Guðmundsdóttir & Skírnisson, 2005; Pálsson et al., 1993, 1994; Chase et al., 1994; Røed et al., 1985; Aschfalk & Thorisson, 2004.

Because of proposed hydropower planning on the highland plateau of East Iceland the National Energufund (Orkustofnun) got Norwegian reindeer scientist to propose a
plan for ecological study on the Icelandic reindeer population, especially Snæfellsherdl (Gaare & Reimers, 1978). In 1979–1983 The Icelandic Institute of Natural History (INH) conducted a detailed ecological study based on that proposal. (Egilsson, 1983, 1993; Þórisson, 1983; Egilsson & Þórisson, 1983; Thorisson, 1984). This was my beginning of reindeer study and monitoring in East Iceland.

INH was also in charge of the Environment Impact Assessment of Kárahnjúkar hydropower project at the turn of the century (Magnússon et al., 2001). Part of this assessment involved the evaluation of the effects of the project on reindeer (Þórisson & Karlssóttir, 2001) belonging to Snæfellsherdl. That herd are split in two subherds, Nødurheiðaherd living in area 1 and Fljótsdalsherdl living in area 2. Eight reindeer females in Snæfellsherdl got GPS-collars around their neck in 2009–2010 and that research became a part of my planned MSc thesis. The main focus will be my researches and monitoring of the population 1978–2015.

As stated earlier the Kárahnjúkar hydropower project promoted a lot of the reindeer research in Iceland because it affected key areas for reindeer herds, especially Snæfellsherdl. The project was granted in 2000. An asphalt road was built in 2002–2003 along Fljótsdalsheiði and Vesturöræfi north of Mt. Snæfell. A water reservoir (57 km²) called Hálslon lagoon was full for the first time in September 2007. On the east side of Mt. Snæfell water was collected into two main water reservoirs, Ufsarlón and Kelduárlón lagoon. The water from the lagoons was diverted through a 73 km underground tunnel to the hydropower plant in Fljótsdalur valley (Figure 1). The project was completed in 2009.
Until 2008 Kringilsárrani, west of Háslón, was the only reindeer area protected by law since 1975. The government had to change that law when the water reservoir of Kárahnjúkar hydropower project drowned 25% of the protected area\(^1\). After the establishment of Vatnajökull National Park in 2008 another protected area was formed around Mt. Snæfell (Figure 4).

In 1993–2013 The National Power Company (Landsvirkjun) financed aerial counts in spring and early summer of Snæfellsöræfi done by Engineering Institute of the University of Iceland (Verkfræðistofnun Háskóla Íslands) (Árnason, 2014).

https://www.ust.is/library/Skrar/Einstaklingar/Nattura/Fridlysingar/Kringilsarrani,%20eldri.pdf

Figure 1. Kárahnjúkar hydropower project. Asphalt road (Kárahnjúkavegur): black line, tracks: broken black lines, dams red, tunnel pink, open ditches green. The power plant being at the end of the tunnel in Fljótsdalur valley (Pórisson & Ágústsdóttir 2014).
In 2005 EINRC initiated research on calving and calving grounds of Snæfellsherd (Þórarinsdóttir & Ágústsdóttir, 2015), and in 2009–2011 a study investigated the herd’s utilization of the area affected by the project using eight GPS-collared females (Þórisson & Ágústsdóttir, 2014). This research was financed by The National Power Company (Landsvirkjun).

Since 2000 East Iceland Nature Research Centre (EINRC) have been in charge of monitoring the reindeer population in East Iceland. Results have been published in reports by the EINRC (Náttúrustofa Austurlands, 2018). Information from these technical reports are used in this thesis to compare the population dynamic and physical condition of the two herds in area 1 and 2. Intense monitoring of the reindeer population became critical, as the number of reindeer increased and expanded all over East Iceland, despite the intensified hunting efforts.

In recent years, a reindeer herder at Isortoq Reindeer Station in Greenland tried to get license to import some of his semi-domesticated reindeer to Iceland. The reindeer were descended from Norwegian reindeer that were introduced to Greenland back in 1952 (Cuyler, 1999). The Icelandic authorities did not permit it after consultancy with the veterinary medical board (Jónsson, 2005). The same person planned in 2013 to start a reindeer herding with part of the Icelandic population in northeast Iceland but was denied by the Ministry for Environment and Natural Resources (Práínsson et al., 2015).

International Union for conservation of Nature and Natural Resources (IUCN) categorized Rangifer tarandus in 2015, as Vulnerable A2a. The ranking was Least Concern in 2008 and 1996. The reason being decreasing of the world population in a changing landscape regarding arthropogenic behaviour (IUCN 2016). This changing landscape will also affect reindeer in Iceland.
2 A brief introduction of the species Rangifer tarandus L.

Only one species belongs to the genus *Rangifer*, namely the reindeer in Europe/Asia and caribou in North America. The species is divided in three groups depending on where they are living; tundra reindeer (barren ground/mountain; 75% of total wild *Rangifer*), high arctic island reindeer (11%) and forest reindeer (14%) (Gunn, 2016). Following Banfield (1961) there are nine subspecies of the genus including two extinct, divided in two groups, Cylindricornis and Compressicornis, based on the appearance of the antlers (Table 1).

### Table 1. Subspecies of the genus *Rangifer* (Banfield, 1961), distribution and estimated population size of wild reindeer/caribou (Gunn, 2016).

<table>
<thead>
<tr>
<th>Subspecies</th>
<th>Distribution</th>
<th>Estimated number (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>R. t. tarandus</em></td>
<td>Europe (Norway)/Asia (Siberia)</td>
<td>30,000/628,000 (2015)</td>
</tr>
<tr>
<td><em>R. t. granti</em></td>
<td>North America (Alaska)</td>
<td>660,000 (2010)</td>
</tr>
<tr>
<td><em>R. t. groenlandicus</em></td>
<td>North America (Canada/Greenland)</td>
<td>800,000 (2013/2015)</td>
</tr>
<tr>
<td><em>R. t. eogroenlandicus</em></td>
<td>North America (East Greenland)</td>
<td>Extinct since ~1900</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subspecies</th>
<th>Distribution</th>
<th>Estimated number (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>R. t. platyrhynchus</em></td>
<td>Europe (Svalbard)</td>
<td>10,100 (2009)</td>
</tr>
<tr>
<td><em>R. t. pearyi</em></td>
<td>North America (Canada arctic islands)</td>
<td>14,000 (2014)</td>
</tr>
</tbody>
</table>

### Table 2. Subspecies, distribution and population size of wild reindeer in Russia (Grubb, 2005; Gunn 2016).

<table>
<thead>
<tr>
<th>Subspecies</th>
<th>Distribution</th>
<th>Estimated number (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>R. t. sibiricus</em></td>
<td>East/West Siberia</td>
<td>626,000/2000 (2015)</td>
</tr>
</tbody>
</table>

### High arctic islands reindeer

<table>
<thead>
<tr>
<th>Subspecies</th>
<th>Distribution</th>
<th>Estimated number (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>R. t. pearsoni</em></td>
<td>Novaya Zemlya Island/other islands</td>
<td>5000/11,000 (2015)</td>
</tr>
</tbody>
</table>

### Forest reindeer

<table>
<thead>
<tr>
<th>Subspecies</th>
<th>Distribution</th>
<th>Estimated number (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>R. t. phylarchus</em></td>
<td>Kamchatka Peninsula</td>
<td>2300 (2015)</td>
</tr>
<tr>
<td><em>R. t. angustirostris</em></td>
<td>SouthEast Russia</td>
<td>Several hundred</td>
</tr>
<tr>
<td><em>R. t. valentinae</em></td>
<td>Northern Mongolia, China</td>
<td>&lt;1000 (2006)</td>
</tr>
</tbody>
</table>
In Grubb (2005) five more subspecies are described in Russia, Mongolia and China (Table 2). The total number of wild reindeer/caribou in the northern hemisphere between 50° and 81° latitude (Figure 2), is believed to be close to 2,900,000 individuals (Gunn, 2016). Some 10−25 years ago they were estimated to be 4,800,000 thus have declined of 40% (Gunn, 2016). Although populations of *Rangifer* have oscillated in numbers through history, anthropogenic factors in many forms are most likely responsible for most of the present decline (Gunn, 2016). Information on status and trends, management and threats for most of the herds of *Rangifer*, including the Icelandic one can be found on the CircumArctic Rangifer Monitoring Assessment (CARMA) homepage².

Reindeer husbandry is practiced in Norway, Finland, Sweden, Russia, Greenland, Alaska, Mongolia, China and Canada, and a small herd is also maintained in Scotland. The present number of semi-domesticated reindeer is 3,400,000³. The reindeer husbandry is importance to many northern communities but many worries about its future because of both natural and social changes (Forbes & Stammler, 2009).

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² https://carma.caff.is/herds
³ http://reindeerherding.org/herders/what-is-reindeer-husbandry/
Domesticated Norwegian reindeer were introduced to Iceland (1771–1787) and South Georgia in the southern hemisphere (1911, 1912 and 1925). Swedish reindeer were introduced to Iles Kerguelen (1956) in the Indian Ocean. In these three instances they became feral (Leader-Williams, 1988; Headland, 2012). From South Georgia a few were taken to Isla Navarino (1944, did not survive) and Falkland Islands (Malvinas) for farming (2001) (Bell & Dietrich, 2010) (Figure 2). The reindeer on South Georgia were recently regarded as invasive alien species damaging native vegetation, having negative effects on native biodiversity and to cause soil erosion. Therefore, they were eradicated in 2013–2014 (Anon, 2014). Eradication of reindeer on Iles Kerguelen in the southern Indian Ocean has also been considered (Headland, 2012).
3 Reindeer in Iceland

Reindeer were introduced from Norway to four different areas in Iceland in the late 18th century (Figure 3). The Norwegian animals were of semi-domesticated origin but have always been feral in Iceland. Three of the herds disappeared or become extinct before 1930 (Table 3). The present-day population is confined to East Iceland numbering ca 6400 animals in summer and their number and distribution is manage by hunting (Þórisson & Þórarinsdóttir, 2017).

<table>
<thead>
<tr>
<th>Year</th>
<th>Origin</th>
<th>Embarkation</th>
<th>Number</th>
<th>♂</th>
<th>♀</th>
<th>†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1771</td>
<td>Sörö Finnmark</td>
<td>Vestmanna Island, S-Iceland</td>
<td>13–14</td>
<td>?</td>
<td>?</td>
<td>1783</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fljótshlíð, S-Iceland</td>
<td>surviving</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1777</td>
<td>Sörö Finnmark</td>
<td>Hafnafjörður, SW-Iceland</td>
<td>30</td>
<td>6</td>
<td>24</td>
<td>1923</td>
</tr>
<tr>
<td>1787</td>
<td>Avjovarre Finnmark</td>
<td>Vopnafjörður, NE-Iceland</td>
<td>35</td>
<td>5</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

It is crucial to know the history of the reindeer population after the introduction. That knowledge can help understanding the life of the reindeer in Icelandic environment. Unfortunately, information regarding the survival of the populations are scarce. We know that they increased fast in the beginning and most likely peaked just before the middle of the 18th century. The population oscillated through the decades, mainly because of harsh winters. They became extinct in the fourth decade of the 19th century, except in East Iceland where a small herd survived. Since then we have more information of the population dynamic.

In 1940 all reindeer in Iceland belonged to a single herd, Snæfellsherd, in East Iceland, and this remained unchanged for the next two to three decades. During the first decades after 1940 only Snæfellsherd roamed the area around Mount Snæfell. The East Iceland highland plateau laying to the west and north of the East Fjords has been the principal distribution area of the herd. As the herd increased in numbers it expanded its distribution all over East Iceland. Around 1970 the population had split up into about six herds, of which Snæfellsherd continues to be the largest nowadays.
Figure 3. Introduction of reindeer to Iceland in 1771–1787 (dates of introduction are indicated for the different areas). Ill Past distribution //// Main past distribution range = Current distribution (updated from Pórisson, 1983).

Around half of the total population spend the entire year in the East Fjords and in the adjoining mountains, while the rest (Snæfellsherds) are restricted to the highland plateau north and northeast of Vatnajökull glacier (Pórisson, 1993; Pórisson & Karlsdóttir, 2001). In 1992 the reindeer ranges were split into nine hunting areas reflecting separate herds and the distribution of the population. These hunting areas have not changed, except for area 1 that expanded to the north in 2014 (Figure 4) (Pórisson, 2004; Pórisson & Pórarinsdóttir, 2015). The westernmost boundary of the entire reindeer population is in the south; Jökulsárlón glacial lagoon, the Vatnajökull glacier, the glacial rivers Kverká, Kreppa and Jökulsá á Fjöllum north of Vatnajökull glacier. About 5 km south of the waterfall Dettifoss the boundary heads NNE to the sea (Figure 4). The largest herd, Snæfellsherds uses two of these hunting areas; area 1 and area 2, separated by the glacial river Jökulsá á Dal. In the following writings, these two areas of the Snæfellsherds will be referred to with the names area 1 (blue in graphs) 5760 km² and area 2 (red in graphs) 3330 km² as it were in 2014. Total area being 15210 km², Snæfellsherds then roaming 60% of land used by reindeer in East Iceland.
Figure 4. Nine hunting areas of reindeer in Iceland in 2015. The red line delimits the highland plateau where Snæfellsherd room (areas 1 and 2) and the East fjords (areas 3 to 9). The blue line shows the northern border of area 1 in the years 1992–2014. Vatnajökull National Park is delimited by a yellow unbroken line. The two uncoloured areas around and west of Mt. Snæfell are the only protected areas for reindeer in East Iceland, where hunting is not permitted. (Þórisson & Þórarinsdóttir, 2015).

The reindeer population in East Iceland is currently managed through harvest. The main goal set by East Iceland Natural Research Centre (EINCR) is to have a sustainable population with density under one animal per km² on vegetated land in winter and six
males per ten females (Þórisson & Þórarinsdóttir, 2017). It is believed that this will secure a healthy profitable population in harmony with the environment and the people that utilizes the land.

In a proposed bill of Nature Conservation in 1999 reindeer were classified as an alien species, as were all species introduced to Iceland after 1750. Good management is a prerequisite for the species not to become invasive in Iceland, as it happened in other areas where reindeer have been introduced like in South Georgia (Leader-Williams, 1988). Concerns have been raised in this direction, because the Icelandic reindeer have no natural predators that can effectively control their populations.

3.1 Management of reindeer in Iceland

From 1943–1990 management of reindeer hunting was conducted by the Ministry of Education and Culture. From 1943 the management was based on a report from Helgi Valtýsson and some local farmers (Valtýsson, 1945). From 1956 the ministry also used the results of annual summer counts from an aeroplane (Thorlacius, 1960).

A hunting quota was divided amongst local communities and a chosen farmer/hunter in each community oversaw the hunting. Limited sport hunting was allowed between 1958 and 1972 (Thorlacíus, 1960; Þórisson, 1983, 2004).

Between 1943–1953 419 male reindeer were shot, on average 38 every autumn. In 1954 the reindeer population was believed to be around 2000 animals and had expanded from the main grazing areas north of the northeast corner of Vatnajökull glacier. For the first time a hunting quota (600) was set and divided between 12 communities (hreppar) (Thorlacius, 1960). For the next ten years the quota was the same but only 325 animals were shot every year on average. The reindeer were protected in 1965–1967 and 1970–1971. From 1972–1977 the quota oscillated between 850 and 1555 with 745 shot

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4 http://www.althingi.is/altext/141/s/0537.html

11
annually at average (Figure 5). Details of hunting in Snæfellsherd 1978–2015 can be found in chapter 6.3.


In 1990 the Ministry of Environment was established and took over governance of reindeer management. The Wildlife Management Unit took over research and monitoring. For the first time, the hunting quota was decided for both sexes of reindeer.

The reindeer ranges were divided into nine hunting areas based on local herds (Figure 4) (Hersteinsson, 1992a; 1992b). A Reindeer Council was established in 1992 and took charge of the hunting and the hunting quota agreed by the Ministry of Environment based on a proposal from the Wildlife Management Unit. All hunting license were sold to hunters. Each hunter could only buy one license and was obliged to hire a professional hunting guide. Hunting guides became responsible for the hunt and required to deliver a
report indicating date, location, sex, and estimated age of hunted animals. Information on lactating females needed to be indicated and hunters were asked to shoot their calf, if possible, and report its sex. From 1995 the guides were asked to give also the carcass weight and thickness of back fat.

In 2003 the Wildlife Management Department of The Environment Agency of Iceland took over the management of reindeer hunting in Iceland. The hunting season was established from 15th of July until 15th of September for males and 1st of August until 20th of September for females. Occasionally, hunting of females in November is allowed.

In 2000, monitoring and research of reindeer populations in Iceland and the annual proposal of a hunting quota became a part of EINRC functions. An overview of monitoring and management of reindeer in Iceland since 1940 is shown in Table 4.

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Monitoring</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940</td>
<td>Law nr. 28/1940 - Hunting regulation and monitoring, only males shot</td>
<td>Ministry of Education and Culture</td>
<td>Ministry of Education and Culture</td>
</tr>
<tr>
<td>1958</td>
<td>Sport hunting allowed</td>
<td>Ministry of Education and Culture</td>
<td>Ministry of Education and Culture</td>
</tr>
<tr>
<td>1972</td>
<td>Sport hunting banned</td>
<td>Ministry of Education and Culture</td>
<td>Ministry of Education and Culture</td>
</tr>
<tr>
<td>1990</td>
<td>Nine hunting areas, quota on sex – no hunting without a hunting guide</td>
<td>Wildlife Management Unit</td>
<td>Ministry of Environment</td>
</tr>
<tr>
<td>1992</td>
<td>Reindeer Council established - allowed to sell hunting license</td>
<td>Wildlife Management Unit</td>
<td>Reindeer Council</td>
</tr>
<tr>
<td>1994</td>
<td>Law nr. 64/1994 - Protection and management of birds and mammals</td>
<td>Wildlife Management Unit</td>
<td>Reindeer Council</td>
</tr>
<tr>
<td>2000</td>
<td>Increased monitoring partly funded by income of hunting licenses since 1992</td>
<td>East Iceland Nature Research Centre</td>
<td>Reindeer Council</td>
</tr>
</tbody>
</table>

http://www.althingi.is/lagas/nuna/1994064.html
3.2 Reindeer in Iceland 1787–1977

3.2.1 Reindeer in East Iceland 1787–1939

Reindeer were introduced to East Iceland in 1787 when 35 animals from Avjovarre in Kautokeino, Norway, disembarked in Vopnafjörður (Figure 3, Table 3). Their numbers increased rapidly and expanded over East Iceland. At the same time farmers started complaining of reindeer spoiling sheep grazing areas and eating Iceland moss (*Cetraria islandica*) in direct competition with human harvesting (Valtýsson, 1945; Þórisson, 2011) (Appendix 10.5).

The population size of reindeer fluctuated through time but decreased drastically in the late 19th century. The cause of this decline is believed to be overgrazing of the winter pastures combined with harsh winters (Valtýsson, 1945; Þorsteinsson et al., 1970; Stefánsson, 1971; Þórisson, 1983). In 1939, all reindeer herds in Iceland had become extinct except for a small herd restricted to the highland plateau at the northeast corner of Vatnajökull glacier (Valtýsson, 1945).

From the scarce information available, it seems clear that the reindeer distribution in the 19th century was mainly the East Iceland highland plateau with greatest concentration of reindeer around and north and northeast of Mt. Snæfell (Þórisson, 2000).

3.2.2 Reindeer in East Iceland 1939–1944

In 1939–1944 the Government financed an excursion to the area north of Vatnajökull glacier believed to be the home of the last reindeer herd in Iceland (Valtýsson, 1939; 1945). In August 1939 one hundred reindeer, 40 males, 40 females and 20 calves were found in Kringilsárrani (Figure 4). Valtýsson believed that the sex ratio of the remaining population was a hindrance to the growth of the population and proposed two things; shooting of males and hiring of a local person to monitor the population mainly by annual summer counts (Valtýsson, 1945). After 1940 the population gradually increased in size, spending summers close to Vatnajökull glacier, migrating east and north in autumn and descending to lower ground in winter.
From 100 individuals in 1939 (Valtýsson, 1945) the herd increased from 150 individuals in 1940 to 1610 in 1950 (Figure 6). Assuming an annual survival of 0.95 in females and 0.90 in males and 60% calves on females/yearlings in July, a population of 100 individuals in 1939 would give a herd of 819 in 1950. To reach the 1610 individuals found in 1950, the initial population must have been at least 163 in 1939 as stated in Þórisson (1983) (Figure 6).

However, assuming an annual survival of 0.97 in females and 0.95 in males and 65% calves on females/yearlings in July would only give an estimated herd size of 1382 in 1950.

![Figure 6. Growth of the reindeer population 1939–1950. Given an annual natural mortality of females 5% and 10% of males, and a proportion of calves in summer 60% of females/yearlings. Summer counts from Thorlacius (1960).](image)

### 3.2.3 Number and distribution of reindeer in Iceland 1940–1977

In 1940 all the reindeer in Iceland were restricted to Snæfellsöræfi and regarded as one herd, Snæfellsher. Staying in Kringilsárrani area and Vesturöræfi wilderness close to the north east corner of Vatnajökull glacier in spring and summer and then moving to the north, Fljótsdalsheiði, in autumn and winter (Figure 4). Ever since Snæfellsöræfi has been the main summer grazing area of Snæfellsher.
In 1954 the reindeer population in Iceland was believed to be around 2000 animals (Figure 7) and had dispersed from the principal grazing areas north of northeast corner of Vatnajökull glacier. The population was regarded as one herd called Snæfellsherδ with its main grazing pastures and calving areas in the wilderness around Mt. Snæfell. No counts were made in 1951–1953 and 1961–1963 but in 1964 the number was like 1950. Oscillations in numbers of reindeer are believed to indicate the quality of the counts rather than real fluctuations in the herds (Figure 7). The main reason why Snæfellsherδ did not grow (with regards to counts) after 1954 is most likely because of an increase in dispersal of the herd to other areas, as suggested by the increased number of communities getting a hunting quota.
In the sixties, Snæfellsherd split up into two reindeer populations in area 1 and 2 with the glacial river Jökulsá á Dal as the boundary between them. Reindeer in area 2 stayed mainly north of Mt. Snæfell (Fljótsdalsheiði) in autumn and winter and most of the population migrated to calving and summer grounds on Vesturöræfi. Within area 1, migration along the valleys of Brúaröræfi wilderness between calving area in Kringilsárrani and autumn and winter grounds in Norðurheiðar evolved in 1955–1960 (Figure 4, Figure 8). Although intermingling between these herds is known to happen occasionally, their main pastures are clearly separated (Egilsson & Þórisson, 1983). From 1955 to 1976 the reindeer population increased from 2000 to 3600 individuals. In 1964 the total population was estimated only 1700 individuals. In 1965–1967 and 1970–1971 the population was protected, and the number rose up to 4100 in 1972. Estimates of the total reindeer population in Iceland was based on summer counts of Snæfellsherd, but in the seventies the population that expanded to the East Fjords increased (Figure 7, Thorlacius (1960); Böðvarsson (1967–1969, 1971, 1973); Böðvarsson & Pálsson (1965, 1966, 1970, 1972); Guðmundsson & Þorsteinsson, (1974, 1976) and Þorsteinsson, (1975, 1978). In 1954 only 13 communities got a hunting quota but had increased to 29 communities in 1977.
3.2.4 Reindeer in area 1 1965–1978


From 1965 to 1978, all land south of Sauðá river, especially the Kringilsárrani area (Figure 8), represented the main calving and summer grazing areas of reindeer in area 1. The animals stayed there until late August or the beginning of September and then migrated north towards Norðurheiðar. Around 10% of males stayed in Norðurheiðar in summer (Figure 9) and are missing from the summer counts in many instances, most likely because it was hard to find them in the vastness of Norðurheiðar. In 1965–1978 the average number of reindeer in July aerial counts in Kringilsárrani area was 263 (range 28–460), and 30 (range: 8–93) in Norðurheiðar (Figure 9). The low numbers in 1965 are most likely because the count was conducted too early in the season (i.e. the 13th of June). The count in 1967 was conducted on 12th of July, which is appropriate in most years, but that year the arrival of spring is said to have been a month later than usual (Böðvarsson, 1967). The count in 1970 was done on 27th–28th of July. In most years it can be too late and could explain why no reindeer were found in Kringilsárrani or Norðurheiðar (Böðvarsson & Pálsson, 1970). In a count report from 1972 separation of area 1 and area 2 is missing (Böðvarsson & Pálsson, 1972) and there was no count in 1977.

3.2.5 Reindeer in area 2 1965–1978

From 1965 to 1976 reindeer in area 2 represented on average 88% of the annual July counts of Snæfellsherd (Figure 10). In some years, counts were performed at the end of July when the autumn migration has started. At this time, herds are smaller and more dispersed, potentially leading to inaccurate counts (Dórisson, 1983). This is also believed to be the reason for the high numbers in some years in Fljótsdalsheiði 1965–1975 (N of Mt. Snæfell; Figure 10). Vesturöræfi (W of Mt. Snæfell) was the main summer grazing area in 1965–1978 (Figure 10).

3.3 Grazing in the reindeer pastures

Egilsson (1983) compared the vegetation in Jökuldalsheiði (area 1; southern part of Norðurheiðar) and Fljótsdalsheiði (area 2, N of Mt. Snæfell, Figure 4, Figure 8). His conclusion was that reindeer grazing pastures were much richer in Jökuldalsheiði than Fljótsdalsheiði. The condition of grazed pastures in East Iceland is said to be generally good and most of the rangelands are among the best in Iceland regarding soil erosion (Arnalds, 2002). On the other hand, in some areas soil erosion reaches the worst severity grades in Iceland like "...the highland rangelands of Vopnafjörður and Jökuldalsheiði common and in the valleys of Brúaröraefi." (Arnalds et al., 2001:70).

Carrying capacity is the maximum number of individuals of a given species that a site can support over a certain period without deterioration of the site (Kristófersson et al., 2012). If the grazing does not exceed the standing crop we have sustainable land use. This process is ever changing because it is dependent on environmental factors like weather, type of soil and timing of grazing (Guðmundsson, 1993). The grazing pressure depends on the number of grazers per area unit. To understand grazing pressure, we must know the quantity of plant species grazed and quality of the plant species at different times and their standing crop in different habitats. Much of this information is lacking for East Iceland.

In reindeer pastures in East Iceland the only mammalian grazers are sheep and reindeer, and in few occasions horses. The Pink-footed Goose (Anser platyrhynchus) have the highest total food intake among avian grazer and, to a lesser extent, the Rock Ptarmigan (Lagopus muta) and the Whooper Swan (Cygnus cygnus). The grazing effects of Rock Ptarmigan could be underestimated (Garðarsson, 1987), especially when populations are at their highest.

Pressure of sheep grazing in Iceland in 1960–1980 was at the highest since the start of settlement with up to 900,000 winterfed sheep (Þórhallsdóttir, 1991). After 1980 it declined and has been stable around 500,000 from 1992 (Figure 11). At the same time fecundity increased (Arnalds & Barkarson 2003). Because of climate change, grazing plant harvest also increased (Bragason, 2013). The average number of winterfed sheep in East Iceland 1998–2014 was 77282 sheep (range: 73934–80680) (Hagstofa Íslands 2018).
Summer grazing sheep would then be 115,923 with ~1.5 lambs per ewe on average.\(^6\) A ewe with two lambs needs about 10 ha of grazing land in summer for an acceptable yield (Magnússon & Magnússon, 1992).

The population of Greenland/Iceland Pink-footed Goose has been counted annually in autumn on winter grounds in Britain from 1960 when the number was 50,000 (Mitchell & Hearn, 2004). In autumn 2014 the number was 393,000 (WWT, 2018). Increased numbers of this species in East Iceland, mainly on the highland plateau and along rivers has been documented (Skarphéðinsson & Þórisson, 1996; Stefánsson & Þórisson, 2015). Increased grazing pressure of the geese worried many sheep farmers, especially on the more densely populated areas like Undir Fellum (Eyjabakkar area), Vesturöræfi area and Kringilsárrani area. Kringilsárrani can’t be reached by sheep (Kringilsá River, Háslón lagoon and Vatnajökull glacier) but is grazed by reindeer (Figure 8).

\(^6\)(http://px.hagstofa.is/pxis/pxweb/is/Atvinnuvegir/Atvinnuvegir__landbunadur__landbufe/LAN10102.px/table/tableViewLayout1/?rxid=be135400-0fc9-42df-a146-600aa4e2877f)
4 Aims of study

The main aims of this thesis are to describe the life history and ecology of reindeer in Iceland and to improve future management. This is done by evaluating the development of the largest reindeer herd in Iceland, Snæfellsher, in the two most important areas for reindeer management by analysing data on abundance, harvest, age and sex composition, food selection, body condition, fecundity and recruitment. What characterizes the climate in East Iceland and how do the reindeer benefit from the absence of insects and predators harassing reindeer in most places in the northern hemisphere? I will address the question of effects of anthropogenic disturbance on the reindeer and if we can improve monitoring and management. I compiled my data from reindeer counts from 1978 to 2015 and collected data from hunters and opportunistically from reindeer that were found dead. In addition, eight females were tagged with GPS-collars to obtain more precise information on area use, home range size and movements during different seasons.

The main questions in the thesis will be;

1) What is the history of reindeer in East Iceland in 1771–1940?
2) How was the population dynamic of the reindeers in East Iceland in 1940-2015?
3) How is the demography of Snæfellsher?
4) Is there a demographic difference between the two subherds of Snæfellsher and if, what promotes it?
5) Is there a similarity between physical conditions of sheep and reindeer in area 1 and area 2?
6) What is the demographic status of Icelandic reindeer compared with herds in Norway?
7) What is the future of reindeer in Snæfellsher with respect to our past and present knowledge and how can we improve future monitoring?

Wildlife management should aim at securing viable and sustainable wildlife populations. I hope that my answers to these questions in this master thesis will help to fulfill that goal in East Iceland with better understanding of the population dynamics and demography of the largest reindeer herd, Snæfellsher.
5 Material and methods

5.1 The study area

The study area is the highland plateau of East Iceland. On the southern border of the plateau close to the northern border of the Vatnajökull glacier lies the dead (or dormant) central volcano Mt. Snæfell, the highest mountain in Iceland outside a glacier, 1833 m a.s.l. Scattered over the 550–650 m a.s.l. plateau there are some isolated mountains/hills and a mountain chain close to the western border. These mountains are all made of tuff by an eruption under a glacier 10,000–3,000,000 years ago, rising up to 750–950 m a.s.l. (Guttormsson, 1987). The plateau is divided in two parts, according to the hunting management on reindeer and delimited by natural boundaries (i.e. the glacial river Jökulsá á Dal); area 1 and area 2 (Figure 4).

Area 1, 5760 km², lies to the west of the Háslón lagoon and north of the glacial river Jökulsá á Dal. Just north of the Vatnajökull glacier lies Brúarörfi, the wilderness of the farm Brú in Jökuldalur valley. Close to the glacier is Kringilsár- and Sauðárrani, a triangle south of the river Sauðá, west of the Háslón water reservoir at 600–700 m a.s.l., bordering to the south with the glacier (together these two areas will be called Kringilsárrani area) (Figure 4). This is, or at least was, the main calving and summer grazing area of reindeer in area 1. Some north-south laying valleys in Brúarörfi (Figure 4) are the main migratory routes of reindeer in spring and autumn. Along the whole western side of area 1 stretches a mountain chain, Fjallgarðar, sparsely vegetated as most of the land on the western side of the mountain chain. To the east of Fjallgarðar lie the main autumn and winter grazing pastures in area 1. These areas are well vegetated heathlands 550–650 m a.s.l. In recent years these areas have become increasingly important as calving areas, summer and autumn pastures. In 2014 area 1 was expanded to north (Figure 4). All calculation regarding area 1 in the thesis is based on the area as it was before the change in 2014.

Area 2, 3330 km², lies on the southern and east side of the glacial river Jökulsá á Dal and is one of few areas in the country with almost unbroken vegetation from the seashore to the edge of the glacier. The main calving and summer grazing area in area 2 is, as in area 1, just north of the glacier on both sides of Mt. Snæfell. Vesturörfi on the western side is the
principal summer grazing area. It is rich in vegetation and lays 600–700 m a.s.l. To the north of Mt. Snæfell are the heathlands of Fljótsdalsheiði and Fellahetíði, 500–700 m a.s.l., the main autumn and winter grazing areas of reindeer in area 2 (Figure 8).

East of Mt. Snæfell lies an area called Undir Fellum and on the East side of the glacial river Jökulsá í Fljótsdal lays Múli, 600–700 m a.s.l. These areas are used as spring, summer and autumn grazing areas. Farther to the east are the heathlands of Austurheiðar were reindeer graze mainly in autumn and winter. The East border of this area is the barren land of Hraun, 700–800 m a.s.l. (Figure 4). Comparison of condition of vegetation in area 1 and area 2 shows one big difference namely much larger desert in area 1 than 2 (Arnalds, 2002). Still the combination of vegetated land is similar in area 1 and area 2 (Figure 12).
5.1.1 Vegetation mapping

Vegetation in area 1 and area 2 will be analysed based on Coordination of Information on the Environment (CORINE) 2006, 2012 and The Icelandic Institute of Natural History (INH) vegetation mapping in 1999–2002 and 2013.

5.1.1.1 CORINE 2006, 2012

The largest CORINE habitat classes in Iceland are moors and heathland ((CORINE Land Cover) CLC class 322) and barren areas (CLC classes 331 and 332), covering 34% (38% and 57% in area 1 and 2 respectively) and 26% (31% and 9% in area 1 and 2 respectively) of the surface (Table 5). Glaciers and perpetual snow (CLC class 335) makes up for 10% of all CLC classes in Iceland (Árnason & Matthíasson, 2009) (Figure 13).

<table>
<thead>
<tr>
<th>CLC classes</th>
<th>Name of class</th>
<th>Iceland</th>
<th>Area 1</th>
<th>Area 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>322</td>
<td>Moors and heath lands</td>
<td>35450 (34.25%)</td>
<td>3321 (38.18%)</td>
<td>1961 (57.40%)</td>
</tr>
<tr>
<td>324</td>
<td>Forest and tree plantations</td>
<td>311 (0.3%)</td>
<td>9 (0.10%)</td>
<td>64 (1.87%)</td>
</tr>
<tr>
<td>321</td>
<td>Natural grassland</td>
<td>3410 (2.96%)</td>
<td>145 (1.66%)</td>
<td>61 (1.78%)</td>
</tr>
<tr>
<td>231</td>
<td>Pastures</td>
<td>2528 (2.44%)</td>
<td>81 (0.93%)</td>
<td>59 (1.73%)</td>
</tr>
<tr>
<td>412</td>
<td>Peat bogs</td>
<td>6627 (6.4%)</td>
<td>881 (10.12%)</td>
<td>418 (12.22%)</td>
</tr>
<tr>
<td>411</td>
<td>Inland marshes</td>
<td>386 (0.37%)</td>
<td>1 (0.01%)</td>
<td>11 (0.33%)</td>
</tr>
<tr>
<td>333</td>
<td>Sparsely vegetated (15-50% plant cover)</td>
<td>13480 (13.03%)</td>
<td>1415 (16.27%)</td>
<td>370 (10.84%)</td>
</tr>
<tr>
<td>331</td>
<td>Beaches, dunes and sand plains</td>
<td>3410 (3.3%)</td>
<td>2724 (31.32%)</td>
<td>317 (9.28%)</td>
</tr>
<tr>
<td>332</td>
<td>Bare rocks</td>
<td>23728 (22.93%)</td>
<td>121 (1.39%)</td>
<td>138 (4.03%)</td>
</tr>
<tr>
<td>511</td>
<td>Water courses</td>
<td>736 (0.71%)</td>
<td>121 (1.39%)</td>
<td>138 (4.03%)</td>
</tr>
<tr>
<td>512</td>
<td>Water bodies</td>
<td>1297 (1.25%)</td>
<td>1 (0.01%)</td>
<td>18 (0.53%)</td>
</tr>
<tr>
<td>335</td>
<td>Glaciers and perpetual snow</td>
<td>10600 (10.24%)</td>
<td>1 (0.01%)</td>
<td>18 (0.53%)</td>
</tr>
</tbody>
</table>
Figure 13. CORINE 2006 mapping and classification in the study area (Þórisson & Ágústsdóttir, 2014).
5.1.1.2 INH vegetation mapping in 1999–2002 and 2013

Magnússon et al., (2009) classified ecotypes in several highland areas. One of the areas is Brúardalir (same as Brúaröræfi, Kringilsárrani area included) and Vesturöræfi, part of the calving and summer grazing areas of reindeer in areas 1 and 2 respectively (Figure 8). Out of 18 ecotypes, the most common ecotype on Vesturöræfi and Brúardalir is melavistir (Gras-, Eyði-, Víði-, glacial moraines with very sparse or no vegetation (H5.2) and sparsely- or unvegetated habitats on mineral substrates (H5.3). This ecotype has a plant cover of 10–50%, and the dominant higher plants are *Salix herbacea*, *Festuca rubra* and *Silene acaulis*. Another very common ecotype in this area is giljamóavist and lyngmóavist (F2.1); subarctic and alpine dwarf willow scrub. It has a plant cover ~95%; dominant higher plants are *Empetrum nigrum*, *Bistorta vivipara*, *Equisetum variegatum* and *Festuca rubra* and other common species are *Carex bigelowii*, *Dryas octopetala*, and *Silene acaulis*. Giljamóavist is one of the seven ecotypes in moors and heathland and cover 17.3% of the study area, while melavistir cover 47.5% of Brúardalir and Vesturöræfi. The third and fourth largest ecotypes were starmóavist; moss and lichen dominated mountain summits, ridges and exposed slopes (E4.2) and héllumóavist; vegetated snowpatch (E4.1) (Table 6). (Magnússon et al., 2009).

Table 6. Classification and description of the four most common ecotypes in Brúardalir and Vesturöræfi in INH mapping 1999–2002 (Magnússon et al., 2009).

<table>
<thead>
<tr>
<th>Ecotype</th>
<th>EUNIS-classification:</th>
<th>Plant cover</th>
<th>Land cover</th>
<th>Dominant plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melavistir</td>
<td>H5.2 Glacial moraines with very sparse or no vegetation.</td>
<td>10–50%</td>
<td>47.51%</td>
<td><em>Salix herbacea</em>, <em>Festuca rubra</em>, <em>Silene acaulis</em>, <em>Luzula spicata</em>, <em>Cardaminopsis petrea</em>, <em>Thymus arcticus</em></td>
</tr>
<tr>
<td></td>
<td>H5.3 Sparsely- or unvegetated habitats on mineral substrates.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gilja- &amp; lyngmóavist</td>
<td>F2.1 Subarctic and alpine dwarf willow scrub</td>
<td>~75–95%</td>
<td>17.3%</td>
<td><em>Salix herbacea</em>, <em>S. arctica</em>, <em>Empetrum nigrum</em>, <em>Bistorta vivipara</em>, <em>Festuca rubra</em>, <em>Carex bigelowii</em>, <em>Dryas octopetala</em>, and <em>Silene acaulis</em></td>
</tr>
<tr>
<td>Starmóavist</td>
<td>E4.2 Moss and lichen dominated mountain summits, ridges and exposed slopes.</td>
<td>~93%</td>
<td>9.16%</td>
<td><em>Carex bigelowii</em>, <em>Salix herbacea</em>, <em>Empetrum nigrum</em>, <em>Bistorta vivipara</em>, <em>S. arctica</em>, <em>Festuca rubra</em></td>
</tr>
<tr>
<td>Héllumosavist</td>
<td>E4.1 Vegetated snowpatch.</td>
<td>~60%</td>
<td>8.41%</td>
<td><em>Anthelia juratzkana</em>, <em>Salix herbacea</em>, <em>S. arctica</em>, <em>Bistorta vivipara</em> <em>Festuca rubra</em>, <em>Silene acaulis</em></td>
</tr>
</tbody>
</table>
As a part of the assessment of the environmental effects of hydroelectric projects in the East Highlands INH mapped vegetation of area covering 3500 km² in 2013. The area mapped constitutes 42% of the home range of Snæfellsherd (Figure 14) (Pórisson & Ágústsdóttir, 2014).

**Figure 14. Vegetation mapping of the Icelandic Institute of Natural History, covering the main summer grazing areas and 42% of the home range of the Snæfellsherd. Area 1 is delineated with a red line and area 2 with a blue line (Pórisson & Ágústsdóttir, 2014).**
5.2 Climate

The climate in Iceland is maritime with cool summers and mild winters (Einarsson, 1984). According to Köppens classification (Einarsson, 1984) there are two climatic types in Iceland; in south and west a temperate rainy climate with cool and short summers and snow climate in the north, east and the highland. The prevailing wind direction on the East Iceland highland plateau is SW-NE. South westerly blowing wet low-pressure areas are common in Iceland. They reach the southwest coast and move over the highlands to the east, loosing most of the rain on their way. Wet south easterly blowing wind loose most of its water in the mountains south and southeast of the highland plateau, as can be seen in the Vatnajökull glacier. The areas north of the northeast corner of the glacier are amongst the driest areas in Iceland with almost a continental climate. Annual precipitation in these areas is low (400–800 mm) when compared to up to 5000 mm on the glacier (Figure 15). Cold north and easterly blowing winds in winter bring snow to the area. Snow cover is more or less stable, meaning that the formation of ice crust in pastures is rare (Einarsson, 1984).

When there is a thick snow cover on the highland plateau, slopes of the plateau and lowlands area can be with little snow. In heavy snow winters there are always less snow on inland areas as in Fljótsdalur valley. Hard winters in the past when farmers, close to the seashore could not graze their sheep in late winter, they often drove their livestock to Fljótsdalur valley (Erlingsson, 1975).
Precipitation in the study area increases towards the north-northeast and to the east from Mt. Snæfell (Figure 15) (Icelandic Meteorological Office, 2007). Mean annual temperature is close to 0°C in both area 1 and 2.

Weather data are available from Kárahnjúkar (639 m a.s.l.) (Figure 16) in the main calving and summer grazing area of reindeer in area 1 and 2. Annual mean precipitation in Iceland
in 2004–2008 was 1132 mm and the average annual temperature 2002–2008 was 4.6°C (Climate Change Knowledge Portal, 2018). In contrast, in Kárahnjúkar mean annual precipitation and temperature were 423 mm and 0.3 °C, respectively (Arnalds et al., 2010; Figure 16).

The North Atlantic Oscillation (NAO) index has been used to analyse the weather in North-western Europe (Hanna et al. 2004).

"The NAO is a climatic phenomenon in the North Atlantic Ocean of fluctuations in the difference in sea level pressure between the Icelandic Low and the Azores High. A high index year (positive NAO) leads to relatively strong westerly winds across the midlatitudes of the Atlantic to Europe resulting in cool, wet summers and mild, wet winters in Europe and to cold and dry winters in Greenland. In contrast, when NAO is negative, European winters are cold, while Greenland will have milder winter temperatures. NAO affects weather, including ambient temperature and precipitation, throughout the North Atlantic region." (Hersteinsson et al., 2009, page 1424).

The NAO has been used to analyse how the weather affects populations of animal species like the arctic fox (Hersteinsson et al., 2009) and reindeer in Norway (Weladji & Holand, 2003) and Iceland (Þórisson & Ágústdóttir, 2014). I will test if there is a relationship between the number of calves per 100 females/yearlings in July and the NAO index in winter (December, January, February and March).

When NAO is positive high we have strong westerly blowing winds meaning sunny and dry weather in East Iceland. Negative NAO index means more northly blowing cold winds and the pack ice often closer to the northern coast of Iceland (Jónsson, 2010). NAO is a complicated phenomenon and not fully understood how it affects the weather in East Iceland. Better understanding of the NAO and its effect on reindeer will helps us to evaluate the importance of the weather to the demography of the reindeer.
5.3 Reindeer data


Only local high fixed-winged aeroplanes have been used to count reindeer in Iceland since 1978 (Table 7). The person in charge of the survey sits by the side of the pilot and photographs the herds when spotted, from an open window. There is always one assistant in the back seat, sometimes two when flight conditions allow. All the pilots know the land very well and are experienced both in the search of reindeer for monitoring purposes and hunting, but also in searching sheep for farmers.

Table 7. Aeroplanes used at midsummer reindeer counts 1979–2015 (unpubl. reports).

<table>
<thead>
<tr>
<th>Registered number</th>
<th>Type of aeroplane</th>
<th>Persons with pilot</th>
<th>Number of flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF-KLÓ</td>
<td>Cessna C-172N Skyhawk</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>TF-OÍA</td>
<td>Cessna A185F Skywagon</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>TF-API</td>
<td>Cessna Aircraft C-152</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>TF-KHB</td>
<td>Piper PA-22-150</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>TF-RPM</td>
<td>Cessna 150H</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Pilots also assist with the search of the herds. The summer counts in the first half of July are based on photographs of reindeer herds taken from an aeroplane. First black and white pictures were used and then slides, but a revolutionary improvement came with digital cameras and the use of computers from 2003. The flight is tracked with a handheld GPS and since 2014 all photographs have an automatic GPS-position. Present day photographic equipment is Canon EOS D5 Mark II and D7 Mark II (with GPS) with Canon 28–70mm/f 2.8 and 70–200 mm/f 2.8 lenses.

Depending on when the aerial count is conducted, different information can be obtained. An overview of different monitoring counts is shown in Table 8. Different herds are visited but Snæfellsherð in area 1 and area 2 is always included in the counts.
The goal of annual summer counts in July is to find all reindeer in a given area. It is crucial that the pilot and the one in charge know the area very well and that knowledge with the help of a GPS equipment ought to secure a good result, finding all the individuals and prevent counting the same herd twice or a herd formatted by two or more previously counted herds. In other counts the main goal is to find minimum number to get significant results of pregnancy rate, age- and sex composition etc.

<table>
<thead>
<tr>
<th>What</th>
<th>When</th>
<th>How often</th>
<th>Where</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual summer counts</td>
<td>early July</td>
<td>annually</td>
<td>mainly area 1, 2, 6 &amp; 7</td>
</tr>
<tr>
<td>Counts at rutting time</td>
<td>October</td>
<td>annually</td>
<td>1,2 plus rotation between areas</td>
</tr>
<tr>
<td>Winter counts</td>
<td>late March</td>
<td>every 3–5 year</td>
<td>areas 1–9</td>
</tr>
<tr>
<td>Counts to assess pregnancy rates</td>
<td>late April</td>
<td>most years</td>
<td>area 1, 2, 6 &amp; 7</td>
</tr>
<tr>
<td>Calving</td>
<td>May</td>
<td>irregular</td>
<td>mainly area 1 &amp; 2</td>
</tr>
<tr>
<td>GPS-females</td>
<td>2009–2011</td>
<td>monthly</td>
<td>area 1, 2, 6 &amp; 7</td>
</tr>
</tbody>
</table>

### 5.3.1 Winter counts

Before the late seventies, when reindeer expanded over East Iceland, the annual aerial population counts in the summer grazing area in the Snæfellsöræfi highlands gave almost total reindeer population numbers. In 1991 counts were conducted for the first time in March/April by the Wildlife Management Unit (Pórisson & Hersteinsson, 1992) and from that time, irregularly until 2014. Since the year 2000 winter counts have been conducted by EINRC organized in late winter with the help of local people covering most of the distribution area on land (Pórisson & Pórarinsdóttir, 2014). An aeroplane is used to cover part of the areas, but flights can be difficult in the East Fjords. Number of calves in late winter provides information on annual recruitment.
5.3.2 Counts to assess pregnancy rates

The reindeer is the only species amongst Cervidae were the females have antlers. The antlers are shed every year, first the adult males in November-December, and young males and barren females (non-breeding) in late winter. Pregnant females usually keep the antlers until around seven days after calving securing them a high dominance status in the herd (Lent, 1965; Espmark, 1971; Bergerud, 1976).

Most of the barren females shed their antlers in early April but pregnant females some days after calving in May (Reimers et al., 2013a). Aerial counts in late April thus provide information on pregnancy rate. These counts are conducted mainly in area 1, 2 and area 6 (Table 5).

5.3.3 Calving

When Snæfellsherd represented the whole reindeer population, the main calving area seems to have been Vesturöræfi (in area 2) and Kringilsárrani (area 1) (Þórisson, 1983). Then, reindeer must have crossed the glacial river Jökulsá á Dal close to the Vatnajökull glacier, both in spring and autumn, because they stayed on Fljótsdalsheiði during winter. The first reindeer to be seen in Jökuldalsheiði after 1940 were two males in 1948. Only males were spotted until around 1956 when the number of reindeer of both sexes increased indicating that females migrated in late summer to the north instead of to the northeast crossing the glacial river. From that time Kringilsárrani has been the main calving area of reindeer in area 1 with a few exceptions like when heavy snow prevented access to the area as in the spring of 1979 when most of the females calved at the southern part of Jökuldalsheiði (Þórisson, 1983). Some crossing of river Jökulsá á Dal is known to occur in winter. A group of pregnant females were spotted crossing the glacial river on ice into Kringilsárrani in the middle of May 1981 (Þórisson, 1983). Calving studies in 2005–2013 show no indication of females crossing the glacial river or the water reservoir (Háslón) from Vesturöræfi into Kringilsárrani in spring. The glacial river Jökulsá á Dal was dammed in 2006, forming a water reservoir that drowned part of the calving and summer grazing areas in area 1 and 2 (Þórisson & Ágústsdóttir, 2014; Þórarinsdóttir & Ágústsdóttir, 2015).
In 2009 and annually in 2011–2015 the females of Snæfellsherd were surveyed from air in late May to help mapping calving areas of Snæfellsherd (Þórarinsdóttir & Ágústsdóttir, 2015; Þórisson & Þórarinsdóttir, 2016).

In 1979–1981 and 1990–1992 the calving on Snæfellsöræfi was monitored by two people staying there for about two weeks in May without a vehicle (Dórisson, 1983; Dórisson & Karlsdóttir, 2001). In 2005 the National Power Company of Iceland (Landsvirkjun) entrusted the EINRC to study the calving in connection with the hydroelectric project Kárahnjúkavirkjun (Þórarinsdóttir & Ágústsdóttir, 2015).


5.3.4 Annual summer counts and recruitment

Different authorities have been in charge of conducting annual summer counts of reindeer: The Ministry of Education and Culture 1940–1990, the Wildlife Management Unit 1991–1999 and EINRC from 2000.

Until 1978 the summer counts only identified adults and calves. After that four sex and age groups were identified: females and yearlings (it is not possible to distinguish between them), calves (2 months old), young males (1–2 years old) and adult males (≥3 years old). The counts give the recruitment as number of calves per females and yearlings.

The first years after 1940, when all the individuals belonged to the Snæfellsherd, total population counts were conducted. Along with the growth of the population, dispersal over East Iceland, with new herds being established, only part of the population was counted. At all times Snæfellsherd was counted.

In 1980 a total population count was arranged in July both with the use of an aeroplane and from the ground with the help of local expertise (Dórisson, 1983; Dórisson & Ágústsdóttir, 2014).
5.3.5 Counts at rutting time

To assess the age- and sex composition of the reindeer herds, counts are conducted in late September-October at mating time (rut). Counts at rutting time have been conducted most years since 1979, and yearly since 1990. The rutting time is believed to be the only period of the year when all sex and age classes are distributed evenly (Reimers, 1983a; Skogland, 1989; Strand et al., 2011) and it is easy to distinguish males and females mainly from the size of the antlers and their postures. One of the aims of the counts at rutting time is to estimate the proportion of males in each of the nine hunting areas to secure appropriate hunting quota on both sexes. Available counts from the ground are also used.

5.3.6 Mortality

The Wildlife Management Unit collected information on reindeer found dead from 1991 to 1999, and EINRC since 2000. From 1991 to 2013 there are 252 records of dead reindeer in Snæfellsherð; 113 belonged to area 1 and 139 to area 2. Age class and sex of the carcasses were recorded when possible, as well as dates of death and potential causes of death after carcass analysis.

5.4 Data from hunted reindeer

The hunting period starts at 1st of August and ends at 20th of September for females but starts at 15th of July for males and ends at 15th of September. In some years restricted hunting is allowed in late November.

5.4.1 Collection of reindeer for scientific purposes

In 1979–1981 INH conducted research of Snæfellsherð as a part of Environmental Impact Assessment for the power energy authorities. Part of this included hunting of 80 reindeer in July, September, February and May in 1980–1981, both in area 1 and 2. The main purpose was to get information on physical condition and nutrition (Appendix 10.4). At the same
time information on carcass weight was collected from hunters (Þórisson, 1983; Egilsson, 1983; Egilsson & Þórisson, 1983; Sigurðarson, 1993).

In 1990 the Wildlife Management Unit got a quota of 100 females in Snæfellsherdl for scientific measurements and to finance reindeer monitoring and research.

In 2003 the Environment Agency of Iceland conducted a collection of 23 reindeer in hunting area 9 to fulfil the hunting quota in that area. The opportunity was used to collect some information on physical condition.

Hunting reports from the years 1992–2015 were analysed to find out the proportion of barren females in different age classes and to see if there was a difference between area 1 and area 2.

5.4.2 Age determination

Hunting guides report the age of a shot reindeer based on eruption and wear of teeth. The age categories are four, i.e. yearling, 2-year-old (based on teeth irruption), 3–5-year-old, and ≥6-year-old (based on tooth wear of premolars and molars).

In the years 1980-1981 and 2001–2003 mandibles were collected, and incisors used for accurate age determination from annual layers in dental cementum (Cowan & Low, 1963; Reimers & Nordby, 1968).

In aerial summer counts the age categories are calves, females and yearlings and young (2–3 years) or adult males (≥ 3 years old). At rut the age categories are females (≥ 1 years old), calves (4–5-month-old), one years old males, two years old males and ≥ 3 years old males. The category from the rutting time can be used throughout the winter. The identification of different age amongst males is based mostly on body and antler size.
5.4.3 Collection of mandibles

Mandible length can be used as an indicator of condition of pastures (Reimers, 1969, 1972). Mandibles have been collected from hunted animals occasionally, but especially in 1979–1981 and 2001–2005. The purpose was to get incisors for determination of age but also to measure them in connection with monitoring of physical condition. The measurements procedure of the mandibles followed Langvatn (1977).

5.4.4 Carcass weight and backfat thickness

Since the Wildlife Management Unit became in charge of the monitoring in 1990 hunting guides were encouraged to report the carcass weight and backfat thickness of shot reindeer. The measurements procedure followed Langvatn (1977). Before that time hunting reports seldom indicated the carcass weight, only number and sex and sometimes roughly estimated age.

5.5 Sheep in area 1 and 2

The reindeer pastures in the study area are also used by sheep in the summer time. As sheep could be competitors for grazing resources, I analyse their number and physical condition (carcass weight) in area 1 and area 2. The results could also give an indication of status of the summer grazing pastures in area 1 and area 2.

All information of sheep numbers in East Iceland is from the Icelandic Agricultural Advisory Centre (RML) homepage. The average number of sheep in summer 2013–2015 in area 1 was 47616 and 49333 in area 2 (Table 9). Roughly 20% of the sheep stays in the lowlands the whole summer.
5.5.1 Slaughter weights of lambs

Information on autumn slaughter weights of lambs from area 1 and area 2 were compared with carcass weight of the reindeer in both areas. Eight farmers, four in area 1 and four in area 2, gave access to their data on carcass weight of theirs lambs in the years 2000–2015. Only male lamb twins born in May of mothers older than one year and slaughtered in September were used for comparisons of the carcass weight. The lambs graze for 3–4 months in summer. The information was provided by The Icelandic Agricultural Advisory Centre (Ráðgjafarmiðstöð landbúnaðarins (RML)) from a central database.
5.6 GPS collars

Telemetry has been used since the 1960s to estimate home range sizes, habitat use and movements of animals, and to evaluate anthropogenic impacts (Benson, 2010). In the 1990s the military Global Positioning System (GPS) became available for civilian use. Collars were fitted with GPS receivers that could store or send the positions (Kenward, 2001). The main advantage of GPS tracking is that it allows obtaining data on animal locations in all weather with a potential accuracy of within five meters (Moen et al., 1996). This technique has been widely used in Scandinavia to monitor reindeer populations, the last decade using GSM network to receive telemetry data (Strand et al., 2005).

Twelve collars (GPS-Tellus Basic 1D from Televilt in Sweden (Televilt, 2018)) were put on reindeer females in 2009 and 2010 (Þórisson & Ágústsdóttir, 2014). Females were captured randomly (Skarin et al., 2008) using a tranquilizer gun (Krieger & Arnemo, 2007) in January to March in 2009 and 2010 under the supervision of veterinarian Hjörtur Magnason. The Tellus Basic 1D collar weights 600g and the total body weight of adult female in Snæfellsherd is close to 75 kg.

In this study the results from three GPS collars on females in area 1 were compared with five collars on females in area 2 (Table 8). The purpose was to cover the activity of the females every hour. The collars were programmed to record locations every 3 hours, switching every eight days with three different time plans, so that overall for each female 24 hours were covered with an interval of one hour (Table 10) (Schmalensee et al., 2008). The collars were programmed to send SMS messages locating each animal every three hours to Televilt in Sweden. Thus, if the animals were within GSM coverage range eight positions were received daily per individual. Without GSM coverage the positions were stored in the collar and sent later. The positions were also stored on the Televilt server from where they could be downloaded.
Table 10. Three different programs of the GPS-collars. Collars recorded locations every three hours, and each collar was programmed to switch between time plans for recording every eight days, so that for each individual information on every hour over a 24-hour cycle would be recorded.

<table>
<thead>
<tr>
<th>Time plan</th>
<th>Time</th>
<th>Time</th>
<th>Time</th>
<th>Time</th>
<th>Time</th>
<th>Time</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0:00</td>
<td>3:00</td>
<td>6:00</td>
<td>9:00</td>
<td>12:00</td>
<td>15:00</td>
<td>18:00</td>
</tr>
<tr>
<td>2</td>
<td>1:00</td>
<td>4:00</td>
<td>7:00</td>
<td>10:00</td>
<td>13:00</td>
<td>16:00</td>
<td>19:00</td>
</tr>
<tr>
<td>3</td>
<td>2:00</td>
<td>5:00</td>
<td>8:00</td>
<td>11:00</td>
<td>14:00</td>
<td>17:00</td>
<td>20:00</td>
</tr>
</tbody>
</table>

The GPS collars located the reindeer females every 3 hours and lasted for 138–480 days from 15th of February 2009 to 2nd of June 2011 (838 days; Table 8, Figure 17). GPS collars collected data for 2674 positions (range 1101–3641; Table 11). When the GPS collars stopped working they were retrieved by shooting the cow. The maximum number of collars transmitting at the same time was seven and this occurred only for 12 days (Figure 17).

![Image](image.png)

Figure 17. The durability of GPS collars (number of days) on different females (see Table 11) from 15th of February 2009 to 2nd of June 2011, blue in area 1 and red in area 2.

Sample size (number of positions) is generally not a problem to estimate home range sizes or habitat use using GPS telemetry, especially if one has >95% successful fixes. Girard et al. (2002) used Maximum Convex Polygon (MCP), fixed-kernel estimators and clusters with data from a moose project to evaluate the influence of sample size on home range estimators. Their results indicated that 100 to 300 locations per animal annually and 30 to 100 seasonally were needed to reach an asymptote (Girard et al., 2002). Our sampling size (number of positions) was thus high enough to estimate home range sizes adequately. Ideally, the number of collars should have been larger to estimate habitat use, as recommended in Hersteinsson & Þórisson (2000). For assessment of habitat selection, we: "should prioritize number of individuals studied rather than number of locations per individual" (Girard et al., 2006:1255).
In addition to the actual locations of reindeer females, GPS-collared data allowed calculating movement of females, as the distance travelled between two consecutive positions in meters in 3 hours. The collared females showed no disadvantages in comparison to the non-collared.

As well, because reindeer live in herds, the positions of the eight females can provide information about all the animals in their groups. To estimate what proportion of the Snæfellsherd is represented by these eight GPS-collared reindeer females, the females and their herds were located at least one a month. Each collared cow was located from air or ground, and a Canon EOS 7D digital camera with 70–200 mm/f 2.8 zoom lens was used for photographing the herds to find the collared females and to count the number of individuals in her group and estimate the age and sex composition of the herd.

Table 11. The usage of GPS-collars on females in area 1 and 2 and their durability.

<table>
<thead>
<tr>
<th>Cow name</th>
<th>GPS-collars in use</th>
<th>Days</th>
<th>GPS-positions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ána</td>
<td>10th of Jan. 2010 – 26th of April 2011</td>
<td>462</td>
<td>3717</td>
</tr>
<tr>
<td>Ranga</td>
<td>16th of March 2010 – 2nd June 2011</td>
<td>445</td>
<td>3440</td>
</tr>
<tr>
<td></td>
<td>Area 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gríma</td>
<td>15th of Feb. 2009 – 9th of June 2010</td>
<td>480</td>
<td>3641</td>
</tr>
<tr>
<td>Heiða</td>
<td>18th of March 2009 – 1st of April 2010</td>
<td>380</td>
<td>2599</td>
</tr>
<tr>
<td>Ása</td>
<td>20th of March 2009 – 27th of Aug. 2009</td>
<td>161</td>
<td>1281</td>
</tr>
<tr>
<td>Hnefla</td>
<td>20th of March 2009 – 10th of April 2010</td>
<td>376</td>
<td>2788</td>
</tr>
<tr>
<td>Stína</td>
<td>21st of March 2010 – 5th of Aug. 2010</td>
<td>138</td>
<td>1101</td>
</tr>
</tbody>
</table>

The durability of the GPS-collars on each reindeer cow is shown in Table 11. In the analysis of the positions the year was divided into seven periods each believed to reflect delimited crucial moment in the life of the reindeer (Figure 18).

Figure 18. Division of the year in seven periods. Day-of-year is shown in the x-axis, and the numbers of days are indicated for each period. Winter is divided in early and late winter.
5.6.1 Proportion of Snæfellsherd represented by GPS-collared reindeer

Each collared female was located from air or ground at least once a month if possible and the number of reindeer older than six months in its group was recorded in 2009–2011 (Table 12). The purpose of this was to see how big a proportion of the Snæfellsherd the GPS-collared females represented at different times of year and in different places.

On average 6.3 (2–15) females were located each month and the collared female and her herd was located and counted on the average 9.5 times (6–14) over the year (Table 12). The number of reindeer older than six months of age around each collared female varied seasonally. On average, herds of the GPS-collared females were composed by 82 individuals (18–157) each month. The GPS-collared females represented on average 12% (range: 1–36%) of the herd at any given time, because of varied number of transmitting females and group size every month. Home range calculations based on locations of eight GPS-collared reindeer females from 15th of February 2009 to 2nd of June 2011 represented the expected distribution of the majority of Snæfellsherd.

Table 12. Number of locations of the herds that included the GPS collared females in each month from 15th of February 2009 to 2nd of June 2011.

<table>
<thead>
<tr>
<th>Area/GPS-cow</th>
<th>Jan</th>
<th>Febr</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Hlíðarenda</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>1 Ána</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>1 Ranga</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>2 Gríma</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>2 Ása</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>2 Heiða</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>2 Hnefla</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>2 Stína</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>15</td>
<td>6</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>76</td>
</tr>
</tbody>
</table>

The total number of reindeer six months and older in Snæfellsherd during this period was believed to be 2200 individuals. To find the proportion of the herd represented by the collared females, the total number of individuals over six months of age (2200) was multiplied with the total number of transmission days (838). That makes for 1,843,600 reindeer days. The average group size for every month was multiplied by the number of...
transmission days for each GPS-collared female making 187,922 reindeer days. The group size was unexpectedly high in December with one herd of 226 in area 1.

As the number of transmitting females and group size differed between months, the proportion of Snæfellsherd represented by GPS collared reindeer females varied from 1% to 36% (Figure 19). The conclusion is that these eight GPS collared females represented 12% of the Snæfellsherd over these 838 days on average (Strand et al., 2005).

![Figure 19. Proportion of Snæfellsherd (black area) represented by GPS collared reindeer females over the study period (838 days). The proportion varies over time, as the number of GPS-collared females and reindeer group size differed between months.](image)

5.6.2 Home range estimation

The first definition of home range was: “that area traversed by the individual in its normal activities of food gathering, mating and caring for young” (Burt, 1943:351 in Kernohan et al., 2001). In Kernohan et al., 2001 (page 126) home range is defined as “the extent of area with a defined probability of occurrence of an animal during a specific time period.” Seasonal movements are used to define the home and core range of specific time periods (Figure 18).

It is important to know the home range size which indicates how much space the reindeer needs at different times and if there are areas that are critical for the survival of the herd.
Kernel estimators of home range size can describe the internal anatomy of the home range by identifying areas of significance (i.e. more intensive use), such as core areas (Samuel et al., 1985 in Kernohan et al., 2001). In this study, Kristín Ágústsdóttir calculated home ranges of reindeer females using Kernel density estimators (Þórisson & Ágústsdóttir, 2014). The space use by the collared reindeer is presented as home range; covering 95% of the positions, and as core range, covering 50% of the positions.

5.6.3 Analysis of habitat use of GPS-collared reindeer

The CORINE habitat classification maps cover the whole home range of the Snæfellsherd (Figure 13). CORINE 2012 was used to look at the changes in habitats between 2006 and 2012. Further, the more detailed mapping of INH covered 42% of the principal home range of Snæfellsherd allowing a more detailed assessment of the habitats. To describe habitat use of reindeer, the combined home range of three females in area 1 and five in area 2 CORINE 2006 was used. The calculations were done by Kristín Ágústsdóttir (Þórisson & Ágústsdóttir, 2014).

5.6.4 Analysis of seasonal movements

The gps positioning were used to analyse seasonal movements by measuring the distance between positions. The calculations were done by Kristín Ágústsdóttir (Þórisson & Ágústsdóttir, 2014). Information from GPS-collared females in 2009–2011 was also used to find calving time and place. When calving approaches, the females slow down. The calving is believed to take place on the day with the shortest daily mean distance between positions.
5.7 Data analyses

Trends of population parameters, like mean carcass weight or pregnancy rates, over time were estimated as linear relationships between year and the parameter of interest. Trendlines were fitted to the data, and the significance of the trends was assessed using correlation tests. Pearson linear correlation coefficients (r), together with sample sizes (n) and p-values are reported. Correlation analyses were used to estimate the relationships between the abundance of reindeer and carcass weight, and between the NAO index and the number of calves per 100 females and yearlings. Again, Pearson linear correlation coefficients (r), together with sample sizes (n) and p-values are reported for these analyses. Analyses of Variance (ANOVA) were used to compare population parameters between the two reindeer populations of this study, reporting the value of the F-statistic, together with the degrees of freedom (df) and the associated p-value. Finally, Chi-square tests were used to assess if the causes of mortality differed from random chance in the two areas.
6 Results

6.1 The reindeer population in East Iceland 1978–2015

The reindeer population in East Iceland is currently divided into 9 herds in 9 hunting areas (Figure 4). Their estimated winter population size in 2015–2016, total area use, density and number in July 2016 are shown in Table 13 (Þórisson & Þórarinsdóttir, 2015). The estimated summer population in East Iceland in 2000 was 3000 animals and 6000 in 2008 (Figure 20).

Table 13. Herds of reindeer in East Iceland in winter 2015–2016, their numbers and density (Þórisson & Þórarinsdóttir, 2016; Arnalds, 2002).

<table>
<thead>
<tr>
<th>Hunting area</th>
<th>Herds name</th>
<th>Numbers in winter 2015–16</th>
<th>Land without deserts (km²)</th>
<th>Density (reindeer/km²)</th>
<th>Estimated number in July 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Norðurheiðaherd</td>
<td>1000</td>
<td>5761</td>
<td>0.2</td>
<td>1250</td>
</tr>
<tr>
<td>2</td>
<td>Fljótsdalsherds</td>
<td>800</td>
<td>2821</td>
<td>0.3</td>
<td>1000</td>
</tr>
<tr>
<td>182</td>
<td>Snæfellsherds</td>
<td>1800</td>
<td>8582</td>
<td>0.2</td>
<td>2250</td>
</tr>
<tr>
<td>3</td>
<td>Víknaherd</td>
<td>300</td>
<td>848</td>
<td>0.4</td>
<td>375</td>
</tr>
<tr>
<td>4</td>
<td>Fjarðaherd</td>
<td>240</td>
<td>475</td>
<td>0.5</td>
<td>300</td>
</tr>
<tr>
<td>5</td>
<td>Fjarðabygðaherd</td>
<td>250</td>
<td>508</td>
<td>0.5</td>
<td>313</td>
</tr>
<tr>
<td>6</td>
<td>Axarherd</td>
<td>610</td>
<td>957</td>
<td>0.6</td>
<td>763</td>
</tr>
<tr>
<td>7</td>
<td>Álftafjarðarherd</td>
<td>1150</td>
<td>862</td>
<td>1.3</td>
<td>1438</td>
</tr>
<tr>
<td>8</td>
<td>Lónsherds</td>
<td>400</td>
<td>705</td>
<td>0.6</td>
<td>500</td>
</tr>
<tr>
<td>9</td>
<td>Mýraherd</td>
<td>200</td>
<td>437</td>
<td>0.5</td>
<td>250</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>4950</strong></td>
<td><strong>13374</strong></td>
<td><strong>0.4</strong></td>
<td><strong>6188</strong></td>
</tr>
</tbody>
</table>

The total reindeer population in East Iceland doubled between 2000 and 2009 although the harvest management aimed at keeping it stable. At the same time, the population expanded its distribution range to the north. The Snæfellsherds now roam the highland plateau while the rest of the population is scattered in smaller herds in the fjord area (Þórisson & Þórarinsdóttir, 2016).
Between 1978–2012, when reindeer had spread over most of East Iceland (Dórisson, 1983), the proportion of Snæfellsherd in the estimated total reindeer population in East Iceland was 44% on average but fluctuated from 27% – 64% (Figure 21). These fluctuations are believed to be partly due to inaccurate counts but also because different number of reindeer in Snæfellsherd staying outside principal summer areas in beginning of July, rather than decreased recruitment between years (Dórisson & Ágústsdóttir, 2014). In 2013–2015 Snæfellsherd represented about 30% of the total reindeer population (Figure 21). The density of reindeer in area 1 and in area 2 was similar and very low (Table 13) compared with the goal of being under 1.0 animal per km² of vegetated land in winter.


Figure 21. Proportion of reindeer in areas 1 and 2 (Snæfellsherd) and 3 (the East Fjords) in the total reindeer population in the years 1978–2015.

48
6.2 Number and distribution of reindeer in Snæfellsher and 1978–2015

In 1978 reindeer in Iceland could be found in three areas: area 1, area 2 and East fjords (seven hunting areas) (Figure 4). The focus of this study will be on area 1 and 2, combined. This herd, termed Snæfellsher, roaming the wilderness close to the north east corner of Vatnajökull glacier in summer. Reindeer in area 1 stay in summer in Kringilsárrani area but migrate to Norðurheidi in autumn. The main summer range of area 2 is Vesturörfi area and then the reindeer move to the north or northeast in autumn (Figure 4, Figure 8).

Between 1978–2015, annual summer counts suggest an overall increase in reindeer populations (Figure 20). This increase is mainly driven by the reindeer population in the East Fjords; reindeer numbers increased slightly in area 1 and decreased in area 2 (Figure 20).


6.2.1 Snæfellsher 1979–1999

From 1979–1991, the summer population of reindeer in East Iceland was estimated to be around 4000 animals, with Snæfellsher representing nearly half of the total population. As an indication of the expansion of reindeer populations during this time, the maximum number of communities with a hunting quota was 32 in 1982 all over East Iceland. Then the reindeer were distributed from Jökulsárlón glacial lagoon in the south to Distiljörður in the north, east of Vatnajökull glacier and the glacial river Jökulsá á Fjöllum, the same area as the hunting areas cover today (Figure 4).
In the beginning of the 1990s the summer population decreased from 4000 to 3000 and remained stable until the end of the century. The population size is based on annual July counts of the Snæfellsherd (Figure 22) but numbers of reindeer in the East fjords are partly based on estimations.

Figure 22. Development of Snæfellsherd 1979–1999 based on summer counts, for area 1 and area 2 (Þórisson, 1979–1999).

6.2.2 Snæfellsherd 2000–2015

In the beginning of the 21st century the reindeer population doubled in size, from 3000 up to 6000 in summer (Figure 20). The overall size of the Snæfellsherd decreased, mainly driven by a drastic decrease in numbers in area 2, despite a slight increase at the same time in area 1 (Figure 23).

The development of Snæfellsherd 1965–2015 is shown in Figure 24, using a 5-year moving average to minimize the fluctuations. Five phases can easily be recognized:

- **Phase 1**: An increase of 20% over a decade.
- **Phase 2**: A decrease of 66% over a decade.
- **Phase 3**: The lowest number (~1000) in the beginning and the end, fluctuations.
- **Phase 4**: Increase in numbers from ~1000–~2800, 50% over a decade.
- **Phase 5**: Decreasing number of animals in Snæfellsherd; decreasing in area 2 but increasing in area 1.

![Figure 24. Five year moving average of reindeer numbers in Snæfellsherd based on summer counts in 1965–2015. Five phases can be distinguished (see text for details).](image-url)
6.2.3 Reindeer in area 1 from 1979 to 2015

In 1979 and 1981 the number of reindeer in Kringilsárrani area was close to 600, compared to 156 in 1978 (Figure 25). From 1982 to 1991 the average number in summer counts was 284 (range 185–474). From 1992–2005 the number of reindeer in Kringilsárrani area fluctuated between 67 and 234 animals with 166 on average. In 2006 there was some indication of increasing number of all age- and sex groups staying in Norðurheiðar over the summertime instead of using Kringilsárrani area as the main calving and summer grazing grounds. In aerial July counts in 2007, 316 males were found in Norðurheiðar but only one male arrived in Kringilsárrani that year, where 48–114 males had roamed in each summer since 1999 (Figure 25). After 2006 the number of reindeer in the former main summer pastures in Kringilsárrani area decreased considerably. However, there were two peaks, in 2009 (542) and 2012 (236), only for females/yearlings and calves. But on 18th of June 2010 a reindeer herd of 413 animals was spotted in Kringilsárrani area, with 261 females/yearlings and 152 calves (Emil Þór Sigurðsson pers. comm.). The three GPS-collared females all stayed in the area in the summer 2010 (Table 15). In conventional aerial counts on the 11th of July the same year only 81 females/yearlings and 62 calves were found (Figure 25), 270 fewer reindeer than on the 18th of June.

On the 21st of May 2015 six females with calves were seen in Kringilsárrani area. At the same time, 219 animals one year and older and 131 calves were found in Norðurheiðar. On 17th of July 2015 there were no reindeer seen in Kringilsárrani area in the annual summer count (Figure 25).

| Table 14. Crossing of GPS-collared females in spring and summer 2010 of two rivers delineating calving and summer grazing areas of reindeer in area 1. |
|--------------------|--------------------|--------------------|--------------------|
| GPS-collared females name | Crossing in spring - moving south | Crossing in summer - moving north |
|                      | Sauðá river | Kringilsá river | Kringilsá river | Sauðá river |
| Ána                  | 2nd of May   | 18th of June     | 5th of July       | 6th of July  |
| Hlíðarenda           | 16th of June | 18th of June     | 8th of July       | 8th of July  |
| Ranga                | 5th of May   | 6th of May       | 21st of August    | 22nd of August |

The tracks of the three GPS-collared females in area 1 in 2010 represented these changes very well (Figure 26). Ranga was the only GPS-collared female behaving "normally", i.e. arriving in early May into Kringilsárrani area, calving there around mid-May and staying there until late August (Table 14). On 22th of July 2010 two of the GPS-collared females were in Kringilsárrani area and the third one stayed in Norðurheiðar. This was clearly an indication of increasing number of females/calves staying outside the main calving/summer grazing area (Table 15). Reindeer also migrated farther to the north than expected, as seen with Hlíðarenda who migrated from Kringilsá River close to the Vatnajökull glacier on the 16th of August to the north, reaching the area around Hafralón Lake on the 22nd of August (Figure 26). This was the first indication of expanding distribution to the north.
Figure 26. Tracks of 3 GPS-collared reindeer females from 1st of May to 31st of August 2010. Ranga: yellow, Ána: red and Hlíðarenda: blue (Google Earth 2018).

While the number of reindeer decreased in Kringilsárrani area, the total number of reindeer in the herd of area 1 increased from 200 animals in 2005 to 1125 in 2015 (Figure 25).

Table 15. Result of the annual summer count on 11th of July 2010 in different parts of area 1.

<table>
<thead>
<tr>
<th>Place</th>
<th>Females/yearlings</th>
<th>Calves</th>
<th>Adult males</th>
<th>Young males</th>
<th>Sum</th>
<th>GPS-collared females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jökuldalsheiði</td>
<td>172</td>
<td>90</td>
<td>59</td>
<td>27</td>
<td>348</td>
<td>Ána</td>
</tr>
<tr>
<td>Brúaröræfi</td>
<td>68</td>
<td>44</td>
<td>3</td>
<td></td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>Sauðárrani</td>
<td>32</td>
<td>25</td>
<td></td>
<td>57</td>
<td></td>
<td>Hlíðarenda</td>
</tr>
<tr>
<td>Kringilsárrani</td>
<td>49</td>
<td>37</td>
<td>0</td>
<td>0</td>
<td>86</td>
<td>Ranga</td>
</tr>
<tr>
<td><strong>Area 1 total</strong></td>
<td><strong>321</strong></td>
<td><strong>196</strong></td>
<td><strong>62</strong></td>
<td><strong>27</strong></td>
<td><strong>606</strong></td>
<td></td>
</tr>
</tbody>
</table>
6.2.4 Reindeer in area 2 from 1978 to 2015

From 1978 to 1985 reindeer in area 2 represented on average 77% of Snæfellsherd in annual July counts. In 1980, only half of the number recorded in 1979 was found. In 1985, less than 1000 reindeer were found in area 2 (Figure 27). From 1987 to 1995 the number of animals in Snæfellsherd stayed rather low but fluctuated widely. During this time, reindeer in area 2 represented on average 82% of the Snæfellsherd.

From 1995 to 2007 reindeer in Snæfellsherd in summer counts more than tripled in numbers. Reindeer counted in area 2 being 85% and reindeer in area 1 being 15% of the Snæfellsherd at average. Until 2002 the land on the western side of Mt. Snæfell, between the mountain and the glacial river Jökulsá á Dal (Vesturöræfi) had been the principal summer grazing pastures of area 2. Between 1976–2000, approximately 82% (range: 45–100%) of all reindeer in area 2 were found there on average in summer, but 2002–2015 only 18% (range: 0–45%) were using this area (Figure 27) during summer.

From 2002 to 2010, approximately 85% of reindeer in area 2 was found north of Mt. Snæfell (Fljótsdalsheiði) in the July counts, but then they completely abandoned the area. From 2011–2015 ~85% (range 55–80%) of reindeer in area 2 was found east of Mt. Snæfell and in Austurheiðar (Figure 27) (Þórisson, 1983; Þórisson & Ágústsdóttir, 2014;
Þórisson & Þórarinsdóttir, 2016). In the years 1993–2001 the main summer grazing area in area 2 was Vesturöræfi. The mean carcass weight trendline for 3–5-year-old lactating reindeer females in the hunt rose by 0.26 kg/year (Figure 28). The trendline was significant \( r = 0.6843, n = 9, \alpha = 0.582 \) for \( p<0.05, r > \alpha \).

![Figure 28](Image)

Figure 28. Mean carcass weight of 3–5-year-old lactating reindeer females between 1993–2001 in area 2 locations (sample size in brackets).

Between 2002 and 2009, when reindeer in area 2 had shifted their summer range to Fljótsdalsheiði, the carcass weight trendline went down by 0.48 kg/year (Figure 29). The trendline was significant \( r = 0.9423, n = 8, \alpha = 0.621 \) for \( p<0.05, r > \alpha \).

In the year 2010 the herd left Fljótsdalsheiði, moving to Austurheiðar and partly Vesturöræfi. In 2010–2015 the carcass weight fluctuated (Figure 30) but the trendline was not significant \( r = 0.3162, n = 6 \alpha = 0.729 \) for \( p<0.05, r < \alpha \).
Figure 29. Mean carcass weight of 3–5-year-old lactating reindeer in 2002–2009 in area 2 locations (sample size in brackets).

\[ y = -0.4831x + 41.629 \]
\[ R^2 = 0.8881 \]

Figure 30. Mean carcass weight of 3–5-year-old lactating reindeer in 2010–2015 in area 2 (sample size in brackets).

\[ y = 0.0733x + 38.733 \]
\[ R^2 = 0.0257 \]
6.2.5 Winter counts

The results of winter counts (Þórisson & Þórarinsdóttir 2014b) show that the number of reindeer were often higher in area 2 than in area 1, as represented in the winter counts of 1991–1997 and 2002. But, in some years (1998, 1999, 2001, 2005 and 2014) more reindeer were found in area 1 than in area 2 (Figure 31) suggesting that part of the reindeer herd in area 2 have been staying in area 1 in late winter at the time of the wintercount. The glacial river Jökulsá á Dal which divides the areas flows partly through an impassable canyon, but in some places, it may be easy for the reindeer to cross during winter. Although they cross the river in some years they seem to go back to previous area before spring. In all counts, the number of reindeer in area 1 decreases from winter to summer but increases at the same time in area 2 as expected after calving.

6.2.6 What is known about migration between area 1 and 2

Since 2002, the number of reindeer in area 1 has been increasing, while the numbers in area 2 have decreased. However, emigration from area 2 seems to be very limited based on tagged individuals (Table 16). One of 54 calves tagged in area 2 in 1980–1992 was shot and two were spotted in area 1 (Þórisson & Karlsdóttir, 2001).

<table>
<thead>
<tr>
<th>Area</th>
<th>Ear tagged</th>
<th>Shot</th>
<th>Found dead</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1</td>
<td>1982</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Area 2</td>
<td>1980–’81/1991–’92</td>
<td>54</td>
<td>14 (25%)</td>
<td>5 (9%)</td>
</tr>
<tr>
<td>Area 2</td>
<td>2005–2013</td>
<td>14</td>
<td>5 (36%)</td>
<td>0</td>
</tr>
<tr>
<td>∑</td>
<td>1980–2013</td>
<td>70</td>
<td>19 (27%)</td>
<td>5 (7%)</td>
</tr>
</tbody>
</table>

In 1994 two young males and two females got radio collars around their neck in area 2. They were positioned at least every month for two years and never moved over to area 1 except one of the females. In 1997 she was spotted in Jökuldalur in area 1. She was also spotted in 1998, 1999 and 2000 but always in area 2 (Þórisson & Karlsdóttir, 2001).

In 2009–2011 none of the three GPS-collared females in area 1 or the five in area 2 crossed the glacial river which is the borderline between the two areas.

A cow, ear tagged as a calf in area 2 was spotted in area 1 on the 12th of September 2010 in Jökuldalsheiði and a cow and a calf in area 1 (Laugarvalladalur) on 22nd of May 2014. Most likely this was the same cow tagged in area 2, Vesturörefi at the 12th of May 2005. A calf born and tagged on Vesturörefi in 2006 was recorded in Kringilsárrani (area 1) in August the same year. This is the only known instance of crossing in that area outside winter. Crossing the Hálslón water reservoir in May on ice should not be a problem for females with calves.

Some crossing of the glacial river Jökulsá á Dal where it is possible (no canyon) is known to happen in winter. It is believed that most of them return to their home area before calving (Figure 31).
6.3 Hunting in Snæfellsherid 1978–2015

The maximum number of communities in East Iceland obtaining a hunting quota was 32 in 1982, when the summer reindeer population was estimated to be 4000 animals. Then, the distribution of the reindeer population was from the Jökulsárlón glacial lagoon in the south to Þistilfjörður in the north, east of Vatnajökull glacier and the glacial river Jökulsá á Fjöllum. This is the same area as the hunting areas cover today (Figure 4).

The population doubled in 2000 to 2008 although 20–25% of the estimated total summer population was hunted annually (Figure 32).


From 2000–2015, on average 99.3% (range: 95.4%–100%) of the hunting quota in Snæfellsherid (area 1 and 2) was shot (Figure 33). Up to 2009 hunters were encouraged to shoot the calf if they had shot the mother. This explains why the number of shot reindeer is sometimes higher than the hunting quota (Figure 32). Shooting of calves stopped in 2010. Analysis of carcass weight of calves indicated that hunters choose the biggest calf instead of the motherless one put an end to calf hunting. Although the distribution area of Snæfellsherid belonged to two hunting areas, hunters could choose were they shot the
reindeer until 2013. Most of the female hunting in Snæfellsherð in 2000–2015 was done in area 2, especially after an asphalt road was built in 2002. In 2013 hunting of reindeer females was restricted to each area. This was done after a heavy increase of reindeer in area 1 (Figure 33). Following the increase in number in area 2 the reindeer shifted their summer ranges to the usual winter and autumn ranges on Fljótsdalsheiði after 2000 (Figure 8). To avoid excessive grazing pressure on the vegetation in this area, the hunting quota was increased (Figure 33). The herd decreased in the area but at the same time, a part of it shifted winter ranges to the east (Austurheiðar) (Figure 8) and even some to area 1 (see section 7.3).

![Figure 33. Hunting quota and hunted reindeer in area 1(a, b) and 2 (c, d), for females and calves (a, c) and males (b, d) in 2000–2015.](image-url)
In the years 2000–2005 the hunting pressure was low in area 1. In 2006–2015 an increased number of adult males were shot in area 1. Up to 2012 very few females were shot but as the herd increased heavily in the next years the hunting quota rose accordingly (Figure 33).

Hunting pressure is the percentage of hunting quota of estimated winter population. It reflects the status of the herd and the goal of the utilization i.e. are we aiming at decreasing, increasing or keeping the number stable. It is shown for both herds in Figure 34 and Figure 35.

![Figure 34. Herd size, hunting and hunting pressure in area 1 in years 2002–2015.](image)

![Figure 35. Herd size, hunting and hunting pressure in area 2 in years 2002–2005.](image)
In area 2, hunting pressure remained relatively constant in 2000–2015, except in 2007–2012 when hunting pressure increased with the goal of reducing the number of reindeer (Figure 35). In 2013–2015, hunting pressure was lowered drastically after reindeer numbers decreased heavily, partly because of some animals emigrating out of the area (Table 17). From 2000–2015 the proportion of males in the hunt were 70% (range: 40% – 94%) in area 1 but 40% (range: 21% – 54%) in area 2.

Table 17. Comparison of hunting pressure (number of reindeer shot as a proportion of herd size) in four periods in area 1 and 2; average hunting pressure for the whole period 2000–2015 is included for comparison between the two areas.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13%</td>
<td>20%</td>
<td>20%</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>13%</td>
<td>23%</td>
<td>5%</td>
<td>16%</td>
<td></td>
</tr>
</tbody>
</table>
6.4 The demography of Snæfellsherd

6.4.1 Pregnancy rates

Some females never grow antlers and within the same population, the frequency of antlerless females can change over time (Reimers, 1993). The proportion of females born without antlers in winter counts in late March was checked in Snæfellsherd annually in the years 1991–2003, 2010 and compared between area 1 and area 2. No significant differences were found between the areas or between years (Table 18). The overall proportion of antlerless females was 4.7%.

Table 18. Proportion of reindeer females born without antlers in area 1 and 2, for different time periods.

<table>
<thead>
<tr>
<th>Area</th>
<th>With antlers</th>
<th>Antlerless</th>
<th>%</th>
<th>chi-square</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991–2003</td>
<td>1</td>
<td>921</td>
<td>43</td>
<td>4.5</td>
<td>0.65</td>
</tr>
<tr>
<td>1991–2003</td>
<td>2</td>
<td>1880</td>
<td>102</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>1</td>
<td>368</td>
<td>11</td>
<td>3.1</td>
<td>2.11</td>
</tr>
<tr>
<td>2010</td>
<td>2</td>
<td>323</td>
<td>17</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>1991–2010</td>
<td>1</td>
<td>1289</td>
<td>54</td>
<td>4.0</td>
<td>2.31</td>
</tr>
<tr>
<td>1991–2010</td>
<td>2</td>
<td>2203</td>
<td>119</td>
<td>5.1</td>
<td></td>
</tr>
</tbody>
</table>

The mean number of antlerless females in late April 2001–2013 was 86% (Dórarinsdóttir & Ágústsdóttir, 2015). The trendline for that period is flat and non-significant (r = 0.0548, n = 13, α = 0.476). Excluding 4.7% females that were born antlerless, the mean pregnancy rate is estimated at 89% (Figure 36).

Figure 36. Pregnancy rate in 2001–2013 (mainly in area 2) based on antlerless females (excluded the one born antlerless) in late April.

R² = 0.0033
Chi-square test showed no significant difference ($P < 0.05$) of age groups between the areas. Of the shot females belonging to Snæfellsherð 1992–2015, 10% of yearlings were lactating, 49% of two years old and 83% of the rest (Figure 37).

### 6.4.2 Timing of calving

The timing of calving in area 2 seem to have been similar in the years 2005–2013 (Þórarinsdóttir & Ágútsdóttir, 2015; Þórarinsdóttir, 2016) as in 1979–1981 (Þórisson, 1983) and 1990–1991 (Þórisson, 2004) with mean calving time\(^7\) close to the 18\(^{th}\) of May. Females calved earlier in area 1 than in area 2 in 2011 and 2013 (Þórarinsdóttir, 2012, 2013). The timing of calving based on GPS collared females is analysed in section 6.5.2.

Strand et al. (2011) showed that from movements of females in May one could identify likely calving time and place. Date of calving for the 3 GPS-collared females in area 1 and 5 in area 2 indicated earlier calving in area 1, up to one week (Appendix 10.1).

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\(^7\) when 50% of the females have given birth (Reimers, 2002).
6.4.3 Recruitment

The proportion of born calves surviving the first two months of life is seen in annual July counts. It is very difficult to distinguish between two years and older females and yearlings, so they are grouped together. In Table 19 is a comparison of proportion of calves per females and yearlings in area 1 and area 2 in the years 1999 to 2012 (except 2001 and 2011). No significant difference was found between the means of the two areas for that period (ANOVA, F=2.44, df 23, p=0.1325). The average proportion of calves per females/yearlings in July for Snæfellsherd in 1999–2015 was 55.9% (46.7% – 60.6%).

Table 19. Proportion of calves per females/yearlings in July counts in area 1 and area 2 in the period 1999–2012 (except 2001 and 2011).

<table>
<thead>
<tr>
<th>Area</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Std Error</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1</td>
<td>61.5%</td>
<td>13.3</td>
<td>3.8</td>
<td>36.4–86.5</td>
</tr>
<tr>
<td>Area 2</td>
<td>55.3%</td>
<td>3.7</td>
<td>1.1</td>
<td>49.3–60.8</td>
</tr>
</tbody>
</table>

6.4.3.1 Recruitment and NAO

The North Atlantic Oscillation (NAO) index is the difference in sea level pressure between the Icelandic Low and the Azores High (Jónsson, 2018). There is a strong significant positive relationship between the number of calves per 100 females/yearlings in July and the NAO index in winter (December-March; r = 0.79, p=0.004; Figure 38). The connection between these two factors is not fully clear. Harsh weather in mid-winter, as indicated by negative NAO values, could induce abortion or have a negative effect on the quantity and quality of food available or the physical condition of the mother, thus affecting calving. Increased winter mortality of calves would increase the proportion of ≥2-year-old females in herds in July and at the same time, the number of calves per 100 females/yearlings.
In contrast with our result Weladji & Holand (2003) concluded that „Winters with a higher NAO index are thus severe for reindeer calves in this area [north Norway] and their effects are associated with nutritional stress experienced by the dams during pregnancy or immediately after calving“.

6.4.4 Mortality

The main cause of death of reindeer in Iceland is believed to be hunting. From 252 recorded carcasses during the period 1991–2013, car accidents seem to be the most common reason for premature death. The police inform EINCR of most of these instances, which occurred at a similar rate between area 1 and area 2. For one fourth of the carcass analyses the cause of death was unknown (Figure 39).
With car accidents and unknown causes of death not considered, incidents connected to rut were the most common cause of death (mainly males). Chi-square test showed no significant difference between causes of death between area 1 and 2. Females dying during the calving period are only ~1/3 of males dying at rut (Figure 39).

Ground-icing is rare in areas 1 and 2 but more likely to happen in the fjord area. Local farmer reported ground-icing in late winter in 2016 in one of the fjords. After 4–5 weeks reindeer started dying, especially calves and males (Dórisson & Dórarinsdóttir, 2017).

Comparison of time of death between area 1 and 2 at different time periods based on carcass analysis 1991–2013 showed no significant difference except in summer (Table 20). About 15% of reindeer died at rut and calving time (Figure 40). Most reindeer (35%) died in winter (December–March) with no difference between area 1 and 2 (Figure 40).

Table 20. Comparison of time of death in area 1 and 2 at different time periods based on carcass analysis 1991–2013.

<table>
<thead>
<tr>
<th>Time of death</th>
<th>Area 1 (n)</th>
<th>Area 2 (n)</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn 16.10.–31.11.</td>
<td>9</td>
<td>12</td>
<td>0.1267</td>
<td>0.722</td>
</tr>
<tr>
<td>Rutting time 21.9.–15.10.</td>
<td>18</td>
<td>23</td>
<td>0.1405</td>
<td>0.708</td>
</tr>
<tr>
<td>Hunting time 1.8.–20.9.</td>
<td>15</td>
<td>12</td>
<td>0.9956</td>
<td>0.318</td>
</tr>
<tr>
<td>Summer 8.6.–31.7.</td>
<td>9</td>
<td>2</td>
<td>5.7722</td>
<td>0.016</td>
</tr>
<tr>
<td>Calving 8.5.–7.6.</td>
<td>16</td>
<td>20</td>
<td>0.0761</td>
<td>0.783</td>
</tr>
<tr>
<td>Late winter/spring 15.3.–7.5.</td>
<td>4</td>
<td>12</td>
<td>3.2081</td>
<td>0.073</td>
</tr>
<tr>
<td>Winter 1.12.–14.3.</td>
<td>37</td>
<td>43</td>
<td>0.0045</td>
<td>0.947</td>
</tr>
</tbody>
</table>
Comparison of numbers of reindeer found dead in different age groups in the carcass data between area 1 and 2 showed no significant difference (Table 21).

**Table 21. Age groups of reindeer carcasses in hunting area 1 and 2 found in 1991–2013.**

<table>
<thead>
<tr>
<th>Age</th>
<th>Area 1 (n)</th>
<th>Area 2 (n)</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 month old</td>
<td>2</td>
<td>10</td>
<td>2.9237</td>
<td>0.087</td>
</tr>
<tr>
<td>1–12-month-old</td>
<td>2</td>
<td>10</td>
<td>2.9237</td>
<td>0.087</td>
</tr>
<tr>
<td>&gt; 1 years old females</td>
<td>9</td>
<td>11</td>
<td>0.3696</td>
<td>0.543</td>
</tr>
<tr>
<td>&gt; 1 years old males</td>
<td>23</td>
<td>25</td>
<td>3.2529</td>
<td>0.071</td>
</tr>
</tbody>
</table>

About half of carcasses with known age were adult males, 22% adult females and 26% younger than one year old (Table 21).

### 6.4.5 Age and sex composition at rut

Age and sex composition of Snæfellsherd at rut 1981–2014 is shown in Figure 41. This information is crucial for the proposal of hunting quota. In 1981 and 1991 there was no restriction on hunting regarding sexes. In 1992 one-year old males were protected and hunting quota set for the older males. Males low number in 1981 and 1991 was related to hunting. Thus, in the years 2000–2014, one-year old males constituted 10.4% on average in the herd. A highly skewed sex ratio was observed in Snæfellsherd in 1979–1981, especially in area 2 (Table 22). The reason was unlimited hunting on males out of total hunting quota (Þórisson, 1983). There was a significant difference between the proportion of males in area 1 and 2 (chi-square=12.536, p=0.0004, p< 0.05) (Table 22).

In 1990–1992 the sex ratio was similar as in 1981 (Figure 41). With the Wildlife Management Unit in charge, in the year 1990, different hunting quotas were set on each sex. The aim was to increase the proportion of males in the herd. The goal was to have 6 males for every 10 females. Study of sex ratio in 2000–2002 showed that changing sex ratio through hunting had worked (Figure 41). Although very few adult males seemed to be available for mating before 1990, no changes in fecundity, calving time, carcass weight and recruitment were observed with the change of sex ratio in the end of the century.

The decision of hunting quota aims at having at least 6 males per 10 females in the herd. As can be seen in (Table 22) this goal has been achieved.

Table 22. Comparison of sex composition in area 1 and 2 in three time periods. Values in bold indicate significant differences (p<0.05).

<table>
<thead>
<tr>
<th></th>
<th>Area 1</th>
<th>Area 2</th>
<th>chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979–1981</td>
<td>♂</td>
<td>27% (50)</td>
<td>♂</td>
<td>14% (41)</td>
</tr>
<tr>
<td></td>
<td>♀</td>
<td>73% (136)</td>
<td>♂</td>
<td>14% (41)</td>
</tr>
<tr>
<td>2004–2009</td>
<td>♂</td>
<td>41% (488)</td>
<td>♂</td>
<td>34% (1158)</td>
</tr>
<tr>
<td></td>
<td>♀</td>
<td>59% (692)</td>
<td>♂</td>
<td>66% (2275)</td>
</tr>
<tr>
<td>2010–2014</td>
<td>♂</td>
<td>38% (559)</td>
<td>♂</td>
<td>41% (777)</td>
</tr>
<tr>
<td></td>
<td>♀</td>
<td>62% (926)</td>
<td>♂</td>
<td>59% (1131)</td>
</tr>
</tbody>
</table>

Until recently, there were always significantly higher proportion of males in area 1 than area 2 during rutting time (Table 22). Some local people have witnessed adult males crossing the glacial river Jökulsá á Dal from area 1 to area 2 at rut.


Table 23. Sex composition (one year and older) in area 2 in four periods. Sample size in brackets. Values in bold indicate significant differences (p<0.05).

<table>
<thead>
<tr>
<th></th>
<th>♂ (n)</th>
<th>♂ (n)</th>
<th>♂ (n)</th>
<th>♂ (n)</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979–1981</td>
<td>14% (123)</td>
<td>16% (40)</td>
<td>16% (40)</td>
<td>84% (206)</td>
<td>0.88</td>
<td>0.347</td>
</tr>
<tr>
<td>1990–1992</td>
<td>84% (206)</td>
<td>16% (40)</td>
<td>14% (123)</td>
<td>84% (206)</td>
<td>38.0</td>
<td>&lt; 0.000</td>
</tr>
<tr>
<td>2000–2002</td>
<td>64% (712)</td>
<td>36% (395)</td>
<td>36% (395)</td>
<td>64% (712)</td>
<td>34.80</td>
<td>&lt; 0.000</td>
</tr>
<tr>
<td>2010–2014</td>
<td>14% (123)</td>
<td>16% (40)</td>
<td>16% (40)</td>
<td>84% (206)</td>
<td>0.88</td>
<td>0.347</td>
</tr>
</tbody>
</table>
6.4.6 Data from harvest
6.4.6.1 Mandible length

All mandibles measured were from exactly aged animals based on year rings in the cement layer of the roots of incisors (Reimers & Nordby, 1968). ANOVA single factor was used for comparison. Difference in mandible length between reindeer in area 1 and 2 was only significant amongst 3–5 years old males in 1979–1981. Small sample size and slightly younger males in area 1 compared with area 2 (at average 3.3 vs 4.0 years old respectively) make it "less significant" both in Table 24 and Table 25.

Table 24. Mean mandible length (mm) in area 1 and 2 in two time periods (significant P<0.05).

| Age and sex | Area 1 | | | | Area 2 | | | | | | | | F | df | ANOVA |
|-------------|-------|--------|--------|--------|-------|--------|--------|--------|--------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|             | Mean  | SE    | n      | Mean  | SE    | n      | F      | df    | p      |       |       |       |       |       |       |       |       |       |       |       |       |
| 1979–1981   |       |       |        |       |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| >2 years old females | 252 mm | 1.63 | 19 | 248 mm | 1.97 | 24 | 1.71 | 42 | p=0.199 | | | | | | | | | | | | | | |
| 3–5 years old males | 290 mm | 5.65 | 5 | 266 mm | 1.53 | 3 | 10.09 | 7 | p=0.019 | | | | | | | | | | | | | | |
| 2001–2005   |       |       |        |       |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| >2 years old females | 251 mm | 2.86 | 8 | 255 mm | 1.08 | 104 | 0.88 | 111 | p=0.350 | | | | | | | | | | | | | | |
| 3–5 years old males | 284 mm | 2.60 | 7 | 284 mm | 1.11 | 73 | 0.00 | 79 | p=0.994 | | | | | | | | | | | | | | |

Comparison of mandible length in area 1 and 2 in two time periods amongst adult females and 3–5 years old males showed significant difference amongst females and adult males in area 2, the mandible being larger in both instances in the later period (Table 25). No difference was found for animals in area 1 in these two time periods.

Table 25. Mean mandible length (mm) in two time periods in area 1 and 2 in adult females and 3–5 years old males (significant P<0.05).

| Age and sex | Area 1 | | | | Area 2 | | | | | | | | F | df | ANOVA |
|-------------|-------|--------|--------|--------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|             | Mean  | SE    | n      | Mean  | SE    | n      | F      | df    | p      |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 1979–1981   |       |       |        |       |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 2+ year old females | 252 mm | 1.63 | 19 | 251 mm | 2.86 | 8 | 0.05 | 26 | p=0.832 | | | | | | | | | | | | | | |
| 3–5 years old males | 290 mm | 5.65 | 5 | 284 mm | 2.6 | 7 | 1.33 | 11 | p=0.276 | | | | | | | | | | | | | | |
| 2001–2005   |       |       |        |       |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 2+ year old females | 248 mm | 1.97 | 24 | 255 mm | 1.08 | 104 | 7.13 | 127 | p=0.008 | | | | | | | | | | | | | | |
| 3–5 years old males | 266 mm | 1.53 | 3 | 284 mm | 1.11 | 73 | 10.36 | 75 | p=0.002 | | | | | | | | | | | | | | |
6.4.6.2 Carcass weight and back fat thickness

There was a significant difference of the mean carcass weight amongst >2 years old females in area 1 and area 2 in the year 1990 (F 4.48, df 37, p = 0.041) but not the mean back fat thickness (Table 26).

Table 26. Mean carcass weight (kg) and mean back fat thickness (mm) in >2-year-old females in area 1 and area 2 in the year 1990 (significant p<0.05).

<table>
<thead>
<tr>
<th></th>
<th>Area 1</th>
<th>Area 2</th>
<th>F</th>
<th>df</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcass weight</td>
<td>41.1 kg  7 0.91</td>
<td>38.2 kg 31 0.60</td>
<td>4.48</td>
<td>37</td>
<td>p=0.041</td>
</tr>
<tr>
<td>Back fat thickness</td>
<td>5 mm  7 1.48</td>
<td>2.7 mm 29 0.69</td>
<td>2.18</td>
<td>35</td>
<td>p=0.149</td>
</tr>
</tbody>
</table>

Adult males (>2 years old) were significantly heavier (F 11.28, df 120, p = 0.001) and with thicker back fat (F 25.90, df 32, p < 0.000) in area 1 than in 2 in 2015 (Table 27). A difference in age composition could affect the difference but appropriate sample size makes it less likely.

Table 27. Mean carcass weight and mean back fat thickness in >2 years old males in area 1 and area 2 in 2015 (significant p<0.05).

<table>
<thead>
<tr>
<th></th>
<th>Area 1</th>
<th>Area 2</th>
<th>F</th>
<th>df</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcass weight</td>
<td>91.9 kg  70 1.46</td>
<td>84.8 kg 51 1.47</td>
<td>11.28</td>
<td>120</td>
<td>p=0.001</td>
</tr>
<tr>
<td>Back fat thickness</td>
<td>63.3 mm 15 2.94</td>
<td>32.8 mm 18 4.88</td>
<td>25.90</td>
<td>32</td>
<td>p&lt;0.000</td>
</tr>
</tbody>
</table>

Comparison of carcass weight of 3–5 years old lactating/pregnant females in area 1 and 2 in September-May in 1980–1981, August 1990 and August-September 2003 and 2005 is shown in Table 28 (see also Appendix 10.4). Females were significant heavier in area 1 than area 2 in February 1981 (F 22.04, df 9, p = 0.002) and August 1990 (F 4.48, df 37, p = 0.041) but the sample size was low. From September 1980 to May 1981 the females in Snæfellsherd lost about 25% of their weight (Table 28) (Þórisson, 1983). There was no significant difference between carcass weight in area 1 and area 2 in September 1980, May 1981 or August-September 2003 and 2005 (Table 28).
Table 28. Mean carcass weight with 95% confident limit of 3–5 years old lactating females in two areas in September-May in 1980–1981, August 1990 and August-September 2003 and 2005 (significant p<0.05).

<table>
<thead>
<tr>
<th></th>
<th>Area 1</th>
<th>Area 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean carcass weight</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>Sept-80</td>
<td>42.3 ± 6.6 kg</td>
<td>6.3</td>
</tr>
<tr>
<td>Feb-81</td>
<td>37.6 ± 3.3 kg</td>
<td>2.1</td>
</tr>
<tr>
<td>May-81</td>
<td>30.6 ± 1.2 kg</td>
<td>0.8</td>
</tr>
<tr>
<td>Aug-90</td>
<td>41.1 ± 2.2 kg</td>
<td>2.4</td>
</tr>
<tr>
<td>Aug-Sep 2003</td>
<td>40.3 ± 2.5 kg</td>
<td>2.6</td>
</tr>
<tr>
<td>Aug-Sep 2005</td>
<td>38.8 ± 2.0 kg</td>
<td>2.2</td>
</tr>
</tbody>
</table>

The same comparison between the areas in 2008–2015 showed significant heavier females in area 1 than area 2 except in 2011 and 2012 (Figure 42). Before 2008 the sample size of 3–5-year-old lactating females was too small in area 1 in most years for comparison with area 2 but adequate in area 2 in all years.

![Figure 42. Mean carcass weight (kg) (with standard error) of 3–5-year-old lactating females at the hunting time in area 1, 2 and 3–8 (Eastern fjords) in 2008 to 2015.](image)

Comparison of the carcass weight of 3–5 years old males in area 1 and area 2 shows a significant difference of means for all years in 2004–2015 except in 2009 (Figure 43). The correlation between these areas are high (Pearson r 0.78). The carcass weight in area 1 being 8.75 kg higher than in area 2 at average in 2004–2015.
Figure 43. Comparison of carcass weight (kg) (with standard error) of 3–5 years old males in area 1 and area 2 in the 2004–2015 hunt.

When reindeer in area 2 shifted summer ranges in 2002 the carcass weight of 3–5-year-old lactating females decreased every year until 2009 and increased or fluctuated from 2010 on (Figure 44).

Figure 44. Size and distribution of reindeer in area 2 in July compared with mean carcass weight of 3–5 years old lactating females in hunt 2000–2015.
The carcass weight of 3–5-year-old lactating females in area 1 increased parallel with the herd size in July 2008–2015. The reason is believed to be the herd expanding its distribution range and decreasing the density at the same time (Figure 45).

When the reindeer in area 1 shifted their principal summer ranges from Kringilsárrani area to Norðurheiðar in 2008–2015 the mean carcass weight of 3–5-year lactating females showed a rise in the trendline by 0.31 kg/year (Figure 45) but this increase was not significant (r=0.5594, n=8, α=0.621).

In area 1, the correlation coefficient between the mean carcass weight and the herd size in 2008–2015 in area 1 was strong (Pearson r = 0.71 but not significant (p=0.496) (Figure 46).
Figure 46. Mean carcass weight (kg) of 3–5-year-old lactating females in area 1 2008–2015 correlated with the herd size in July.

In area 2, the correlation coefficient between the mean carcass weight of 3–5-year-old lactating females and the total herd size from 2002 to 2009 in area 2 is almost none (Pearson r = 0.26 and is not significant (p=0.54) (Figure 47).

Figure 47. Mean carcass weight (kg) of 3–5-year-old lactating females in area 2 2002–2009 correlated with the herd size in July.

For the period 2010–2015 the correlation was negative (Pearson r = -0.40 but not significant p=0.426) (Figure 48).
The carcass weight of calves of both sexes in area 1 and area 2 were compared in 1993–1999 and 2000–2009. Calf hunting was not allowed from 2010 and onwards. A significant difference was found in carcass weight between the areas among male calves in 2000–2009 (F_{11.83}, df 359. p = 0.001) in favour of area 1 and 1993–1999 in favour of area 2 (F_{6.50}, df 94, p = 0.012) but in 1993–1999 the number of weighed male calf was only three in area 1 (Table 29).

A comparison of available samples of both sexes showed no significant difference in calf carcass weight between the two periods (Table 30). The average carcass weight for female calves in both areas in 1993–2009 was 20.96 kg (n: 344, range: 10–31kg).

Table 29. Mean carcass weight (with 95% confidence limits) of 4 months old reindeer compared between area 1 and 2 in two time periods (significant P<0.05).

<table>
<thead>
<tr>
<th></th>
<th>Area 1</th>
<th>Area 2</th>
<th>F</th>
<th>df</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993–1999♂</td>
<td>21.0±5.6</td>
<td>2.00</td>
<td>3</td>
<td>22.4±2.3</td>
<td>3.91</td>
</tr>
<tr>
<td>2000–2009♀</td>
<td>25.4±1.7</td>
<td>4.89</td>
<td>18</td>
<td>22.4±0.4</td>
<td>3.51</td>
</tr>
<tr>
<td>2000–2009♂</td>
<td>22.4±1.9</td>
<td>2.62</td>
<td>14</td>
<td>20.8±0.4</td>
<td>3.62</td>
</tr>
</tbody>
</table>

Table 30. Mean carcass weight (with 95% confidence limits) of 4 months old reindeer compared between two time periods in area 1 and 2 (significant P<0.05).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (kg)</td>
<td>Mean (kg)</td>
<td>Mean (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area 1 ♂</td>
<td>21.0±5.6</td>
<td>25.4±1.7</td>
<td>2.30</td>
<td>20</td>
<td>p=0.146</td>
</tr>
<tr>
<td>Area 2 ♂</td>
<td>21.6±0.9</td>
<td>20.8±0.4</td>
<td>1.99</td>
<td>343</td>
<td>p=0.160</td>
</tr>
<tr>
<td>Area 2 ♂</td>
<td>22.0±2.3</td>
<td>22.4±0.4</td>
<td>0.80</td>
<td>422</td>
<td>p=0.372</td>
</tr>
</tbody>
</table>
6.4.7 Comparison of autumn carcass weight in sheep and reindeer

To compare the carcass weight of lamb grazing 3–4 months in summer in area 1 and area 2, data was obtained from eight local farmers, four in area 1 and four in area 2. Ram lambs were chosen, born in May and slaughtered in September from 2000 to 2015. The mean weight for both area is shown in Table 31. A comparison of the mean weight between the areas for each year between 2000 and 2015 and sample size is shown in Figure 49.

Table 31. Comparison of carcass weight of ram lambs in area 1 and area 2 from 2000 to 2015.

<table>
<thead>
<tr>
<th></th>
<th>Mean kg</th>
<th>CL (95%)</th>
<th>n</th>
<th>SD</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1</td>
<td>16.61</td>
<td>0.45</td>
<td>16</td>
<td>0.85</td>
<td>14.82</td>
<td>18.18</td>
</tr>
<tr>
<td>Area 2</td>
<td>15.97</td>
<td>0.38</td>
<td>16</td>
<td>0.71</td>
<td>14.59</td>
<td>17.58</td>
</tr>
</tbody>
</table>

The comparison of ram lamb and 3–5-year-old lactating females in areas 1 and 2 start in 2008 because sample size of carcass weight for the females in area 1 is too small before that year.

The mean carcass weight of ram lambs in the years 2000–2015 was significantly higher in area 1 (16.61 kg) than in area 2 (15.97 kg) (ANOVA, F 5.29, df 31, p 0.029) (Table 31, Figure 49).

The mean trend in carcass weight of reindeer females in 2000–2015 in area 2 decreased 113g per year, but increased 128g and 58g in ram lambs in area 1 and area 2 respectively (Figure 49). The trendline for reindeer females in area 2 was significant (r=0.514 n16 α=0.426: r> α, p<0.05) and for ram lambs in area 1 (r=0.715 n16 α=0.426: r> α, p<0.05) (Figure 49).

Between 2008 and 2015 the carcass weight of reindeer females and ram lambs don’t show a significant trend.
Figure 49. Mean carcass weight of adult reindeer females in area 2 and ram lambs in area 1 and area 2 in 2000–2015.
6.5 GPS-collars

Home range, habitat usage and movements of reindeer females were studied in 2009–2011. Their positions and movements are shown Figure 50 and Figure 51.

Only positions based on at least 4 satellites (95.5–99% of all positions) and with enough accuracy, as measured by values of the dilution of precision <10 (>99% of all positions) were used, as recommended by Anttonen et al. (2011) and Kumpala & Colpaert (2007) (Þórisson & Ágústsdóttir, 2014).

![Figure 50. Tracks of three GPS-collared reindeer females 2010–2011 in area 1 (Google Earth map).](image-url)
6.5.1 Comparison of herd sizes in area 1 and 2

As assessed based on monthly locations of GPS-collared females, the average annual herd size was 115 in area 1 and 66 in area 2 but varied over time. The herd size in area 2 is typical and as expected, it is low in winter, smallest at calving and highest in summer. In area 1 the herd size was larger than in area 2, except in February and April. In December there is only data from area 1, with an unusually large herd size for winter that continued to be large in January (Figure 52).

![Figure 51. Tracks of five GPS-collared reindeer females 2009–2010 in area 2 (Google Earth map).](image)

![Figure 52. Mean herd size of GPS-collared females in area 1 and 2 in 2009–2011.](image)
The evaluation of herd size based on GPS-collared females at different times of the year were most likely not too accurate because of limited sample size. A better picture comes from studies in 1980–1981 although lacking some months (Figure 53) (Þórisson, 1983). There is a lot of raw data available on herd size since then but have not yet been adequately analysed.

![Figure 53. Herd size in Snæfellsherd 1980–1981 in different months, number of herds in parenthesis (Þórisson, 1983).](image)

Comparison of the average annual herd size based on monthly locations of GPS-collared females was 115 and 66 in area 1 and area 2 respectively but varied over time (Figure 52). It is difficult to explain this difference in herd size between the areas. One reason could be bigger home range in area 1 than area 2. More samples would have been appreciated.

### 6.5.2 Time and place of calving based on GPS-collared females 2009–2011

Evaluation of calving time based on movements of GPS-collared females (Strand et al., 2011) gave birth dates the 13\textsuperscript{th} of May (11\textsuperscript{th}–16\textsuperscript{th}) as the average for the three females in area 1, and the 20\textsuperscript{th} of May (18\textsuperscript{th}–24\textsuperscript{th}) for the five females in area 2 (Table 32). There is a significant difference between the mean date of the two areas (ANOVA, P=0.0066).

The movement of three GPS-collared females in each herd from 8\textsuperscript{th} of May to the 31\textsuperscript{st} of May in the years 2009 to 2011 is shown in appendix 10.1. In Table 32 the inferred day of calving in May is shown.
<table>
<thead>
<tr>
<th>Females</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hlíðarenda</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>with antlers on the 8th of May 2010</td>
</tr>
<tr>
<td>Ána</td>
<td>-</td>
<td>11th of May</td>
<td>x</td>
<td>with a newborn calf on the 15th of May 2011</td>
</tr>
<tr>
<td>Ranga</td>
<td>-</td>
<td>16th of May</td>
<td>13th of May</td>
<td>with a calf on the 19th of May 2012</td>
</tr>
<tr>
<td><strong>Area 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gríma</td>
<td>19th of May</td>
<td>0</td>
<td>-</td>
<td>with antlers on the 8th of May, no calf on 31st of May 2010</td>
</tr>
<tr>
<td>Heiða</td>
<td>18th of May</td>
<td>-</td>
<td>-</td>
<td>with antlers on the 8th of May 2010</td>
</tr>
<tr>
<td>Ása</td>
<td>20th of May</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Hnefla</td>
<td>24th of May</td>
<td>x</td>
<td>-</td>
<td>with a calf on 21st of June 2010 and 13th of July 2011</td>
</tr>
<tr>
<td>Stína</td>
<td>-</td>
<td>21st of May</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

The time of calving of the GPS-collared females of Snæfellsherd was 11th to 24th of May indicating mid-calving (when half of the calves are born) on 18th of May.
All three females in area 1 showed different calving behaviour (Appendix 10.1).

**Hlíðarenda** had her antlers on the 8th of May 2010, as observed from a plane in Jökuldalsheiði. From that, and her movements in May there was no indication of calving. Abortion or stillbirth could have happened on the 9th or 11th of May when her movements slowed down a little bit (Figure 3 in Appendix 10.1).

**Ána** calved most likely on the 11th rather than the 16th of May 2010 based on her movements after calving. The calving took place in Sauðárrani just north of the river Kringilsá (Figure 54, Figure 55, Figure 1 in Appendix 10.1). On the 15th of May 2011 she was spotted with a newborn calf in Fiskidalur valley about 30 km to the north of her calving place in 2010 (Þórarinsdóttir & Ágústsdóttir, 2015).
Figure 55. Positions of three GPS-collared females in area 1 from 8th to 31st of May 2009–2012: Ána 2011 (15th of May) and Ranga 2012 (19th of May) spotted after the GPS-collars stopped transmitting and Gríma in area 2. (Þórarinsdóttir & Ágústsdóttir, 2015).

Ranga showed site fidelity, calving at almost the same spot (within a 1 km radius) for three years (Figure 54, Figure 55, Figure 2 in Appendix 10.1.).

Gríma calved in 2009, most likely on the 19th of May, but no calf followed her in 2010. The difference of a cow with a calf and without is clear looking at the behaviour of Gríma from 8th – 31st of May (Figure 4 in Appendix 10.1, Figure 54 and Figure 55).

Heiða calved on 18th (or 19th) of May 2009. With antlers on the 8th of May 2010 therefore presumably pregnant (Figure 5 in Appendix 10.1., Figure 54).

Ása calved most likely on the 20th of May 2009 (Figure 6 in Appendix 10.1., Figure 54).

Hnefla went straight toward the Vatnajökull glacier and calved most likely on the 24th of May 2009. She was seen with a calf both in 2010 and 2011 in the same area but the place of calving for those two years is uncertain as she stayed outside the principal winter grazing area in 2010 (Figure 7 in Appendices 10.1. and 10.2., Figure 54).

Stína calved most likely on the 21st of May 2010 (Figure 8 in Appendix 10.1., Figure 54).
6.5.3 Home range

Home (95%) and core range (50%) for individual animals were different in size, shape, time and space (Figure 56). The ranges were smallest during the calving period and largest during the hunting season. In Appendix 10.2 home ranges are shown for all eight GPS-collared females at different times of the year. In area 1, Hlíðarenda has the largest home range of all females for the whole year, with a home range of 1558 km². The largest home range in area 2 is that of Ása with 1178 km². The largest home ranges over time, were found during the hunting period (Figure 18) in area 1, for Hlíðarenda with 2261 km² and Ána with 1736 km². However, the other female in area 1, Ranga, had a home range of 789 km² during the hunting period, like most of the females in area 2. Gríma had the largest home range in area 2 (1046 km²) during the hunting period, just half of Hlíðarenda’s home range in area 1. Ranga had twice as large home range (470 km²) during spring migration as the other two GPS-collared females in area 1 but had an unusually small home range in summer and calving. The most striking difference in area 2 is Ása at spring migration and Gríma at hunting time with around twice as large home range as the others, and Hnefla at rutting time with three-times as large as the others (Figure 56).

The average core range size for the GPS-collared females was 19% (range: 18–26%) of the home range in area 1 and 17% (range: 16–19%) in area 2. The average size of core ranges of all periods was 269 km² in area 1 and 179 km² in area 2. The differences between individuals were like those for the home range (Figure 56). There was a significant difference in home and core range size between area 1 and area 2 (p<0.001), between individual females (p<0.001) and between different periods (p<0.05). The calculation used was ANOVA done by Kristín Ágústdóttir (Pórisson & Ágústsdóttir, 2014).
Figure 56. Home and core range sizes (km$^2$) of three females in area 1 and five females in area 2 in different periods of the year.
The mean home range for three females in each area is shown in Figure 57. Home range of reindeer in area 1 was always larger than in area 2 except in summer and at calving. The home range for the whole year was 30% larger and core range size 60% larger in area 1 than in area 2.

![Figure 57. Comparison of home range between area 1 and area 2 at different times of year.]

### 6.5.4 Movements

There was a significant difference \((p<0.001)\) between the annual mean travelling speed of GPS-collared females in area 1 (279 m/hour) and area 2 (258 m/hour). Movements also differed between individuals and time of year (Figure 58 and Figure 59) (Đórisson & Ágústsdóttir, 2014). Looking at the travelling speed or the distance travelled between two consecutive locations, they seem to be different in most periods for reindeer in area 1 and 2 (Figure 60). It is almost the same in summer but in area 1 travelling speed is 24% and 62% higher during the hunting period and at rut, respectively. In autumn reindeer in area 2 moved 46% more than in area 1.

---

8 Only females giving information from all periods.
In winter, reindeer in area 1 moved 23% more than in other periods but the herds moved similarly at the spring migration. Reindeer in area 2 moved 14% longer distance between positions at calving time (Figure 60).
Figure 60. Average movements (m/hour) with standard error in area 1 and 2 at different time of year.

All these differences are significant (P<0.01, ANOVA nonparametric Kruskal-Wallis test, all calculations done by Kristín Ágústsdóttir) (Pórisson & Ágústsdóttir 2014). Mean maximum movement speed of individuals in Snæfellsherd based on GPS-positioning was 500 m/hour during the hunting period but lowest in autumn, winter and calving, with values of 162–186 m/hour (Figure 60). The greatest difference being in the rutting time with 1.62 higher average movement of reindeer in area 1.

Differences between individuals are large, as can be seen in Figure 61 were step length (distance travelled) over 5 km per 3 hours is compared. The long run winner is Hlíðarenda at hunt in area 1. It is also clear when looking at the home range of Hlíðarenda in appendix 10.2.

Figure 61. Number of step lengths >5 km per 3 hour at different time of year of all three GPS-collared females in area 1 and five in 2.
6.5.5 Comparison of movements and home ranges

The comparison of average movements, home and core ranges between area 1 and 2 at different periods is shown in Figure 62.

![Graph showing comparison of movements, home and core ranges between area 1 and 2 at different periods.](image)

*Figure 62. Comparison of average movements, home and core range between area 1 and 2 at different periods.*

The lactating females in area 2 were ~9% lighter in 2009 and 2010 than the ones in area 1 and the differences were highly significant. At the same time their energy expenditure is ~11% less considering total distance between positions in a year (Table 33).
### Table 33. Total distance between positions over a year in area 1 and 2. Total distance calculated with 2900 positions (8 positions for 365 days).

<table>
<thead>
<tr>
<th>Names of GPS collared females</th>
<th>Period</th>
<th>Mean distance (m) between positions</th>
<th>Calving</th>
<th>Number of positions</th>
<th>Total distance between positions (km)</th>
<th>Mean carcass weight 2+ years old lactating females 2009 &amp; 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ána</td>
<td>24.4.2010–25.4.2011</td>
<td>723</td>
<td>yes</td>
<td>2860</td>
<td>2111</td>
<td></td>
</tr>
<tr>
<td>Ranga</td>
<td>1.6.2010–2.6.2011</td>
<td>697</td>
<td>yes</td>
<td>2793</td>
<td>2035</td>
<td></td>
</tr>
<tr>
<td>Area 1 total</td>
<td></td>
<td>766</td>
<td></td>
<td></td>
<td>6707</td>
<td>42.1 kg</td>
</tr>
<tr>
<td>Gríma</td>
<td>7.6.2009–8.6.2010</td>
<td>734</td>
<td>no</td>
<td>2645</td>
<td>2143</td>
<td></td>
</tr>
<tr>
<td>Hnefla</td>
<td>8.4.2009–9.4.2010</td>
<td>612</td>
<td>yes</td>
<td>2368</td>
<td>1787</td>
<td></td>
</tr>
<tr>
<td>Heiða</td>
<td>31.1.2009–1.4.2010</td>
<td>693</td>
<td>yes</td>
<td>2272</td>
<td>2024</td>
<td></td>
</tr>
<tr>
<td>Area 2 total</td>
<td></td>
<td>680</td>
<td></td>
<td></td>
<td>5954</td>
<td>38.2 kg</td>
</tr>
</tbody>
</table>

#### 6.5.6 Vegetation mapping of area 1 and 2

CORINE 2006 was used to compare land classes between area 1 and 2 as these hunting areas were classified before 2015 (Figure 4). Proportional size of land classes for each area is shown in Figure 63.

Area 1 is 8698 km², 31% of which is barren land and 16% sparsely vegetated (together 4139 km² or almost half of the land). Area 2 is 3417 km², 20% of which is barren or sparsely vegetated land (687 km²). The area of peat bogs is half as big in area 2 as in area 1, and moors and heathlands (dwarf scrub heaths) two third less in area 2 than in area 1 (Figure 64).
Figure 63. Proportional size of CORINE land classes (CORINE class codes are indicated by numbers in brackets) in area 1 and area 2.

Figure 64. Comparison of actual CORINE land classes in area 1 and area 2.

In Figure 66 habitats within the area mapped by INH are compared between area 1 and area 2. It is difficult to compare them because the mapped land within each area is not of equal size. As was obvious in the CORINE classification Salix moors and heathlands are widespread and account for a similar proportion in area 1 and 2. The biggest difference being gravel in area 1 and Carex moors and heathlands and bogs in area 2 (Figure 65).

About 47% of all GPS positions of the eight individuals in Snæfellsherød with GPS-collars were inside that area (Figure 14) (Þórisson & Ágústsdóttir, 2014).
Figure 65. Proportional division of habitats according to the INH vegetation map in area 1 and area 2, and specifically for the combined home range and core range in areas 1 and 2.

Figure 66. Habitats inside INH mapped home range of reindeer in area 1 and 2.
To compare the two areas, it is necessary to look at the proportion of the habitats inside the INH mapped area. The greatest difference between home and core range is that *Salix* moors and heathlands are five times larger in core range in area 1 than 2 and *Carex* moors and heathlands are three times bigger in area 2 than 1 (Figure 67).

The vegetation of Iceland is changing (Raynolds et al., 2015). The changing of vegetation by CORINE classes from 2006 to 2012 in the study area is shown in Table 34. The largest change is on glaciers and perpetual snow (CLC class 335) that has decreased by 267 km$^2$ (2.42%) between 2006 and 2012 (LMÍ, 2015). Moors and bogs have decreased by 94 km$^2$ and barren areas (dunes and sand plains, bare rock) increased by 269 km$^2$. Water bodies have also increased by 75.6 km$^2$, mainly due to the construction of the water reservoirs of the Kárahnjúkar hydropower project (LMÍ, 2015).
Table 34. Changes of CORINE classes (km²) in Iceland 2006–2012 (LMÍ, 2015).

<table>
<thead>
<tr>
<th>CLC classes</th>
<th>Name of class</th>
<th>km²</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>322</td>
<td>Mólendi, mosi, kjarr</td>
<td>-80.66</td>
<td>-0.21%</td>
</tr>
<tr>
<td>324</td>
<td>Skógrur og skógrækt</td>
<td>21.36</td>
<td>5.95%</td>
</tr>
<tr>
<td>321</td>
<td>Graslendi</td>
<td>32.68</td>
<td>1.03%</td>
</tr>
<tr>
<td>231</td>
<td>Tún og bithagar</td>
<td>19.8</td>
<td>0.75%</td>
</tr>
<tr>
<td>412</td>
<td>Mýrar</td>
<td>-13.08</td>
<td>-0.19%</td>
</tr>
<tr>
<td>411</td>
<td>Flæðiengi</td>
<td>-1.1</td>
<td>-0.27%</td>
</tr>
<tr>
<td>333</td>
<td>Hálfróið land</td>
<td>3.6</td>
<td>0.02%</td>
</tr>
<tr>
<td>331</td>
<td>Ógróið</td>
<td>99.27</td>
<td>3.01%</td>
</tr>
<tr>
<td>332</td>
<td>Ógróið</td>
<td>169.75</td>
<td>0.71%</td>
</tr>
<tr>
<td>511</td>
<td>Annað, straumvötn</td>
<td>-58.82</td>
<td>-7.43%</td>
</tr>
<tr>
<td>512</td>
<td>Annað, stöðuvötn, uppistöðulón</td>
<td>75.6</td>
<td>6.09%</td>
</tr>
<tr>
<td>335</td>
<td>Jöklar og fannir</td>
<td>-267.14</td>
<td>-2.42%</td>
</tr>
</tbody>
</table>

6.5.7 Habitats used by reindeer based on GPS-collared reindeer females

A high fix rate was in the reindeer pastures on the highland plateau and in the open low laying winter area but not as good in the valleys inland from the fjords. In some of those areas forestry (mainly Siberian Larch (*Larix sibirica*)) has increased in the last decades but observation indicates that the reindeer avoid going into dense forests.

About 56% of the home range and 59% of the core range areas are inside the area mapped by INH (Figure 14). This is similar for all females except for Hnefla (Figure 68, Table 35). Hnefla left the principal distribution area of reindeer in area 2 in autumn and roamed in winter outside area 2 (in area 7, Figure 4).

The proportion of home range and core range of all GPS-collared females inside the mapped area at different times of the year is shown in Table 35 (Þórisson & Ágústdóttir, 2014). It appears to be similar with few exceptions, it is over 80% in spring, summer and at calving.
Figure 68. Proportion of INH vegetation mapping of home range (HR=95%) and core range (CR=50%) of GPS-collared females in area 1 (Ána, Hl.enda, Ranga) and in area 2 (Asa, Gríma, Hnefla, Heiða, Stína) (Þórisson & Ágústdóttir, 2014).

The proportion is lowest in winter in both areas and low at rut in area 1. In autumn, females in area 1 are almost outside the mapped area (Table 35).

Table 35. Proportion of home range (HR=95%) and core range (CR=50%) of all GPS-collared females inside INH mapped area at different time of year.

<table>
<thead>
<tr>
<th></th>
<th>Area 1</th>
<th></th>
<th>Area 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ÁNA</td>
<td>Hl.ENDA</td>
<td>RANGA</td>
</tr>
<tr>
<td></td>
<td>HR</td>
<td>CR</td>
<td>HR</td>
</tr>
<tr>
<td>All</td>
<td>48%</td>
<td>55%</td>
<td>49%</td>
</tr>
<tr>
<td>Calving</td>
<td>99%</td>
<td>100%</td>
<td>66%</td>
</tr>
<tr>
<td>Winter</td>
<td>54%</td>
<td>59%</td>
<td>39%</td>
</tr>
<tr>
<td>Summer</td>
<td>47%</td>
<td>63%</td>
<td>86%</td>
</tr>
<tr>
<td>Autumn</td>
<td>0%</td>
<td>0%</td>
<td>7%</td>
</tr>
<tr>
<td>Rut</td>
<td>0%</td>
<td>0%</td>
<td>28%</td>
</tr>
<tr>
<td>Hunt</td>
<td>30%</td>
<td>19%</td>
<td>49%</td>
</tr>
<tr>
<td>Spring</td>
<td>100%</td>
<td>100%</td>
<td>92%</td>
</tr>
</tbody>
</table>

Positions of GPS-collared reindeer females every 3 hours were used to evaluate the utilization of different habitats based on the INH vegetation mapping. Only four (out of 17, see Figure 66 and Figure 67) of the most common habitats were utilized by the GPS-collared reindeer females. Positions on these habitats represent 55% and 65% of all records in area 1 and area 2 respectively (Figure 69).
Figure 69. Proportional average annual habitat uses in home (HR; 95%) and core (CR; 50%) range of GPS-collared females in area 1 and 2.

A closer look at the utilization of different habitats by the GPS-collared females shows the difference more clearly. *Carex* moors and peatbogs were the most common habitats used by reindeer in area 2, but gravel and *Salix* heathlands were the most common habitat used in area 1 (Figure 70), although the proportional differences in area size of *Salix* moors and heathlands are only seen in the core range (Figure 71)

Figure 70. Area size of the four most common habitats utilized by reindeer in home range in area 1 and 2.
Figure 71. Reindeer utilization of four of the most common habitats in core range in area 1 and 2.

Individual differences in habitat use in home and core ranges of all GPS-collared females in area 1 and area 2 are shown in Figure 72. The comparison of area 1 and 2 were gravel is excluded in Figure 73.

Figure 72. Habitat use in home and core ranges of all GPS-collared females in area 1 and area 2.
Figure 73. Average proportional annual habitat use in home and core range of GPS-collared females in area 1 and 2, gravel excluded.

A detailed comparison of used habitats between area 1 and 2 and at different time of year is shown in Appendix 10.3.
6.6 Comparison of food intake by different herbivores

Total food intake in the pastures of Snæfellsherd by different grazers is complicated to calculate. A very rough evaluation for the year 2015 (based on updated data from Garðarsson, 1987) is shown in Table 36 and Figure 74 for area 1 and area 2.


<table>
<thead>
<tr>
<th>Species</th>
<th>Area</th>
<th>Mean weight (kg)</th>
<th>Population size</th>
<th>Daily intake DM (g)</th>
<th>Grazing days in a year</th>
<th>Total annual intake DM (T)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagopus muta</td>
<td>1</td>
<td>0.5</td>
<td>70000</td>
<td>60</td>
<td>365</td>
<td>1533</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>40000</td>
<td></td>
<td></td>
<td>876</td>
<td>6.6</td>
</tr>
<tr>
<td>Rangifer tarandus</td>
<td>1</td>
<td>80</td>
<td>1000</td>
<td>2625</td>
<td>365</td>
<td>958</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>1000</td>
<td></td>
<td></td>
<td>958</td>
<td>7.3</td>
</tr>
<tr>
<td>Anser brachyrhynchus</td>
<td>1</td>
<td>2.8</td>
<td>30000</td>
<td>130</td>
<td>175</td>
<td>683</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>70000</td>
<td></td>
<td></td>
<td>1593</td>
<td>12.1</td>
</tr>
<tr>
<td>Ovis aries</td>
<td>1</td>
<td>65</td>
<td>47616</td>
<td>2100</td>
<td>120</td>
<td>11999</td>
<td>86.6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>49333</td>
<td></td>
<td></td>
<td>12432</td>
<td>73.9</td>
</tr>
</tbody>
</table>

From this evaluation of food intake, it seems clear that the sheep, only grazing for ~120 days in the highland consume 4–5 times more than the other big grazers in East Iceland together (Figure 74). To get an acceptable result of the effects of grazing on vegetation much more data is needed.

Figure 74. Comparison of estimated annual food intake of four grazers in pastures in area 1 and area 2 in East Iceland in 2015. Data based on Garðarsson (1987).
7 Discussion

7.1 The reindeer as an introduced species

The reindeer population in Iceland are descendants of 35 animals introduced to East Iceland in 1787 and possibly another 35 coming to N-Iceland in 1784 all from Finmark. Røed et al. (1985) studied the genetic structure of the Icelandic reindeer and concluded that the founder population was possibly less than 15 animals. There do not seems to be negative signs of this genetic bottleneck in the demography of the present reindeer population. In the beginning, the introduced reindeer population increased with some oscillations in numbers in the 19th century. Without natural predators and exoparasitic insects, little or primitive hunting, the main factors driving the population dynamics must have been weather and food availability in winters (Þorsteinsson et al., 1970; Þórisson, 1983). In the first half of the 20th century reindeer became extinct in the southwest and in the northeast of Iceland, surviving only in a small herd in the east (Valtísson, 1945).

The reason for their survival in East Iceland is believed to be the climate. The climate in the area, where they survived, just north of the northeast corner of the Vatnajökull glacier, is considered continental with low participation. This is also the only place in Iceland with continuous vegetation from the seashore to the glacier.

Reindeer were introduced to Saint Matthew Island in 1944, an island without predators. After a rapid, exponential increase the population crashed in a hard winter with limited grazing in an overgrazed pasture in this rather small island (Klein, 1968). The only native land mammal in Iceland is the arctic fox (Hersteinsson, 1993). Along with the people colonising Iceland some 1200 years ago came the Wood mouse (Apodemus sylvaticus) and the House mouse (Mus musculus). The Brown rat (Rattus norvegicus) is believed to have reached Iceland around the middle of the 18th century (Skírnisson, 1993a), the American mink (Neovison vision) was introduced in 1931 (Skírnisson, 1993b) and the reindeer in 1787. All these species are classified as alien species (von Schmalensee et al., 2013), and the mink and the rats are classified as invasive alien species. In the 19th century the reindeer were often looked upon as invasive, especially by farmers who perceived reindeer as competitors for Icelandic moss (Cetraria islandica) for human consumption, and with
sheep in winter pastures (Friðlaugsson, 1933; Valtýsson 1945; Þorvaldsson, 1960). The reindeer is potentially an invasive species given the lack of natural predators, but after the establishment of hunting management around 1940, the reindeer is rarely regarded as invasive.

7.2 Abundance and density

In 1980, only half of the number recorded in 1979 in Snæfellsherdr was found. The reason was believed to be immigration of part of the herd from winter ranges north of Mt. Snæfell (Fljótsdalsheiði) to the east with the consequence that part of the herd did not migrate to the principal summer grazing areas around Mt. Snæfell the next years. The annual count was conducted in the end of July but a few years later, the autumn migration implied smaller and more dispersed herds that can lead to inaccurate counts (Þórisson, 1983). This is also believed to be the reason for the high numbers detected in some years in Fljótsdalsheiði 1965–1975.

Fluctuations in reindeer in areas 1 and 2 are believed to be partly due to the different quality of the counts and partly because of different number of animals migrating to Snæfellsöræfi, the summer grazing area of Snæfellsherdr. The main reason for the sharp decline in Snæfellsöræfi after 1991 is most likely because reindeer in area 2 shifted winter ranges to the east with the consequence that part of them did not go back to the principal summer pastures of area 2. On 7th of July 1996 there were only 704 reindeer found on Snæfellsöræfi but on the 11th of August they had increased of 300 on the easten side of Mt. Snæfell most likely coming from the fjords.

Counts often underestimate population number due to visibility bias (Caughley, 1974) and the fact that the counters and the pilot might be unfamiliar with the area and/or the timing of the count is not appropriate. This seems to be at least partly the reason for the variations in the results of annual summer counts of reindeer in East Iceland.

Reindeer hunting management in Iceland, as promoted by EINRC, aims at keeping a density of reindeer less than 1 animal per square km of vegetated land in winter (Þórisson
These densities are close to the 1.2 reindeer per square km recommended as a maximum density in Greenland that probably will not harm the vegetation (Cuyler et al., 2011). This goal is connected to food availability; hence, this density should not exceed the carrying capacity of the vegetation in most winters. However, the number of reindeer and, especially, food availability are not always very well known. The winter density in area 1 and 2 in 2014–2015 were 0.2 reindeer per square km of vegetated land (Þórsson & Þórarinsdóttir, 2016). Estimation of carrying capacity for reindeer winter pastures in Scandinavia focus mainly on available lichen crop (Helle et al., 1990) making it difficult to compare with winter grazing in Iceland, where lichens are insignificant part of the winter diet in many areas (Egilsson, 1983).

In Iceland hunting is the main factor regulating reindeer population size. Without hunting, the availability of food resources is believed to be the main factor regulating herbivore numbers (Strand et al., 2012). In the Arctic, the main limiting factor of reindeer populations is the availability of food during winter (Strand et al., 2012). The first signs of density-dependent processes at high reindeer density is an increased mortality of yearlings (Skogland, 1985). Without hunting I presume that climate variation (f.e. ground-icing) in connection with overgrazing in winter pastures would be the main driver of reindeer population dynamics especially since there are no predators (Tveraa et al., 2014, Hansen et al., 2011). Ground-icing is rare in area 1 and 2 but more likely to happen in the fjord area.

Climate change will have effects on arctic ecosystems (Ospina, 2017). Warmer temperatures can increase the food supply for reindeer but can also bring some negative effects like growth of unwanted plant species and establishment of new diseases and parasites (Bernes et al., 2015). This should be considered when evaluating the density goal for the management of the species in the future.

### 7.3 Shifting ranges of both herds

The establishment of a reindeer herd in area 1 begun in the 1960s. Its origin was in area 2. The herd in area 1 represented a minor part of Snæfellsherd until around 2006 when it started to increase in number and distribution. The main reason for this expansion in area 1
is likely related to very low hunting pressure on females in 2000–2012 and, possibly, by immigration from area 2. Resightings of ear tagged calves and the movements of the gps-collared females indicates a minimum immigration between area 1 and area 2.

In 2002 the main summer ranges of reindeer in area 2 shifted from Vesturöræfi, the principal summer grazing area, to Fljótsdalsheiði. Human disturbance (Klein, 1971; 1991; Curatolo & Murphy, 1986; Nelleman & Cameron, 1998; Nelleman et al., 2000, Stankowich, 2008) in the area, associated with the construction of a road building because of a hydropower project in the area (Figure 1) started in August 2002, so human activity is hardly to blame or at least not as the only cause. The reindeer did not return to Vesturöræfi the next years but instead part of the herd shifted their ranges to the east and some immigrated to area 1 but their number is unknown. Similar shifts of ranges happened in the seventies, and then the cause was believed by local people to be the result of heavy grazing of favourite food items by the reindeer9. In 1965 the number of reindeer in area 2 in July was around 2000 increasing to 3300 in 1976. This is the peak number that reindeer in area 2 has reached in summer, with most of the herd staying in Vesturöræfi. After 1976 their numbers decreased partly because of emigration to the east.

The behaviour of reindeer in area 1 regarding calving and summer grazing changed considerably after 2006. A large proportion of the herd left Kringilsárrani area with increasing number of individuals in Jökulsárhöfði at calving and during summer. In 2007 a water reservoir was filled for the first time after Jökulsá á Dal was dammed at Kárahnjúkar, forming the 57 km² Háslón lagoon (Figure 1). Part of Sauðárrani and 25% of Kringilsárrani were drowned10. Human activity increased in the area because of this hydropower project and increased tourism in 2003–2006, especially after a traditional cableway was put over the river Kringilsár and thus opened the way into Kringilsárrani in 2005. Before that time the area was surrounded by the glacier and glacial rivers, and therefore it was very difficult to reach. Cumulative long-term effects of these activities were most likely responsible for the abandonment of these areas by reindeer. Many studies

9 Personal communication with local reindeer hunting guides 2014
10 http://ust.is/library/Skrar/Einstaklingar/Fridlyst-svaedi/Auglysingar/Kringilsarrani_kort.pdf
show similar response to anthropogenic activity like increased tourism, road building and electricity lines (Nellemann & Vistnes, 2007; Reimers & Colman, 2006;).

In 2000–2012 hunters with a hunting license of females in Snæfellsherdl could choose if they shot it in area 1 or area 2. Because of a new asphalt road (Kárahnjúkavegur, Figure 1) through the hunting grounds in area 2 most of the hunters shot their female there leaving the females in area 1 with no or very little hunting pressure. From 2013 hunters were obliged to hunt the area 1 female hunting quota in that area (Figure 33a).

7.4 Physical condition and recruitment

There was a significant difference of carcass weight of 3–5 years old lactating females between area 1 and area 2 in 2008–2015, except in 2011 when carcass weight was almost the same in the two areas (39.8 kg and 39.6 kg respectively). Despite the difference individuals in both areas are in prime condition. Increased carcass weight of reindeer females in area 1 in years 2011–2015, coupled with a shift in summer ranges from Kringilsárrani area to Norðurheiðar could be partly a response to heavy grazing impact in Kringilsárrani area by the pink-footed goose (Óskarsdóttir, 2016), which may have forced reindeer to search for more productive summer ranges. Drop in carcass weight between 2010 and 2011 could indicate immigration from area 2 were the females are lighter.

Significant difference in carcass weight of 3–5-year-old males was also observed. The ones in area 2 being 8% lighter than males in area 1 in the 2015 harvest.

Comparing the body size of reindeer in both herds by measurements of mandible length (1979–1981 and 2001–2005) which reflects the quality of the reindeer pastures while growing showed no significant differences between the two areas, except for males in 1979–1981. The males in area 1 had longer mandibles (8% on average) than males in area 2. The reason is most likely related to selective hunting of older males in area 2. Comparing the mandible length between the time periods indicated that both females and males had become significant bigger in area 2 in 2001–2005.
In all reindeer populations there are some females born without antlers but the proportion of them varies greatly (Reimers et al., 2013a). Reimers (1993) concluded that there appeared to be a relationship between habitat quality, body size or physical condition, and antler status. Antlerless females being more common in herds with animals in poor conditions.

The overall proportion of antlerless females was 4.7% in 1991–2010 and did not differ between the two areas. This value is relatively high, compared with 2.4% reported in 1978 (Reimers, 1993). Reimers (1993) claimed that populations in prime physical condition had fewer antlerless females or they were absent (Reimers, 1993). Cronin et al. (2003) pointed out that his could be used when monitoring the physical status of herds in connection with carcass weight. However, we found no indications of worse physical condition in terms of carcass weight in recent years compared with 1978, although the number of antlerless females seems to have doubled in East Iceland. Therefore, we warn against the use of the proportion of antlerless females as an indication of physical condition of reindeer herds.

Because non-pregnant females usually shed their antlers a few weeks before the calving season, the number of females without antlers in counts conducted in late April has been used to estimate pregnancy rates (Lent, 1965; Espmark, 1971; Bergerud, 1976). However, recent research on antler casting in a domestic reindeer group concluded that "...antler status prior to parturition does not accurately predict pregnancy status". (Reimers et al., 2013a:17). This controversial result should be considered when viewing the following coverage.

The mean pregnancy rate from antlerless females in late April 2001–2013 was 86% (Þórarinsdóttir & Ágústsdóttir, 2015). Pregnancy rates range from 75–100% among 2 1/2 year or older wild or domestic reindeer (Reimers, 1997). Our calculations of pregnancy rates include naturally antlerless females (4.7%) and yearlings (10% shot in autumn with a calf) indicating that real pregnancy rate might be closer to 90% for ≥2 years old females on average.

Reimers (1997) showed that there was a positive relationship between the pregnancy rate of calves and carcass weight at the onset of rutting. Pregnancy had not been recorded in
calves weighing less than 21 kg (Reimers, 1997). The average carcass weight for female calves in both areas in 1993–2009 was 20.96 kg (n: 344, range: 10–31kg); 56% were over 21 kg. About 10% of yearlings shot in autumn were lactating, which indicates good physical condition (Reimers, 1997) in Snæfellsherid.

Þórarinsdóttir's (2016) conclusion was that mid calving time in area 2 was 14th or 15th of May in 2005 but close to 19th of May in the years 2006–2013. The timing of mid calving can be different between years in the same herd because of different condition of the vegetation that influences the onset of the rut and it can vary up to 14 days (Skogland, 1994). In 1980 the mean calving time in area 2 on Vesturöræfi was 21st of May but the 18th the year after (Þórisson, 1983). One reason for earlier calving could be connected to heavier females at rutting time in area 1 than 2 (Reimers, 1983b).

At the beginning of the 21st century an increased number of newly born calves was observed in late summer and up to the end of October (24th of October, a newly dead reindeer calf on Fljótsdalsheiði heath (Þórisson, unpubl.). The reason for this is unknown and unlikely to be related to skewed sex ratios as stated by Holand et al., (2002). A highly skewed sex ratio in 1979–1981 and 1990–1992 compared with 2000–2002 and 2014 (Figure 41) does not seem to have influenced the time of birth (Þórisson, 1983; Þórarinsdóttir & Ágústsdóttir, 2015).

Monthly precipitation is higher in Eyjabakkar on the East side of Mt. Snæfell than in Kárahnjúkar on the western side (Icelandic Meteorological Office, 2007). This could partly explain why reindeer in both herds have chosen the land south of Kárahnjúkar as the main calving areas in many years.

There was no significant difference of carcass weight between 3–5-year-old lactating/pregnant females in area 1 and area 2 in August-September 1980, 2003 and 2005.

A drastic decrease in the number of animals in area 2 after 2008 is believed to be partly because of emigration to hunting areas 6 and 7. At the same time the carcass weight of 3–5 years old lactating/pregnant females in those areas decreased. A very noticeable drop in
carcass weight in area 1 in 2011 is most likely because of immigrant of lighter females from area 2.

There was not a significant correlation between herd size and carcass weight of 3–5-year-old lactating females in area 1 and area 2.

In the period 2008–2015 (except 2011 and 2012), 3–5-year-old lactating/pregnant females were significantly lighter (8% on average, range 0.3–13%) in area 2 than in area 1.

Before 1991 the adult males were overhunted. The reason was unsexed hunting quotas (Þórisson, 1983, Hersteinsson, 1992a). There are no indications that this biased sex composition affected the recruitment. One of the goals of the monitoring of the population is to secure enough number of males both for the benefit of the population and trophy hunters.

### 7.4.1 Comparison of calving in Iceland and Norway

Reproductive performance, calving time, calf birth weight and neonatal mortality are believed to be strongly positive correlated to the body weight of the mother (Reimers, 1997, Flydal, 2002). In the present study, there was a strong negative correlation \( (r=0.9033) \) with a significant trendline \( (p=0.05, \alpha=0.521) \) between pre-rut carcass weight of females and calving midpoint when area 1 and area 2 were plotted together with reindeer herds in Norway (Figure 75) (Reimers, 1983b; Reimers et al., 1983). The timing of calving in Iceland in relationship with pre-rut carcass weight is in line with what would be expected in Norway (Figure 75), with heavier females calving earlier (Þórarinsdóttir & Ágústsdóttir, 2015). The mean calving time in area 2 is close to the 18th of May as in semi-domesticated herds in Kautokeino, Finnmark (Skjenneberg et al., 1968) were the Icelandic population originated from.
7.4.2 Comparison of body weight in Icelandic and Norwegian reindeers

Comparison of pre-rut total body weight\(^{11}\) of 2+ year old females of domestic, mixed and wild origin in Norway (Reimers, 1997, 2013b) with reindeer in area 1 and 2 (of domestic ancestry, calculated total body weight) confirms an excellent physical condition especially in area 1 (Figure 76). The body size of a reindeer is believed to be more dependent on summer food rather than winter food (Skogland, 1983; Klein, 1967; Reimers, 1980). Limited winter food can on the other hand affect the growth of the foetus and milk production of the female and thus the size of the calf after its first summer. It could also reduce the survival of the calf (Skogland, 1983). Comparison of carcass weight of calves between the areas was not significantly different in 1993–1999. However, in 2000–2009 male calves were significantly lighter (12%) in area 2 than in area 1. An explanation for these differences could be the difference in summer food but the difference of lichens in winter food, area 1 in favour could be part of it. The proportion of calves of

\[^{11}\] Changing carcass weight to body weight: TBW = 5.9 + 1.66 x carcass weight (Reimers 1997).
Figure 76. Comparison of pre-rut mean total body weight (pre-rutTBW) of 2+ year old reindeer females with different ancestry in Norway; wild (green), mixed (violet), domestic (blue) (Reimers, 1997; 2013) and Icelandic (area 1; dark blue, area 2; red).

Females/yearlings in July counts was significant higher in area 1 in 2010 and 2012 in the period 2002–2013 (Þórarinsdóttir & Ágústsdóttir, 2015).
7.5 Vegetation and grazing

Egilsson (1983) concluded that the vegetation in Jökuldalsheiði (area 1) was more productive than on Fljótsdalsheiði (area 2). Lichens were more abundant, and their mean cover was higher in winter- and spring grazing areas of Jökuldalsheiði (Egilsson, 1983). Crowberry (*Empetrum nigrum*) and Arctic willow (*Salix arctica (= callicarpea)*) had greater cover in Jökuldalsheiði but moss cover on Fljótsdalsheiði (Egilsson, 1983). When gravel areas were excluded, it was clear that the average annual habitat use in home and core ranges of GPS-collared females in area 1 and 2 differed. In area 2, Carex moors and peatbogs were the most common habitats in home and core ranges of reindeer, whereas in area 1 Salix heathlands were the most common.

Information on summer grazing by reindeer in area 2 was investigated by Egilsson (1983). He found that the main species consumed were Stiff sedge (*Carex bigelowii*), Arctic willow (*S. arctica*) and Dwarf willow (*S. herbacea*). Rumen analyses showed a dietary difference between the two herds in September, February and in May (Egilsson, 1983). In area 1 diet was dominated by lichens, especially *C. islandica* while monocotyledons (mainly *C. bigelowii*) and to some extent dwarf-shrubs dominated the diet of reindeer in area 2 (Egilsson 1983). Similar results are seen in two populations in Greenland (Lund et al., 2000). The main difference between the vegetation of the two herds in Iceland is believed to be the limited availability of lichens in Fljótsdalsheiði due to overgrazing, whereas in Greenland differences were likely driven by climate (Egilsson, 1983; Lund et al., 2000).

On Fljótsdalsheiði grasses (mainly Smooth meadow-grass (*Poa pratensis*)) were the main food item in autumn to spring, with increasing proportion of dwarf-shrubs, such as Mountain Avens (*Dryas octopetala*), crowberry and Trailing Azalea (*Kalmia procumbens*) (Egilsson, 1983). A diet of low forage quality in Fljótsdalsheiði (area 2) could be responsible for the lower body weight of females in February in this area, 16% lighter than in Jökuldalsheiði (Klein, 1968; Thing, 1984; Egilsson, 1983; Þórisson, 1983).

A high abundance of lichens in winter pastures is thought to have a positive effect on the condition of reindeer (Skogland, 1985). A winter diet dominated by dwarf-shrubs could
possibly affect the wear of teeth. Increased particulates on the vegetation in summer because of dust blown from shores of the water reservoir Hálslón could also increase the wear of teeth of reindeer grazing in the summer pastures on Vesturöræfi and Kringilsár- and Sauðárrani. This could affect the utilization of the food (Cuyler unpubl., in Lund et al., 2000). In Iceland, it is likely that ash from volcanic eruptions blown over the reindeer pastures could affect the wear of teeth. No comparison has been done of tooth wear between area 1 and area 2. Because of airborne dust from the Hálslón lagoon to adjacent summer grazing area monitoring of tooth wear could become crucial (Vebjörn et al., 2007).

A detailed description of grazed plant species by reindeer in area 1 and area 2 at different times of year in 1980–1981, based on the only available study (Egilsson, 1983) is to be found in Appendix 10.4. The results from that study are already nearly four decades old. Detailed studies are needed to update our knowledge of what reindeer are eating at different time and places today.

After 35 years, utilization of Icelandic moss for more than a decade and increasing number of reindeer in area 1, it is more than timely to check the present situation of the vegetation. There are no indications of improvement of vegetation on Fljótsdalsheiði (Óskarsdóttir, 2017). On the contrary, the herd left the autumn and winter grazing areas in 2010 and moved to the east side of the glacial river Jökulsá í Fljótsdal. Some emigration occurred over to area 1 as seen by ear tagged females in Jökuldalsheiði tagged as a newborn calves on Fljótsdalsheiði (Pórisson & Þórarinsdóttir, 2011).

A detailed discussion of the utilization of Icelandic moss and competition between reindeer and humans is to be found in Appendix 10.5.

7.5.1 Summer grazing of sheep and reindeer

After the culling of sheep in 1990 because of the disease scrapie (transmissible spongiform encephalopathies), the number of sheep in Fljótsdalur has not reach the same number as before (Figure 77) (Sæmundsen et al., 2014). With new sheep and fewer individuals after 1992, the carcass weight of lamb in autumn was higher than before 1990 at the farm.
Mælivellir in Jökuldalur valley - around 17 kg in the beginning but decreased down to around 15 kg as the sheep increased in number.\textsuperscript{12} These sheep graze in summer in the winter pastures of reindeer in area 2.

Most of the sheep from the farm Aðalból in Hrafnkelsdalur valley graze on Vesturöræfi. The estimated total number of sheep on Vesturöræfi in summer 2013 was 500–1000. Gísli Pálsson farmer at Aðalból claims\textsuperscript{13} that their number has decreased the last decades. The average number of winterfed sheep in East Iceland in 2002 to 2013 was 77233 (73934–80680).\textsuperscript{14}

It is difficult to evaluate the impact of sheep grazing on reindeer. Decreased number in recent years of sheep in the highlands could possibly be beneficial for the reindeer. Comparison of carcass weight of ram lambs and reindeer females show the same trend between area 1 and 2, with individuals both reindeer and sheep on area 1 being significantly heavier.

A closer comparison of food selection between sheep and reindeer can be found in Appendix 10.4.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{sheep_number_fljotsdalur.png}
\caption{Sheep number in Fljótsdalur community 1990–2011 (Sæmundsen et al., 2014 (Picture1-5, p. 7)).}
\end{figure}

\textsuperscript{12} Sigurður Jónsson, Mælivöllum, pers. com. 17\textsuperscript{th} of February 2016.
\textsuperscript{13} pers. inform. March 2014
\textsuperscript{14} http://www.rml.is/is/bufjarraekt/skyrsluhald/saudfjarraekt/skyrsluhald
7.6 Factors that could affect reindeer populations in the future

Changing abundances of other wild herbivores than reindeer in East Iceland and climate change could influence the dynamics of reindeer populations in the future. In next chapters a will discuss couple of them in more details.

7.6.1 Pink-footed Goose in East Iceland and reindeer

Since the middle of the last century the Greenland/Iceland Pink-footed Goose population has grown from ~30,000 to ~393,000 in autumn 2014\textsuperscript{15,16}. At the same time, the number of geese has increased in the reindeer pastures in East Iceland (Skarphéðinsson & Þórisson, 2001; Stefánsson & Þórisson, 2015). Increased grazing pressure of the geese worries many sheep farmers, especially on the most crowded areas like Eyjabakkar area, Vesturörfi area and Kringilsárrani area, which are also the principal summer grazing areas of Snæfellsherd. In 2010, Stefánsson & Þórisson (2010) estimated the number of Pink-footed Goose in East Iceland in late summer to be around 100,000 individuals. Most of these geese graze in the same pastures as the reindeer of Snæfellsherd.

Will increased numbers of the Pink-footed Goose on the East highland plateau affect the physiological condition of the reindeer in Snæfellsherd in the future or affect the distribution of reindeer from May to September? Combined monitoring of the Pink-footed Goose and the reindeer by EINRC could answer this question in the coming years.


\textsuperscript{16}http://jncc.defra.gov.uk/pdf/UKSPA/UKSPA-A6-18.pdf
7.6.2 Greening

Increased productivity of vegetation, i.e. greening, has been detected in Iceland over the last three decades using remotely-sensed indices of vegetation greenness, such as the Normalized Vegetation Difference Index (NDVI, 1982–2010; Raynolds et al., 2015). The reasons behind these increases at the country level are thought to be reduction in grazing, afforestation, new land from retreating glaciers and warming climate. However, trends in NDVI are not homogeneous throughout the country or over time. From 2002 to 2013 there was a negative trend in greening (Raynolds et al., 2015). The main cause in East Iceland is believed to be drowning of vegetation under three water reservoirs of the Kárhnjúkar power project: Háslón (2006), Kelduárón and Ufsarlón (2008). Retreating glaciers and warming of climate have somewhat counteracted these changes. Ash from volcanic eruptions (Eyjafjallajökull, 2010 and Grímsvötn, 2011) had very little effect in East Iceland.

When looking at the two main summer grazing areas of reindeer in area 2, Vesturöræfi and Undir Fellum and the NVDI-index 1982–2013, the outcome is an increasing biomass of more than 0.02 kg/m²/a year or 0–0,0025 kg/m²/a year (Náttúrufræðistofnun Íslands, 2014). One of the reasons for the greening around Mt. Snæfell could the reduction in numbers of sheep in this area. In 1990 all sheep (ca 14000) were culled because of the disease scrapie between the glacial rivers Jökulsá á Dal and Jökulsá í Fljótsdal or the main part of the principal reindeer pastures in area 2 (Figure 77).
7.7 The use of GPS technology in wildlife studies

Telemetry studies with GPS and SMS technique give accurate results of how animals use the land. The main disadvantage is the cost, although GPS-collars for wildlife studies are becoming more affordable. The key question regarding choosing the sample size and hence affecting the cost is what proportion of the population is represented by GPS-collared individuals. For example, in 1999–2004 37 reindeer females (6–12 every year) were equipped with GPS collars to collect data on reindeer movements on Hardangervidda, Norway (Strand et al., 2005). The GPS-collared animals were believed to represent 70–80% of the population, but no actual estimates of these values were given (Strand et al., 2005). No other estimation was found in the literature dealing with the question on how big a proportion of the population is represented by certain number of GPS-collared animals.

The possibilities to observe reindeer in different times of year are better in East Iceland than in many other places because of intimate monitoring of the population (Þórisson & Þórarinsdóttir, 2011) and therefore easier to approach an accurate number. Turning on the GPS collars at the same time and using longer lasting batteries would clearly improve a project like this. The performance of GPS collars for fix rate can be influenced by topography and vegetation (Cain III. et al., 2005). There are some indications of lower fix rate in the valleys of the East fjords (Þórisson & Þórarinsdóttir 2016).

7.7.1 Home range

Year-round home range sizes of reindeer vary between populations, from 2000 km² in Manitoba, Canada (Schindler, 2005), to larger than 300–600 km² in Lapland (Kumpula & Nieminen, 1992). The results of this study of reindeer populations in Iceland lie somewhere in between, with 1424 and 1086 km² in area 1 and 2 respectively. The home range of Snæfellsherd differed between time periods, as it does in other populations (Schindler, 2005). Quality of available vegetation most likely affects the size of the home ranges for the different herds (Skarin et al., 2010). The size of home ranges for Icelandic and Greenland reindeer was similar (Tamsdorf, 2004; Cuyler & Linnell, 2004). The larger home and core ranges and faster travelling speeds in area 1 than in area 2 are believed to reflect better physical condition and differences in habitats between the two areas. More
surface is classified as gravel in area 1 and that is believed to be also the reason for faster travelling speed.

7.7.2 Movement analysis

In the years 2009–2011 the GPS collared females in area 1 travelled at average 2444 km/year while the females in area 2 travelled 2260 km/year or 7.5% shorter distance. At the same time the carcass weight of 3–5 years old lactating females in the hunt were 7.5% lighter in area 2 than area 1 (Þórisson & Þórarinsdóttir, 2014). These results indicate that more energy expenditure of the females in area 1 because of travelling didn't affect their physical condition.

There are no natural predators to disturb the reindeer in Iceland; the only cause of disturbance is of anthropogenic nature. That seems to be reflected in area 1 seeing how often the animals move beyond 5 km per 3 hours (1667 m/hour) at hunt but not as clear in area 2. Running in summer could possibly be explained with disturbance by tourism.

Comparison of movements of two reindeer herds in Greenland, in Akia (lichen rich diet) and Kangerlussuaq (lichen poor diet) showed the latter moving more around searching for lichens in winter and that behaviour was believed to affect their physical condition (Cuyler & Linnell, 1999). In Snæfellsherød it is vice versa, reindeer in area 1 travelling more although having plenty of lichens with no obvious effect on body condition.

In this study the step length is calculated from positions every 3 hours. It only measures the distance between these two positions not the wandering of the animal; therefore, it is a minimum movement. As the time between positioning decreases, we expect more exact information about the wandering of the animal. Positioning every 2 hours was believed to underestimate the step length by 40% (Skarin et al., 2010). In another study, step lengths for red deer decreased by 30% with position every hour (Pepin et al., 2004). Although the step length is based on the distance between positions and only gives minimum values, it is useful when comparing movements in different areas at different times but should be used with caution in comparisons were methods are different.
7.7.2.1 Comparison of movements of reindeer in Iceland and Norway

Movement analysis can be used to evaluate the effects of human disturbance, for example hunting, on reindeer populations (Strand et al., 2005). Average travelling speed (m/hour) seems to be very similar for reindeer females on Hardangervidda (mixed ancestry) and in area 1 (domestic ancestry). Reimers et al., (2012, 2013b) concluded that reindeer in Norway with predominantly wild ancestry had 2–3 times higher vigilance level than reindeer with domestic ancestry.

Comparison of travelling speed of 8 GPS-collared females in Snæfellsherd and 28 on Hardangervidda, Norway with positions every 3 hours at different time periods are shown in Figure 78. At all times the Norwegian reindeer move more. Travelling speed is comparable with both Swedish and Norwegian reindeer (Fallsdorf, 2013; Reimer et al., 2013; Skarin et al., 2010) except in summer when Icelandic reindeer move 20% slower than reindeer on Hardangervidda most likely because of absence of warble and mosquito flies, without them the Icelandic reindeer don’t move as much as the Norwegian do. Higher travelling speed at hunt in Norway could indicate the difference between origins. The ones of wild origins being more vigilant and "wilder" than the ones of domesticated origins. At the same time, the hunting pressure in Iceland is more intense. For example, hunting in Iceland is much more motorized than in Norway. The explanation of the difference in winter could be similar, the genetic origins but the absence of predators in Iceland could also make the reindeer tamer and less vigilant. The average travelling speed on annual basis is 17.4% less in East Iceland than on Hardangervidda (Reimers et al., 2012, 2013b).

Using the same information, but now comparing reindeer in area 2 and 1, suggests differences between the herds (Figure 78). As they are of the same origin the difference must be explained with variance in the environment and their physical condition. The females in area 2 moved less than the ones in area 1, in most periods except early summer and autumn. The reindeer in area 1, being heavier than reindeer in area 2, can use more energy on escaping from hunters but the hunting impact is also believed to be more intense not least because big areas are gravel with lot of tracks but area 2 has less gravel and more wetland that makes harder to use vehicles. Individual differences are also obvious (Figure
These differences make accurate comparisons difficult, especially when the sample is small.

Figure 78. Average speed (m/hour) in different time periods on Hardangervidda in Norway (Fallsdorf, 2013) and in two herds in Iceland (Þórisson & Ásgústsdóttir, 2014). The Icelandic data adjusted to the Norwegian time periods.

A comparison of two population of reindeer in Norway, one of domestic ancestry and another of wild ancestry showed significant differences in average travelling speed (Reimers et al., 2013b). Comparison with reindeer in area 1 and 2 showed the Icelandic herds to resemble more the one of domestic ancestry. During the hunting period, reindeer in area 2 had almost the same average travelling speed as the ones of domestic ancestry. The reindeer in area 1 being closer to the ones of wild ancestry (Figure 79). The time periods used in comparing movements in Iceland and in Norway (Reimers et al., 2013b) are not completely the same as seen in Table 37 but believed to be close enough.
Figure 79. Average travelling speed (m/hour) in Iceland (area 1 and 2) and two herds in Norway, one with domestic ancestry the other wild ancestry (adjusted from Reimers et al., (2013b): table 1. p. 28.).

Table 37. Average travelling speed (m/hour) in area 1 and 2 and two herds in Norway, one with domestic ancestry the other wild ancestry (Þórisson & Ágústsdóttir, 2014 and the Norwegian information’s adjusted from Reimers et al., 2013b: table 1. p. 28).

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<thead>
<tr>
<th></th>
<th>Iceland</th>
<th>Norway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area 1</td>
<td>Area 2</td>
</tr>
<tr>
<td></td>
<td>D. ancestry</td>
<td>D. ancestry</td>
</tr>
<tr>
<td>Spring migration</td>
<td>16th April -7th May</td>
<td>267</td>
</tr>
<tr>
<td>Calving</td>
<td>8th May -7th June</td>
<td>172</td>
</tr>
<tr>
<td>Summer</td>
<td>8th June -31st July</td>
<td>372</td>
</tr>
<tr>
<td>Hunt</td>
<td>1st August-20th Sept.</td>
<td>553</td>
</tr>
<tr>
<td>Winter</td>
<td>16th Oct -15th April</td>
<td>184</td>
</tr>
</tbody>
</table>
7.8 The future

Around half of all reindeer found dead belonging to Snæfellsherd can be attributed to human causes. Effort is needed to reduce the number car accidents, collateral damage during hunting and remove dangerous wire/fences.

Climate change could (will) affect reindeer populations in the future, through its impacts on vegetation and climate. Warming in climate could possibly bring us insects that haunt most reindeer herds in the northern hemisphere like mosquitoes and warble flies (Skjønneberg & Slagsvold, 1968), also some unexpected endoparasites and diseases. Discovery in 2010 of the fox tapeworm *Echinococcus multilocularis* in Sweden (Lind et al., 2011) and Chronic Wasting Disease in Norway (Ricci et al., 2016) could be an indication of global warming effects. Increased records of the tick *Ixodes ricinus* in Iceland (Alfredsson et al., 2017), even one on a reindeer calf in autumn 2009, could also be a consequence of global warming. Alfredsson (2017) encouraged further surveys on wild mammals e.g. reindeer to better understand their role as potential host for *I. ricinus*. Orf (*Ecthyma Contagiosum*)\(^{17}\) outbreak in area 2 (at least 26% of all shot females) in 2016 (first time noticed) (Þórisson & Þórarinsdóttir, 2017) is another example that could also be related to climate change.

The Arctic and sub-arctic is believed to continue to warm more rapidly than the global mean (IPCC, 2014). Anthropogenic disturbances will increase in the future but with good planning and monitoring of the reindeer population it should be able to minimize the negative effects. Most likely, tourism will increase heavily in coming years and hopefully we will be able to manage it in a way that minimizes the disturbance on reindeer and nature.

\(^{17}\) A parapox-virus causing Ecthyma Contagiosum, common for decades in sheep in East Iceland.
8 Conclusions

Reindeer were introduced in the end of the 18th century to four places in Iceland but did not survive except in East Iceland. They were at the brink of extinction in 1940 and restricted to a small area close to the northeast corner of Vatnajökull glacier. In summer 2017 the population size was close to 6400 animals and dispersed all over East Iceland. Demographic data of the population show that the animals are healthy and in prime condition benefiting from the absence of parasitic insects and natural predators. Plenty of food, suitable grazing habitats and very little competition in winter grazing also ensure the survival of reindeer populations. The largest part of the Icelandic reindeer population belongs to Snæfellsherdi, which roams the highland plateau of East Iceland. Snæfellsherdi broke up into two herds, more or less separated in area 1 and area 2. Comparisons of the two herds show that animals in area 1 are heavier than the ones in area 2, although the latter also seem to be in a good physical condition. The reason for the difference is believed to be difference in habitats and food intake. Very sparse lichen cover in area 2 shows that reindeer in Iceland can thrive well almost without lichen. To secure a strong and healthy reindeer population in Iceland the hunting quota must be based on animal density and food availability in the different reindeer pastures. Hunting is necessary because without hunting, I presume that climate variation in connection with overgrazing in winter pastures would be the main driver of the population dynamics especially since there are no predators around. I presume that without limits to the population growth the reindeer in East Iceland would soon become an invasive species.

Analysis of data presented in this thesis indicates that present monitoring of the reindeer population and the management strategy fulfils the goal of maintaining a sustainable reindeer population in Iceland. In the future, the aim should be to improve data collection from hunting and monitoring changes in environmental factors connected to global warming, especially in relation with grazing and health of the reindeer. One should bear in mind that low genetic diversity in the Icelandic population could limit adaptability to rapid ecosystem changes and emerging pathogens.
9 References


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Náttúrustofa Austurlands (2018). Útgefið efni. Viewed on 26th of April 2018:
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Nellemann, C., Vistnes, I. & Thórisson, S. (2000). Environmental impacts of the Fljótdalur and Kárahnjúkar hydro-electric power supply to an aluminum smelter by Norsk Hydro in Iceland - Preliminary assessment of impacts on reindeer. (A study initiated upon a formal request from members of the Icelandic parliament to NINA and NLH to solicit our evaluation and conduct a preliminary assessment of potential environmental impacts of hydro power development in Iceland) (unpubl.).


132


10 Appendices

10.1 Predicted calving date based on GPS-collared females

Predicted calving day (yellow bar) from average distance between positions every 3 hours in May, for each of the GPS-collared females. The yellow bars show the minimum movement of the female in May and is believed to be the day of calving (Figure 1–8).

![Figure 1. Movements of Ána in area 1 in May 2010, yellow bar show the minimum movement.](image1)

![Figure 2. Movements of Ranga in area 1 in May 2010 and 2011, yellow bars show the minimum movement. In 2011 Ranga was seen running with a calf on the 15th of May.](image2)
Figure 3. Movements of Hlíðarenda in area 1 in May 2010.

Figure 4. Movements of Gríma in area 2 in May 2009 and 2010, yellow bar show the minimum movement.
Figure 5. Movements of Heiða in area 2 in May 2009, yellow bar show the minimum movement.

Heiða, area 2

Figure 6. Movements of Ása in area 2 in May 2009, yellow bar show the minimum movement.

Ása, area 2
Figure 7. Movements of Hnefla in area 2 in May 2009, yellow bar show the minimum movement.

Figure 8. Movements of Stína in area 2 in May 2010, yellow bar show the minimum movement.
10.2 Home range of GPS collared females in Snæfellsherd at different times
The whole year

Winter

Spring migration

Calving

Summer

Hunting time

Rutting time

Autumn

ANA (472 days)
10th of January 2010 to 26th of April 2011

Core range (50% KDE*)
70% KDE
90% KDE
Home range (95% KDE)

*KDE= Kernel Density estimation
2013/2017 Kristín Agústsdóttir
Base map data, I550V©Landmælingar Íslands
The whole year | Winter | Spring migration
---|---|---
Calving | Summer | Hunting time
Rutting time | Autumn | HEIDA (380 days)
18th of March 2009 to 1st of April 2010
- Core range (50% KDE*)
- 70% KDE
- 90% KDE
- Home range (95% KDE)

*KDE= Kernel Density estimation
2013/2017 Kristín Agústsdóttir
Base map data, I550V©Landmælingar Islands
The whole year

Winter

Spring migration

Calving

Summer

Hunting time

Rutting time

Autumn

STINA (138 days)
21th of March 2010 to 5th of August 2010

Core range (50% KDE*)
70% KDE
90% KDE
Home range (95% KDE)

*KDE = Kernel Density estimation
2013/2017 Kristín Ágústsdóttir
Base map data, ISOSV©Landmælingar Islands
10.3 Used habitat at different times based on GPS-collared females

Used habitat at different times based on GPS-collared females and Icelandic Institute of Natural History (INH) vegetation mapping, in area 1 and area 2, both fore core and home range (Figure 1–3).

Figure 1. Proportional division of habitats is based on the INH vegetation mapping in the home (95% of positions) and core range (50% of positions) for females in area 1 and 2 compared with the whole area.
Calving  Summer  Hunt  Rut  Autumn  Winter  Spring

Calving  Summer  Hunt  Rut  Winter  Spring

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Percentage in Core Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moss land</td>
<td></td>
</tr>
<tr>
<td>Carex and Kobresia moors and heathlands</td>
<td></td>
</tr>
<tr>
<td>Bogs</td>
<td></td>
</tr>
<tr>
<td>Heaths</td>
<td></td>
</tr>
<tr>
<td>Carex and Kobresia moors and heathlands</td>
<td></td>
</tr>
<tr>
<td>Bogs</td>
<td></td>
</tr>
<tr>
<td>Betula nana moor and heathlands</td>
<td></td>
</tr>
<tr>
<td>Grassland</td>
<td></td>
</tr>
<tr>
<td>Wetland</td>
<td></td>
</tr>
<tr>
<td>Salix moors and heathlands</td>
<td></td>
</tr>
<tr>
<td>Planted and fertilized</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>Inland marshes</td>
<td></td>
</tr>
<tr>
<td>&lt;10% vegetated</td>
<td></td>
</tr>
<tr>
<td>Gravel, moraine</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Proportional division of habitats is based on the INH vegetation mapping in the core range (50% of positions) for females in area 1 (Norðurheiðahjörð) and 2 (Fljótsdalshjörð) at different times of the year.

Calving  Summer  Hunt  Rut  Autumn  Winter  Spring

Calving  Summer  Hunt  Rut  Winter  Spring

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Percentage in Home Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moss land</td>
<td></td>
</tr>
<tr>
<td>Carex and Kobresia moors and heathlands</td>
<td></td>
</tr>
<tr>
<td>Bogs</td>
<td></td>
</tr>
<tr>
<td>Heaths</td>
<td></td>
</tr>
<tr>
<td>Carex and Kobresia moors and heathlands</td>
<td></td>
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<tr>
<td>Bogs</td>
<td></td>
</tr>
<tr>
<td>Betula nana moor and heathlands</td>
<td></td>
</tr>
<tr>
<td>Grassland</td>
<td></td>
</tr>
<tr>
<td>Wetland</td>
<td></td>
</tr>
<tr>
<td>Salix moors and heathlands</td>
<td></td>
</tr>
<tr>
<td>Planted and fertilized</td>
<td></td>
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<tr>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>Inland marshes</td>
<td></td>
</tr>
<tr>
<td>&lt;10% vegetated</td>
<td></td>
</tr>
<tr>
<td>Gravel, moraine</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Proportional division of habitats is based on the INH vegetation mapping in the home range (95% of positions) for females in area 1 (Norðurheiðahjörð) and 2 (Fljótsdalshjörð) at different times of the year.
10.4 Grazing by reindeer and sheep

10.4.1 Reindeer food in area 1 and 2

In 1980–1981 80 reindeer were shot to study the grazing of reindeer. It was a part ecological study to evaluate the impacts of Hydropower plans in the East highlands on the reindeer population and was conducted by the INH (Egilsson, 1983; Þórisson, 1983; Egilsson & Þórisson, 1983).

In area 1 food samples were collected in September, February and May 1980–1981 in Jökuldalsheiði (Figure 1). Also, four food samples from hunter’s, reindeer shot in Brúaröræfi, migrating from summer grounds in Kringilsárrani area to autumn/winter grounds in Norðurheiðar were studied (Egilsson, 1983).

The percentage of plants grazed by reindeer was also studied at the same time in area 2 (Figure 2). Samples were collected in September, February and May as in area 1 but also in summer (July-August) in the principal summer grazing pastures in area 2 (Egilsson, 1983).
Most consumed plants were Stiff sedge (*Carex bigelowii*) 29%, Arctic willow (*S. arctica*) 22% and Dwarf willow (*S. herbacea*) 12% (Egilsson, 1983). Nothing is known about the summer food of reindeer in area 1, which stayed during summer on the west side of the glacial river/water reservoir Jökulsá á Dal/Hálslón in Kringilsárrani area. This area has a natural protection against sheep grazing (the river Kringilsá or Sauðá) but there is increasing grazing pressure by Pink-footed Goose (Stefánsson & Þórisson, 2013; Óskarsdóttir, 2016). No driving or reindeer hunting are allowed in the area since it was protected by law in 1975\(^\text{18}\). Hálslón water reservoir drowned 25% of that total area in 2007.

A terminal moraine traversing the area formed in 1890 is called "Töðuhraukar", which means a moraine with high dense grasses. That was a true name in 1939 (Valtísson, 1945) but this description no longer holds. Heavy grazing pressure could be one of the reasons why reindeer left the area (Þórisson & Ágústsdóttir, 2014). A comparison of selected plant groups (% grazed) by reindeer in summer 1980 in Vesturöræfi and east of Mt. Snæfell is shown in (Figure 3).

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\(^{18}\) Stj.tíð. B, nr. 524/1975

https://www.ust.is/library/Skrar/Einstaklingar/Nattura/Fridlysingar/Kringilsarrani,%20eldri.pdf
In September the main difference in food consumption between the areas are lichens being 64% in area 1 with (C. islandica 61%, Cetraria delisei 2%) and 22% in area 2 (C. islandica 9%, Cetraria delisei 12%). At the same time other plant items are much more common in Fljótsdalsheiði, like dwarf shrubs 16% (Salix herbacea 9%, S. arctica 6%) and sedges 23% (mainly C. bigelowii 21%). Mosses comprised up to 9% of food items in Fljótsdalsheiði and only 3% in Jökuldalsheiði. Since mosses are not usually eaten by reindeer, this could be explained by incidental consumption by reindeer when grazing small and sparse lichens (Egilsson, 1983).
Comparison of autumn grazing in September 1980 shows significant differences (p<0.05) between all food groups except grasses and fungi (Figure 4, Table 1).

The difference in February is like September but more striking. Lichens represented 46% in area 1 (C. islandica, 38%) but only 3% in area 2. Instead dwarf shrubs made the bulk of the diet in area 2, 40% (Kalmia procumbens, 9%, E. nigrum 8%, Dryas octopetala 7% and unidentified small branches 11%). Gramineae made up to one third of the diet in both areas with P. pratensis representing 13% and 14% of the diet in area 1 and 2, and Festuca rubra comprising 9% of the diet in both areas. Cyperaceae score a little higher in area 2, 14% than area 1, 9% with Carex bigelowii being the main species (10% and 9%). The same goes for the mosses in February as in September (Figure 4) (Egilsson, 1983).

![Figure 5. Plant groups selected (% grazed) by reindeer in February 1981 in area 1 and area 2 (Egilsson, 1983).](image)

Females were shot in early May 1981 to observe the food items. The situation was like February with a lot of snow. The difference of food was also like February except Cyperaceae was now 18% (C. bigelowii 13%) in area 1 against 7% in area 2 (C. bigelowii 4%). Gramineae differed being 33% in area 2 but 23% in area 1 with P. pratensis the main species (17% and 12% respectively). Grazing on dwarf shrubs is like February except it decreased in area 1 from 40% to 26%. Still, lichens were the main food item in area 1 (48%), three times higher than in area 2. Comparison of plant groups grazed by reindeer in early May 1981 in area 1 and area 2 (Egilsson, 1983) is shown in Figure 6.
10.4.2 Comparison of food intake by reindeer in area 1 and area 2

In the food study in 1980–1981 (Egilsson, 1983) there was a significant difference in most instances between plants grazed in September, February and May. The amount of grazed Monocotyledons was similar in February and May in both areas (Table 1) (Egilsson, 1983).

| Table 1. Reindeer food intake in area 1 and 2 in 1980–81 (combined tables 40, 43 and 46 in Egilsson, 1983). |
|--------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | area 1 | | area 2 | | comparison of area 1 and 2 |
| | n | area 1 | n | area 2 | t | df | p |
| Dwarf shrubs | | | | | | | |
| September | 9 | 6 | 10 | 16 | 3.28 | 17 | p<0.01 |
| February | 10 | 7 | 10 | 40 | 14.22 | 18 | p<0.001 |
| May | 10 | 5 | 10 | 27 | 9.86 | 18 | p<0.001 |
| Equisetum | | | | | | | |
| September | 9 | 2 | 10 | 9 | 4.25 | 17 | p<0.001 |
| February | 10 | 2 | 10 | 2 | 1.15 | 18 | n.s. |
| May | 10 | 2 | 10 | 4 | 2.37 | 18 | p<0.05 |
| Monocotyledons | | | | | | | |
| September | 9 | 21 | 10 | 36 | 3.51 | 17 | p<0.01 |
| February | 10 | 38 | 10 | 42 | 1.02 | 18 | n.s. |
| May | 10 | 41 | 10 | 39 | 0.14 | 18 | n.s. |
| Dicotyledons | | | | | | | |
| September | 9 | 3 | 10 | 8 | 7.2 | 17 | p<0.001 |
| February | 10 | 4 | 10 | 3 | 0.6 | 18 | n.s. |
| May | 10 | 1 | 10 | 4 | 3.54 | 18 | p<0.01 |
| Lichens | | | | | | | |
| September | 9 | 64 | 10 | 21 | 10.24 | 17 | p<0.001 |
| February | 10 | 46 | 10 | 3 | 4.11 | 18 | p<0.001 |
| May | 10 | 49 | 10 | 16 | 4.19 | 18 | p<0.001 |
| Mosses | | | | | | | |
| September | 9 | 3 | 10 | 9 | 5.81 | 17 | p<0.001 |
| February | 10 | 3 | 10 | 10 | 9.61 | 18 | p<0.001 |
| May | 10 | 2 | 10 | 10 | 6.7 | 18 | p<0.001 |

Figure 6. Plant groups selected (% grazed) by reindeer in early May 1981 in area 1 and area 2 (Egilsson, 1983).
10.4.3 Plant species grazed

Looking at the plant species grazed it becomes clear that three species made up the bulk of food for the reindeer: *Carex bigelowii*, *Cetraria islandica* and *Poa pratensis*. Together they constitute 27%–73% of the food at all times. The willow species *Salix arctica* and *S. herbacea* were also important, especially in summer and autumn (Table 2) (Egilsson, 1983).

Table 2. Main plant species grazed (≥5% of food items) on different time of year in area 1 and area 2, only area 2 in summer (pastures around Mt. Snæfell) (Egilsson, 1983). (Area numbers in brackets).

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Summer (2)</th>
<th>Autumn (1)</th>
<th>Autumn (2)</th>
<th>Winter (1)</th>
<th>Winter (2)</th>
<th>Spring (1)</th>
<th>Spring (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equisetum variegatum</td>
<td>7%</td>
<td></td>
<td>9%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carex bigelowii</td>
<td>29%</td>
<td>8%</td>
<td>21%</td>
<td>9%</td>
<td>10%</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>Calamagrostis neglecta</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Festuca rubra</td>
<td></td>
<td>8%</td>
<td>9%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poa pratensis</td>
<td></td>
<td></td>
<td></td>
<td>14%</td>
<td>13%</td>
<td>12%</td>
<td>17%</td>
</tr>
<tr>
<td>Dryas octopetala</td>
<td></td>
<td></td>
<td></td>
<td>7%</td>
<td></td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Empetrum nigrum</td>
<td></td>
<td>8%</td>
<td></td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loiseleuria procumbens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9%</td>
</tr>
<tr>
<td>Salix callicarpacea</td>
<td>18%</td>
<td></td>
<td>6%</td>
<td></td>
<td>6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salix herbacea</td>
<td>11%</td>
<td></td>
<td>8%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cetraria delisei</td>
<td></td>
<td></td>
<td></td>
<td>12%</td>
<td></td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>Cetraria islandica</td>
<td></td>
<td></td>
<td></td>
<td>61%</td>
<td>9%</td>
<td>38%</td>
<td>10%</td>
</tr>
<tr>
<td>Cornicularia aculeata</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7%</td>
</tr>
<tr>
<td>Racemium canescens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6%</td>
</tr>
<tr>
<td><strong>Σ</strong></td>
<td><strong>66%</strong></td>
<td><strong>74%</strong></td>
<td><strong>64%</strong></td>
<td><strong>69%</strong></td>
<td><strong>62%</strong></td>
<td><strong>46%</strong></td>
<td><strong>40%</strong></td>
</tr>
</tbody>
</table>

The main food items in the rumen of four females shot in autumn 1981 in area 1 (not included in Table 2, on Brúaröræfí was 39% *Salix arctica* and 26% *Calamagrostis neglecta*. This is quite different from plants grazed on Jökuldalsheiði with *Cetraria islandica* as the main food item (61%) in autumn.

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19 Kalmia procumbens
20 Salix arctica
21 Cetraria aculeata or C. muricata
10.4.4 Comparison of sheep and reindeer grazing

The plant species grazed by sheep were studied in July and August 1980 in the main reindeer summer pastures of area 2 (Vesturöræfi) based on shot animals (Þórhallsdóttir, 1981). Fistulised sheep were also used in 1981–1982 to study the plant selection in two areas in Fljótsdalsheiði, the principal autumn-spring pastures of reindeer in area 2. Around 70% of plants selected by sheep in Fljótsdalsheiði were sedges, willows and grasses. The main sedge was Carex bigelowii and the willow Salix arctica (= callicarpa). The main grass species were Festuca rubra and Calamagrostis neglecta (Þórhallsdóttir & Þorsteinsson, 1993). The comparison of plant selection by sheep and reindeer in the same area in summer is shown in Figure 7.

![Figure 7. Plant selection (% grazed) by sheep and reindeer in summer. From 12 fistulised sheep in two places (500 and 600 m a.s.l.) in 1981–1982 on Fljótsdalsheiði (Þórhallsdóttir & Þorsteinsson, 1993). Rumen samples from sheep (Þórhallsdóttir, 1981) and reindeer (Egilsson 1983) on Vesturöræfi in 1980.](image)

A closer look at the comparison between the diets of sheep and reindeer in Vesturöræfi show rather little difference in the plant groups selected. Sheep tend to graze more on grasses and reindeer on willows (Figure 8).
Figure 8. Plant selection (% grazed) by sheep and reindeer in summer. Rumen samples from sheep.
10.4.5 References


10.5 Icelandic moss (Cetraria islandica)

In ancient folklore two sister ogresses, one living in Jökuldalsheiði and the other in Fljótsdalsheiði lived on arctic char/trout and Icelandic moss. In a fight, one made the spell that all fish would disappear in Fljótsdalsheiði but fill the lakes in Jökuldalsheiði, but the other ogress cast the spell that all Icelandic moss would disappear from Jökuldalsheiði but become abundant in Fljótsdalsheiði (Sigfússon, 1982). I think there is some truth in many folklores so here is an indication of abundance of Iceland moss in Fljótsdalsheiði in the old days.

In 1794, Sveinn Pálsson (Pálsson, 1983) wrote that the people to the south of Vatnajökull glacier used to travel to Snæfellsöræfi to collect Icelandic moss. He also stated that the local people in Fljótsdalur valley went to the area Maríutunga close to the northern border of the glacier to collect Icelandic moss. These lichens are said to have disappeared in "Móðuharðindin" (Mist Famine/hardship) in 1783 when enormous amounts of gasses like poisonous hydrofluoric acid and sulphur dioxide compounds were released in the volcanic eruption of Laki. It was catastrophic both for vegetation and animals. It killed over 50% of Iceland's livestock population, leading to a famine which then killed approximately 25% of all Icelanders (Karlsson, 2000: p. 181).

The same information comes from the dean in Vallanes, Guttormur Pálsson, in his description of the dean’s district; "The utilization of Icelandic moss was widespread in Múlaþing [East Iceland] until 1783. The ash from the volcanic eruption in Skáftafellsþýslu [the Laki eruption] destroyed almost all Icelandic moss...." (Pálsson, 1947; p. 68). When the reindeer invaded this area around the turn of the 17th century it is unlikely that there was a lot of the Icelandic moss on the heathlands of East Iceland.

In the 1874 description of Hofteigs-, Möðrudals- and Brúarsókn, Ásgeirsson (2000) writes: “...Icelandic moss was a great benefit until 1830, now [1874] much less picked because of constant hardness in spring, autumn weathers, inhabitation in Jökuldalsheiði and because of the reindeer in Fljótsdalsheiði where they are the most numerous in Iceland”

22 A confusing name because it is lichen not a moss, the Icelandic name is Mountain grasses (fjallagrös).
Another big volcano erupted on Easter 1875 in Dyngjufjöll Mountain (the caldera Askja) and a huge amount of acidic ash was blown over East Iceland. The thickest ash layer close to settlement was in Jökuldalsheiði heath lands, up to 20 cm (Björgvinsdóttir, 2015) Before the ash, collection and use of Iceland moss was considerable but after the ash fell, collection stopped completely (Thoroddsen, 1922).

Just before the middle of last century there was a lot of Iceland moss growing on Fljótsdalsheiði. Local farmers collected it for human consumption. When the Snæfellsherd started to increase, grazing in autumn and winter in Fljótsdalsheiði local people claimed that the Icelandic moss decreased considerably and almost disappeared in the late 20th century (Benedikt Stefánsson (1907–1989) Merki, Jökuldal, pers. com. in the 1980th). In Egilsson (1983), there is a citation to Óli Stefánsson (1923–2016) a former farmer in Merki, Jökuldal, and the official reindeer hunter for the community, claiming that around 1935 it took a short time to fill few bags with Icelandic moss in the middle of Fljótsdalsheiði heathland (Móraðumelar). Lichens were regarded as sparse in Fljótsdalsheiði (Egilsson, 1983) and in the summer grazing areas around Mt. Snæfell (Guttormsson et al., 1981).

Icelandic moss was abundant in Jökuldalsheiði before the ash in 1875 (Stefánsson, 1947) and also considered abundant around 1980 (Egilsson, 1983). In the 19th century and beginning of the 20th people travelled from nearby communities to the heathlands to collect Icelandic moss (Finnsson, 2000). This was done mainly in June, after lambing and wool shearing and before the onset of haying and also in late summer/autumn.

Jökuldalsheiði moors and heathlands have lush vegetation compared to land at similar elevation elsewhere in Iceland. In many places lichens like Cetraria islandica and C. deliseii are abundant. This was one of the reasons for establishment of 16 farms in this area in 1841–1946 (Egilsson & Kristinsson, 1992).

In 1993, a local family got a license from landowners to utilize Icelandic moss on Jökuldalsheiði heathlands, both for domestic use and export and did so until 2006 (Gíslason, 2005). In autumn 2000, a new asphalt road was opened through Jökuldalsheiði,
one of the main winter grazing areas of reindeer in area 1. In the verdict from 19\textsuperscript{th} of November 1998 on the landowners claim of compensation because a new main road through their heathlands would damage their use of the land, especially regarding collecting Iceland moss. To explain the loss, they used information from the family who had been collecting lichens for many years. Their average harvest was said to be close to 1193 kg per year and the market prize was 1500 ISK/kg\textsuperscript{23} equivalent to around 2500 ISK (17.5 €) in February 2016\textsuperscript{24}. If a reindeer cow is 80 kg and daily food (dry weight) intake 2.1% of live weight\textsuperscript{25}, then 1193 kg could feed about 100 reindeer females eating exclusively Icelandic moss for a week in winter.

\textsuperscript{23} http://www.urskurdir.is/DomsOgKirkjumala/MatsnefndEignarnamsbota/nt/1288
\textsuperscript{24} https://www.landsbankinn.is/markadir/gjaldmidlar/gengisthroun/#/A/08-08-2015/08-02-2016/GVT-ISK/
\textsuperscript{25}http://deerfarmer.org/index.php/component/content/article?id=171:reindeer-feeding-and-nutritional-requirements
10.5.1 References


