024 BRIEF REPORT SERIES/KORTRAPPORT
NORSK POLARINSTITUTT 2012

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Brief Report Series/Kortrapport no. 24

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Editorial work: Åshild Ønvik Pedersen (Norwegian Polar Institute)

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Reference: Hansen, B.H., Veiberg, V. and Aanes, R. 2012. Material from harvested Svalbard reindeer. Evaluation of the material, the data and their areas of application for research and management. Norwegian Polar Institute Brief Report Series 24.

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Cover photo:	Svalbard reindeer, Brøggerhalvøya. Photo: Tore Nordstad/Norwegian Polar Institute
Printed:	May 2012
ISBN:	978-82-7666-289-4
ISSN	1504-3215

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Summary

This report evaluates biological material from reindeer harvested in Svalbard and discusses application areas for research and management. A collection of lower jaws located at the University of Oslo (UiO) covers most of the period 1984–2009. Some material is, however, currently missing from the collection. The available samples have been analysed for jaw length and age (based on tooth set and counts of *cementum annuli*) by the Norwegian Institute for Nature Research (NINA). A subset of the material has also been analysed previously (by different personnel) for molar height and dressed weight. The hunting material has broad applicability for research and management and represents an important resource for studying jaw lengths (i.e. body growth) in relation to climate, population density, hunting area, and sex and age structure of the harvested population. Based on preliminary analyses, there is clear variation between subpopulations and also clear climate signals in body growth. Though limited by a smaller sample size, similar information can be obtained from molar heights (e.g. tooth wear variation with sex, age, and climate) and dressed weights. Furthermore, the hunting statistics reflect spatiotemporal variation in sex-age distribution (of harvested animals) that could be of great interest for the management of this species on Svalbard. A standardised procedure for collection and handling of the material, including continuous sample analysis, is highly recommended.

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1. Background

Located at the northern distribution limit of reindeer and caribou (*Rangifer tarandus*), the Svalbard reindeer (*R. tarandus platyrhynchus*) is an endemic subspecies that has been isolated for a long period (since ~ the end of the last ice age; Røed 2005). Historical records suggest that reindeer were common across most of the archipelago when human activities (whaling) began in Svalbard in the 17th century. Unregulated hunting reduced the animal numbers dramatically, possibly down to ~1000 individuals (Governor of Svalbard 2009), and caused local extinctions before hunting was banned in 1925. Subsequently, many local ranges have been re-colonised and the animal numbers have gradually recovered. The total population size has been roughly estimated to the order of ~10,000 individuals (Governor of Svalbard 2009), but the estimate is based on poor data and does not take annual fluctuations into account.

Following the population recovery during the 20th century, a regulated hunting activity was initiated from 1983 onwards. Although originally initiated for research purpose, the hunting was generally carried out by locals with approval from the Governor of Svalbard and eventually became a “regular” recreational hunt from 1998. Hunters have been obliged (since 1983) to deliver the lower jaw from shot animals together with information about hunting area, date of shooting, animal sex and assumed age. The jaws (or more precisely, the teeth) are used for accurate age determination. In addition, measures of tooth wear may potentially indicate variation in foraging conditions (Loison et al. 2001) and life-history (Veiberg et al. 2007), and jaw length may serve as a measure of individual body size (in the absence of other measures). Although jaw length gives no information about seasonal variation in body condition, it gives a robust measure of each individual’s skeletal size. Unfortunately, the proportion of the hunted animals that is available in terms of jaw/teeth material and associated information varies considerably between years (for various reasons). Despite being incomplete, however, the existing material represents a valuable source of individual-based information from Svalbard reindeer in six hunting areas in the Nordenskiöld region, and the time series has potentially broad applications both within research and management.

The “simple” high-arctic tundra system in Svalbard is generally characterised by no or only insignificant predation, inter-specific competition and insect harassment, which makes the Svalbard reindeer a highly suitable model species for answering a number of basic and applied research questions. This includes issues related to climate, population ecology, and harvesting effects. It is well established that the population fluctuations are mainly shaped by a combination of density-dependence and variation in climate (by influencing the available resources: Reimers 1977; Aanes et al. 2000, 2002; Solberg et al. 2001; Tyler et al. 2008), as well as an effect of gastrointestinal parasites (Albon et al. 2002). However, little is known regarding these processes on the individual level, or how life-history traits vary with animal density or in time (annual variation and trends) and space (e.g. between populations). The hunting statistics and the material collected from shot animals represent an important source for such knowledge as well as a continuously updated basis for an adaptive management.

The Svalbard reindeer is considered a key environmental indicator and currently represents an important resource for recreation, tourism, research and harvest (Governor of Svalbard 2009). The recent management plan for Svalbard reindeer stressed the need for a systematic examination, analysis and evaluation of the available material from hunted reindeer (Governor of Svalbard 2009). In the present report, we summarise the available jaw/teeth material from the regular hunt on Svalbard reindeer during 1983–2009. We describe the type and extent of data that have been extracted from the samples and the lab-analytical methods used. Furthermore, we evaluate the areas of applicability for research and management and illustrate this through some examples based on preliminary analyses. Finally, we pinpoint sources of error or uncertainties and give some recommendations for future sampling, collection, handling and analysis of the material.

2. The material from harvested Svalbard reindeer

2.1. In the field (hunters)

In practice, all locals who passes a shooting test and apply to the Governor of Svalbard get a hunting permit for one animal. The number of permits have ranged between 136 (1983) and 344 (2009). The regular hunting period has been restricted to 15 August–20 September since 2008 (previously 20 August–10 September). Each particular hunting permit is additionally restricted to one out of six specific areas (Fig. 1), and to a specific age/sex class (currently classified into calf, yearling/female, and unspecified [free choice]). The proportion of the different age/sex classes in the total quota varies between years according to e.g. variation in calf production estimated from population surveys. For instance, the quota was set to 30% calves, 40% yearling/female and 30% free choice in 2009, whereas the low-productive years 2008 and 2010 had quotas of 10% calves, 40–50% yearling/female and 40–50% free choice. The number of shot animals has ranged from 105–238. Besides providing the lower jaw (cleansed for meat) and the information listed above (see *1. Background*) to the Governor of Svalbard, dressed weights (animal body weight excluding head, skin, viscera, metapodials and bleedable blood) were reported in some years.

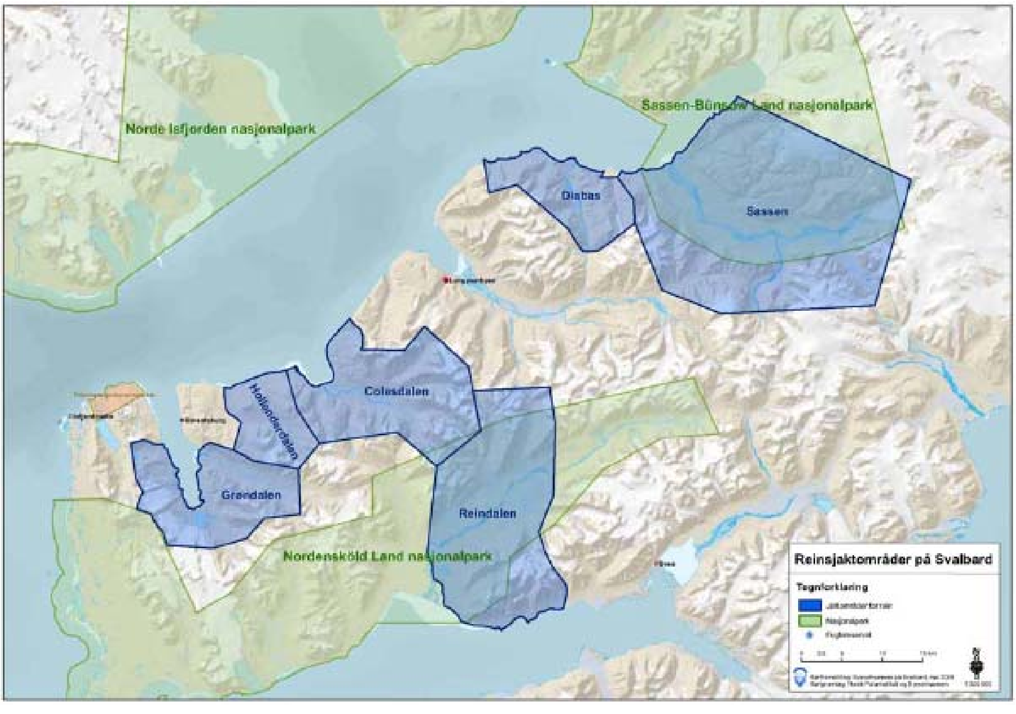

Figure 1. The six hunting areas (in blue) for the regular hunt on Svalbard reindeer. Note that Hollenderdalen was previously named Kapp Laila (until 2005). Source: Governor of Svalbard (2009).

2.2. Collection and availability of the harvest material

Most of the jaw/teeth material has been sent to the Natural History Museum (University of Oslo [UiO]) for preparation and storage. There are some missing years and other holes in the available collection. Firstly, no material seems to exist for the years 1983, 1985, and 1988–1990. Secondly, the material from 1994 was disposed following lab-analysis (R. Langvatn, Norwegian Institute for Nature Research [NINA]). Thirdly, material from 1991–1993 and 1995–1997 is located at the University of Tromsø (UiT, contact person N. J. C. Tyler) and has been unavailable until present. Fourthly, much of the available material is in poor shape (missing teeth, not marked etc.) and thus partly or completely unsuitable for analysis.

2.3. Lab measurements and associated data

A number of people at different institutions have performed various measurements of smaller or larger parts of the material. Material from 1984, 1986 and 1987 was analysed at the lab by N. A. Øritsland (NPI/UiO). The material from 1994 and 2002–2004 was analysed by R. Langvatn (NINA), including age determination from tooth sections. The remaining material until 2000 was analysed for NPI by O.G. Støen (measuring jaw lengths), and parts of the material have also been analysed by S. Henriksen (NPI) and R. Andersen (NINA). Finally, as part of the present project, V. Veiberg (NINA) analysed all the material available at the Natural History Museum (1984–2009) during 2010, providing data on age and total jaw length of samples for which this was measurable.

The currently established dataset consists of n = 3428 cases and is based on a compilation of the hunting data base of the Governor of Svalbard (background data) and the different sources of lab analyses described above. The background data provide information on animal id, shooting date (n = 2015), year (n = 3428), hunting area (n = 3249) and sex of the animal (n = 3081). Cases with unknown sex are of little value and are therefore excluded from the analyses in the present report. Besides age, additional data of potential importance from the lab analyses include jaw length, tooth measurements and dressed weights.

2.3.1. Age determination

There are two reliable methods of age determination based on jaw/tooth material from animals shot in autumn. Calves (hereafter age 0), yearlings (age 1) and most 2-year-olds can be aged based on the tooth eruption pattern (Fig. 2). Age of older individuals can be determined by counting annuli in the cementum of incisors (Reimers and Nordby 1968, Hamlin et al. 2000). The incisor roots are decalcified and stained before they are longitudinally sectioned with a rotary microtome. The slices are then glued to a microscope slide before they are read with a microscope. The age of each individual is then recorded as the number of annuli plus one, since the animals are one year old when their permanent incisors erupt. Age of older individuals may also be estimated based on tooth wear, but this requires a lot of practice and is less reliable, both due to the high spatiotemporal variation in tooth wear (see below) and individual variation in life-history (Veiberg et al. 2007). The available dataset contains ageing data from various personnel (often anonymous, hereafter NN), with some degree of overlap. One can distinguish between four sources of age determination which are listed with (assumed) decreasing reliability:

1. Age read by V. Veiberg and R. Langvatn based on tooth set of young animals or tooth sections (hereafter *known* age).
2. Age *estimated* by various people (including NN) based on tooth set of 0–1-year-olds.
3. Age *estimated* for > 2-year-olds by V. Veiberg based on tooth wear (no counts of cementum annuli).
4. Age estimated for > 1-year-olds by various people (not V. Veiberg) based on unknown methods, probably including estimation from tooth wear in the lab and estimation by hunters in the field.

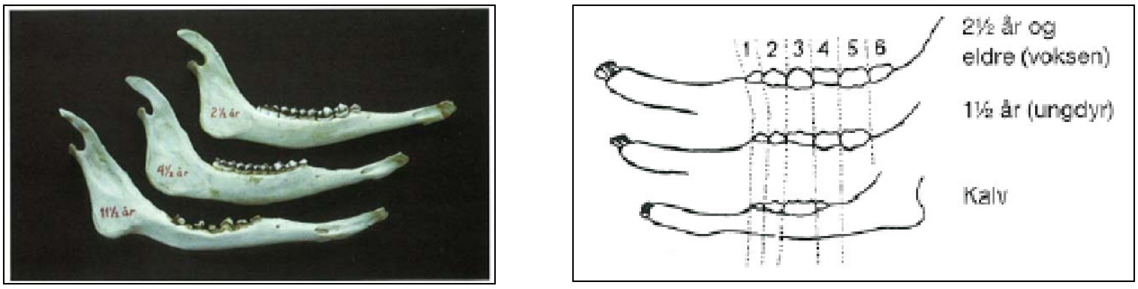

Figure 2. Left: Lower mandibles (jaws) from adult Svalbard reindeer showing an increase in tooth wear with age. Right: The characteristic molar tooth set in reindeer calves, yearlings and adults. Source: Governor of Svalbard (2009).

For cases where age is given in both categories 1 and 2, there is a high degree of correct age estimates for 0 year olds (98.4%, n = 366) and 1 year olds (92.4%, n = 354). For older ages, the proportion of matching cases is considerably less (not presented here). In the present report we therefore consider only cases falling into category 1 and 2 (with known sex) as adequately reliable for most areas of application. Including category 2 improves the dataset extent substantially by increasing the number of 0–1-year-olds (Table 1), mainly for 1991–1993 and 1995–1997 when very few data are available with ages in category 1 (Table 2). This is important for several areas of applicability for research and management, which rely on data from young individuals distributed in time (see below).

Table 1. Sample size (n) of the material from harvested Svalbard reindeer divided by age class and method of age determination. Known ages are from readings of tooth sets or tooth cross-sections by V. Veiberg or R. Langvatn, estimated ages are from various methods by various people. The data are quite evenly distributed among the sexes (cases with unknown sex are excluded).

Age class	n – known age	n – estimated age	n – known and estimated age
0	314	109	423
1	349	134	483
2	354	120	474
3	247	136	383
4	177	192	369
5	115	144	259
6	101	84	185
7	63	50	113
8	42	35	77
9	22	23	45
10	25	45	70
11	12	21	33
12	17	31	48
13	6	7	13
14	6	8	14
15	2	20	22
16	3	3	6
17	-	2	2
Total	1855	1164	3019

As shown in Table 2, the data are unevenly distributed in time, with very few or no data from most years in the period 1983–1997. The reasons for this are described in section *2.2. Collection and availability of the material*. Note however that most of the material from 1991–1993 and 1995–1997 is currently located at NPI and will be available for analyses in the future.

Table 2. Sample size (n) of the material from harvested Svalbard reindeer by shooting year and method of age determination. Known ages are from readings of tooth sets or tooth sections by V. Veiberg or R. Langvatn, estimated ages are from various methods by various people. The data are quite evenly distributed among the sexes (cases with unknown sex are excluded).

Year	n – known age	n – estimated age (0–1 year)	n – estimated age (> 1 year)	n – known and estimated age
1983	-	-	-	-
1984	39	1	65	105
1985	-	-	-	-
1986	38	5	4	47
1987	9	7	27	43
1988	-	-	-	-
1989	-	-	-	-
1990	-	-	-	-
1991	-	24	95	119
1992	9	39	69	117
1993	15	36	51	102
1994	41	-	-	41
1995	1	33	102	136
1996	8	33	121	162
1997	9	33	76	118
1998	153	-	6	159
1999	141	-	14	155
2000	139	-	20	159
2001	127	9	30	166
2002	143	2	4	149
2003	161	-	-	161
2004	153	1	33	187
2005	79	-	30	109
2006	129	5	45	179
2007	150	1	35	186
2008	111	4	58	173
2009	200	10	36	246
Total	1855	243	921	3019

The spatial distribution of the dataset is shown in Table 3. The sample sizes from the six hunting areas range from n = 103 (Diabas) to n = 754 (Sassendalen) when only including the most reliable age determination methods (categories 1 and 2, see description above). Some data are available from outside the six hunting areas, e.g. occasional reports from hunting stations or animals shot for educational or research purpose; these were pooled for simplicity ("Other").

Table 3. Sample size (n) of the material from hunted Svalbard reindeer by hunting area and method of age determination. Known ages are from readings of tooth sets or tooth cross-sections by V. Veiberg or R. Langvatn, estimated ages are from various methods by various people. The hunting area “Hollenderdalen” was named “Kapp Laila” until 2005. The data are quite evenly distributed among the sexes (cases with unknown sex are excluded).

Hunting area	n – known age	n – estimated age (0–1 year)	n – estimated age (> 1 year)	n – known and estimated age
Colesdalen	313	52	162	527
Diabas	95	8	33	136
Grøndalen	146	22	112	280
Hollenderdalen	279	24	68	371
Reindalen	310	22	165	497
Sassendalen	640	114	368	1122
Other	72	1	13	86
Total	1855	243	921	3019

2.3.2. Jaw lengths, molar heights and dressed weights

Various measures of lower jaw lengths (1 mm precision) occur in the data set, with varying degree of overlap. First, *total jaw length* has been measured as the longest distance from the front of the incisor alveolar to the back of the jaw bone. There are two different sources (different columns in the dataset) of total jaw length with partial overlap; one read by V. Veiberg and one read by NN, of which the latter usually gives jaw length for both the left and the right jaw bone. Next, there are measurements of the length of specific parts of the jaw, read by O.G. Støen or NN. This includes e.g. *anterior jaw length* (the distance between the front of the incisor alveolar to the mid point between the back of the fourth premolar alveolar and the front of the first molar alveolar) and *posterior jaw length* (the distance between the mid point between the back of the fourth premolar alveolar and the front of the first molar alveolar, and the back of the jaw bone).

Sample sizes for the jaw length measurements are unevenly distributed among ages (Table 4), years (Table 5) and hunting areas (Table 6) and depend on which age determination methods are included. Including 0–1-year-olds with estimated ages (category 2) increases the sample size of total jaw lengths read by V. Veiberg from n = 214 to 259 (age 0) and n = 228 to 290 (age 1). When also including total jaw lengths read by NN, the sample increases slightly to n = 284 (age 0) and n = 310 (age 1). In order to avoid any observer effect, we hereafter consider only total jaw lengths read by V. Veiberg. Furthermore, we only consider total jaw lengths (and not posterior, anterior lengths etc.) for reasons of simplicity.

The height and length of the first molar has been measured sporadically for samples from the mid 1990s (Table 5), and almost exclusively from ≥ 1-year-olds (mainly estimated age; Table 4). There is thus a great potential for increasing the sample size and quality (through linkage to “known age”) of the molar data based on the material collection located at UiO and the samples currently located at NPI.

Dressed weights are only available from 1984, 1986–1987 and 1994 (Table 5) and mainly from animals ≥ 1-year-old (Table 4). How and by whom weights were measured is not known. Large variation within sex-age classes indicates that different methods are applied. For instance, there are some obvious outliers in the data that indicate a mix of undressed weights, partly dressed weights and fully dressed weights.

Table 4. Sample size (n) of total jaw length, dressed weight and molar height in the material from harvested Svalbard reindeer divided by age class and method of age determination (cases with unknown sex are excluded).

Age class	n – total jaw length (incl. est. ages 0–1)	n – total jaw length (incl. est. ages)	n – dressed weight (incl. est. ages 0–1)	n – dressed weight (incl. est. ages)	n – molar height (incl. est. ages 0–1)	n – molar height (incl. est. ages)
0	259	259	3	3	3	3
1	290	290	19	19	54	54
2	269	325	26	27	6	61
3	180	247	24	29	2	35
4	131	252	9	23	-	48
5	81	166	2	17	-	49
6	73	126	3	10	-	18
7	42	76	1	9	-	11
8	32	58	4	9	-	6
9	18	37	5	10	-	-
10	16	42	2	11	-	13
11	7	24	-	4	-	-
12	14	31	1	6	1	10
13	6	12	-	1	-	-
14	5	11	-	5	-	-
15	2	13	-	1	-	4
16	2	5	1	1	-	-
17	-	2	-		-	-
Total	1427	1976	100	185	66	312

Table 5. Sample size (n) of total jaw length, dressed weight and molar height in the material from hunted Svalbard reindeer divided by year and method of age determination (cases with unknown sex are excluded).

Year	n total jaw length (incl. est. ages 0–1)	n total jaw length (incl. est. ages)	n dressed weight (incl. est. ages 0–1)	n dressed weight (incl. est. ages)	n molar height (incl. est. ages 0–1)	n molar height (incl. est. ages)
1983	-	-	-	-	-	-
1984	39	97	29	85	-	-
1986	39	43	39	43	-	-
1987	15	37	16	41	-	-
1991	14	73	-	-	-	-
1992	35	82	-	-	19	69
1993	45	79	-	-	13	38
1994	32	32	16	16	-	-
1995	8	46	-	-	9	72
1996	13	64	-	-	14	82
1997	6	34	-	-	11	51
1998	126	129	-	-	-	-
1999	116	126	-	-	-	-
2000	117	130	-	-	-	-
2001	111	123	-	-	-	-
2002	124	125	-	-	-	-
2004	1	1	-	-	-	-
2005	63	88	-	-	-	-
2006	119	147	-	-	-	-
2007	132	160	-	-	-	-
2008	95	150	-	-	-	-
2009	177	210	-	-	-	-
Total	1427	1976	100	185	66	312

Table 6. Sample size (n) of total jaw length, dressed weight and molar height in the material from harvested Svalbard reindeer divided by year and method of age determination (cases with unknown sex are excluded). The hunting area “Hollenderdalen” was named “Kapp Laila” until 2005.

Hunting area	n total jaw length (incl. est. ages 0–1)	n total jaw length (incl. est. ages)	n dressed weight (incl. est. ages 0–1)	n dressed weight (incl. est. ages)	n molar height (incl. est. ages 0–1)	n molar height (incl. est. ages)
Colesd.	257	357	12	34	19	63
Diabas	82	98	-	-	2	16
Grønd.	109	181	9	30	3	34
Hollend.	198	233	2	2	7	24
Reind.	212	321	19	29	4	37
Sassen	515	724	55	87	31	135
Other	54	62	3	3	-	3
Total	1427	1976	100	185	66	312

3. Potential areas of application

The data associated with the Svalbard reindeer material have potentially broad applicability within research and management. Firstly, individual-based data on morphological traits related to body size and tooth wear can be studied in relation to climatic conditions, population density, hunting area, sex and age, cohort effects, and fluctuating or directional asymmetry (comparing left and right jaw lengths). Secondly, sex-age distributions of shot animals may enable detection of important demographic patterns in the populations studied. Thirdly, descriptive hunting statistics and how they vary in time and space could be of great interest for the management as well as the hunters. Some areas of applicability and applied examples based on simple preliminary analyses are given below.

3.1. Variation in body growth (jaw length)

Jaw length is the morphological trait that is clearly best covered in time and space by the material (Tables 5 and 6). Being closely related to body size in reindeer (Skogland 1983), jaw length measurements represent an important opportunity to study variation in individual growth of Svalbard reindeer. A few applied examples are given based on the total jaw lengths measured by V. Veiberg.

3.1.1. Sex-age patterns in jaw lengths

A statistically significant difference between the sexes in total jaw length (Fig. 3) appears already from age 0 ($t = 2.43$, $df = 256$, $P < 0.05$), although the effect size is small (157.7 ± 5.8 mm [mean ± SD] in male calves vs. 155.8 ± 7.1 mm in female calves). In females, there is an increase in jaw length until ~3 years of age ($t_{3vs2} = 3.66$, $df = 197$, $P < 0.001$, $t_{4vs3} = 1.05$, $df = 116$, $P = 0.296$). In contrast, male jaw lengths increase until ~6 years of age ($t_{6vs5} = 3.66$, $df = 97$, $P < 0.01$, $t_{7vs6} = -0.14$, $df = 68$, $P = 0.890$).

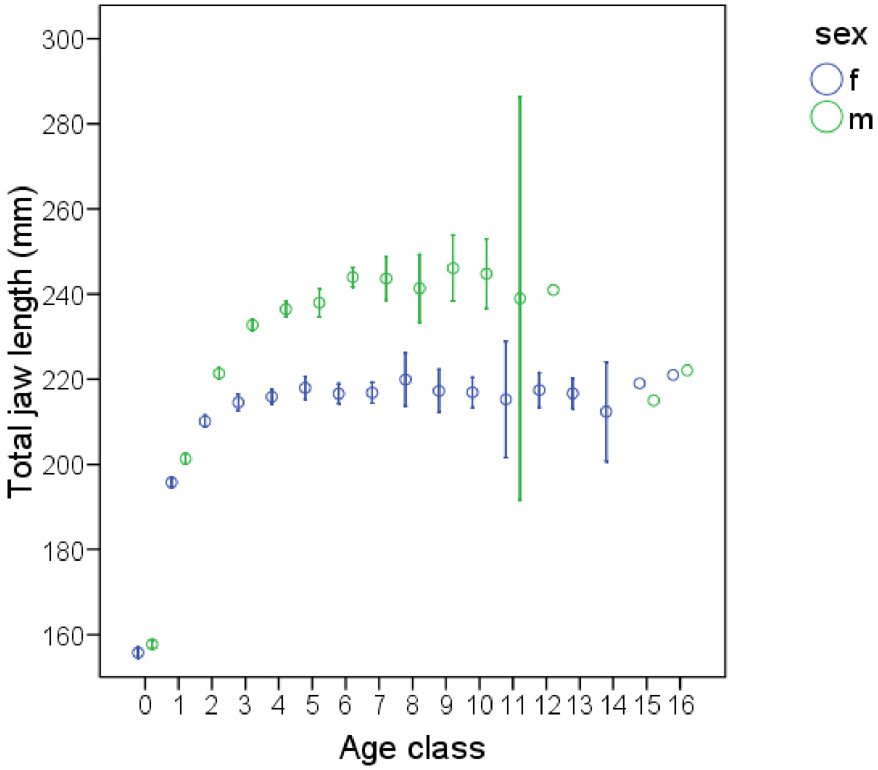

Figure 3. Mean total jaw lengths of hunted Svalbard reindeer categorised by sex and age class. Whiskers represent 95% confidence intervals. For sample sizes, see Table 4 (the figure includes samples with estimated ages 0–1).

3.1.2. Trends and climate signals in jaw lengths

When controlling for the age effects (classified as 2/3/4/5/6+ yrs), there is a tendency for a negative trend in total jaw length in adult males ($\beta = -0.184$, SEM = 0.096, Wald Chisq = 3.67, df = 1, P = 0.055) (Fig. 4). The estimated decline is however only ~1.8 mm per decade, the biological significance of which is questionable. Note also the small sample sizes prior to 1998 (particularly during the 1980s, which were excluded). No strong temporal trends appear for 0 or 1-year-old males or any of the female age classes (0, 1, 2 and 3+) (analyses not presented).

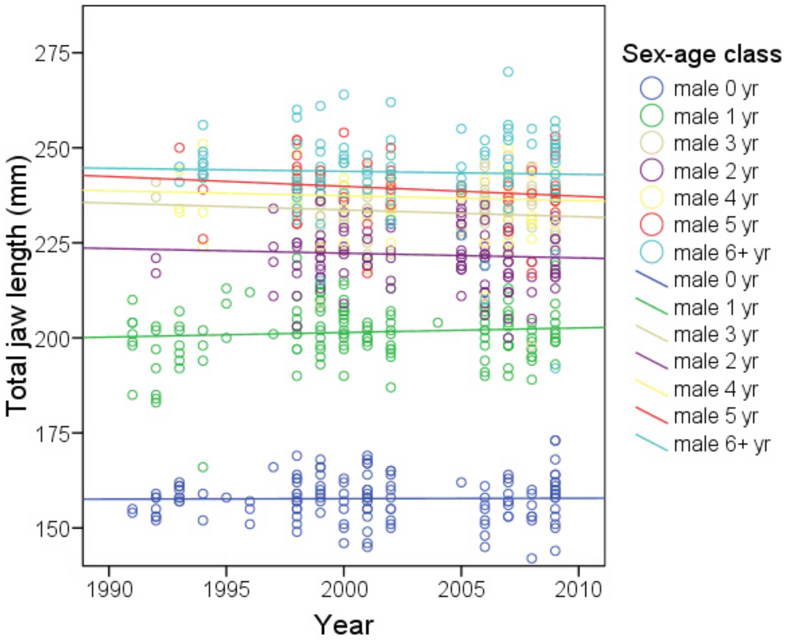

Figure 4. Temporal trends in total jaw lengths of hunted male Svalbard reindeer categorised by age class. Samples from the 1980's were few and thus excluded.

It is reasonable to expect some climate signals in calf and yearling (0–1 year) body growth and, hence, jaw lengths. Climate effects on calves could be expected to operate through (1) the previous winter's foraging conditions, by influencing the mother's body condition directly during pregnancy and subsequently during lactation, and (2) an effect of the current summer foraging conditions, possibly by influencing both mother and calf. Without accounting for potential density-dependent effects but controlling for sex and population (hunting area), calf jaw length seems to be related to a positive effect of July temperature in Svea ($\beta = 1.51$, SEM = 0.67, $t = 2.27$, $P < 0.05$) and a negative effect of the amount of precipitation falling the previous winter (October–April) at Longyearbyen airport (precipitation data not available for Svea) ($\beta = -0.038$, SEM = 0.017, $t = -2.28$, $P < 0.05$; Fig. 5). This suggests that both the preceding winter foraging conditions and summer foraging conditions influence calf growth, presumably through the negative effect of amount of winter precipitation on the mother's forage accessibility (Solberg et al. 2001) and the positive effect of summer temperature on forage abundance (Aanes et al. 2002; van der Wal and Hessen 2009), respectively. Note however that the mechanisms through which climate operates are not fully understood and that the present analyses are preliminary.

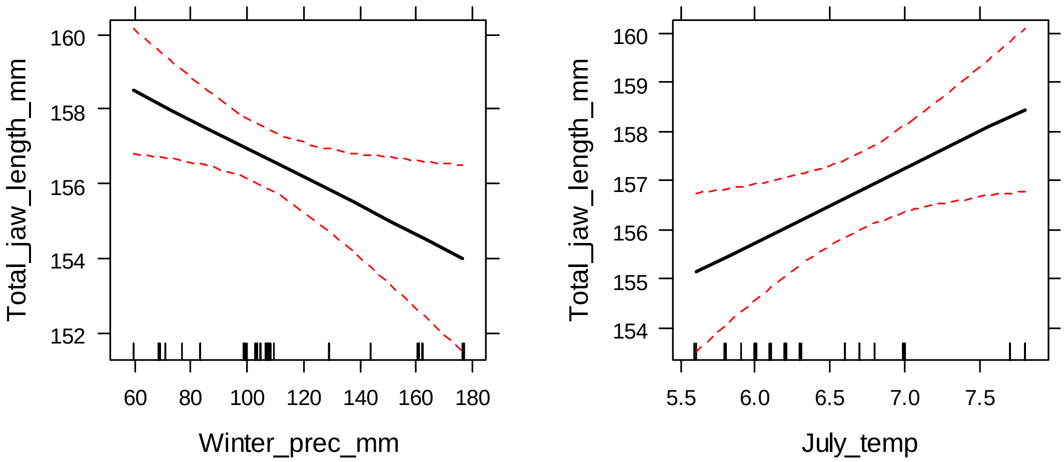

Figure 5. The effects of amount of winter precipitation (left) and July temperature (right) the respective year on total jaw lengths of Svalbard reindeer calves (age 0) shot in autumn, when accounting for the effects of hunting area and sex.

Also in yearlings, total jaw length seems to be related to the amount of precipitation falling the previous winter (β = –0.065, SEM = 0.016, t = –4.18, $P < 0.001$), combined with a tendency for a positive effect of July temperature the previous year (β = 1.34, SEM = 0.71, t = 1.88, P = 0.061; Fig. 6). The latter indicates that the summer foraging conditions following birth may have lasting effects on the body condition of Svalbard reindeer (i.e. a cohort effect).

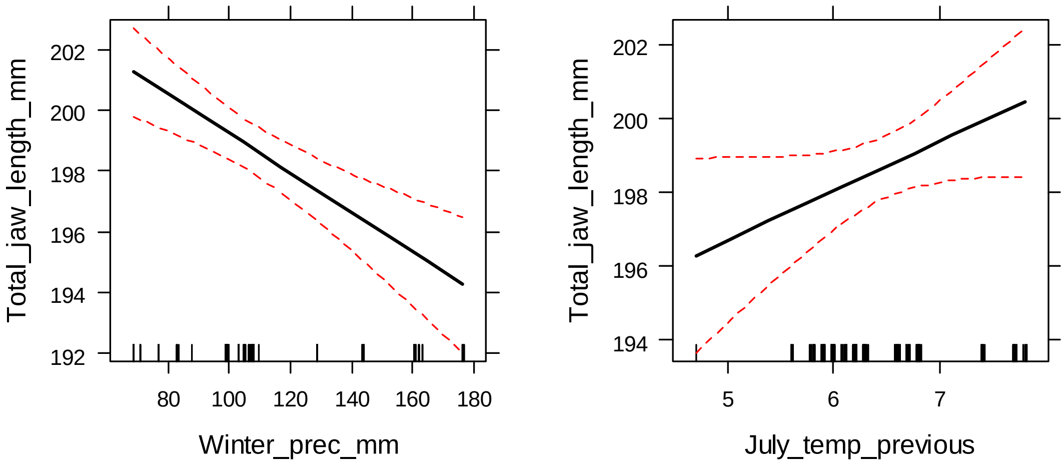

Figure 6. The effects of winter precipitation (left) and the previous summer's July temperature (right) on jaw lengths of reindeer yearlings in autumn, accounting for hunting area and sex.

The current dataset is probably too limited for a proper analysis of whether climate effects on the body size of young animals are long-lasting or compensated with increasing age. However, following a poor start in life, there seems to be compensatory and even over-compensatory growth (possibly enabled by postponed first reproduction) in females (Fig. 7). Note that the samples sizes are very small for certain cohorts/ages and that a proper quantitative analysis depends on the entire sample (1983-2009).

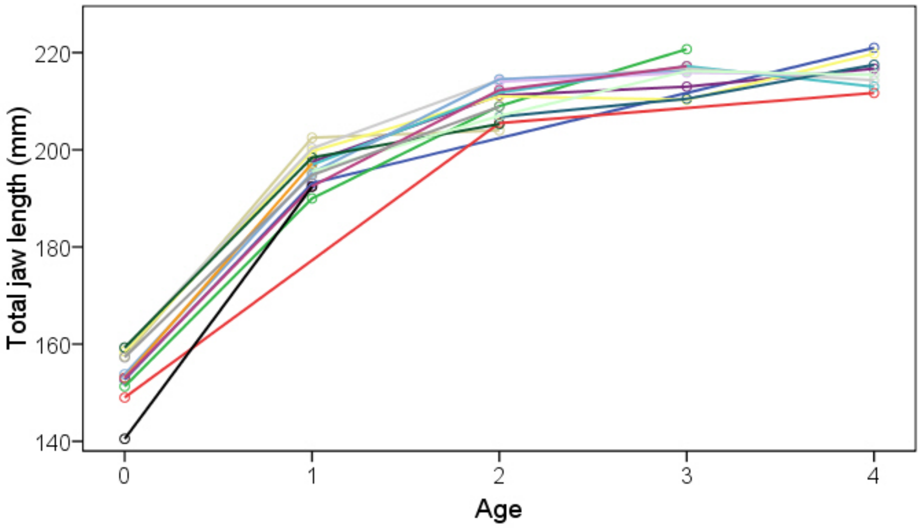

Figure 7. Changes in mean total jaw length with age for female cohorts (different colours for animals with different birth years).

3.1.3. Spatial variation in jaw lengths

When accounting for sex and year (random effect), the only statistically significant difference between hunting areas in calf jaw lengths were in Colesdalen versus Sassendalen (smallest in the latter; $\beta = 3.28$, SEM = 1.09, $t = 3.01$, df = 245, $P < 0.01$; Fig. 8). Calf jaw lengths were intermediately large in Hollenderdalen and Reindalen. Note that spatiotemporal variation in population densities is not accounted for. Also for yearlings, total jaw lengths were significantly smaller in Sassendalen versus Colesdalen ($\beta = 3.30$, SEM = 1.17, $t = 2.82$, df = 281, $P < 0.01$), as well as Hollenderdalen ($\beta = 6.15$, SEM = 1.28, $t = 4.79$, df = 281, $P < 0.001$). Yearling jaw lengths were also smaller in Reindalen than Hollenderdalen. The tendency for relatively small animals in Sassendalen seems present also for adult males and females (analyses not presented).

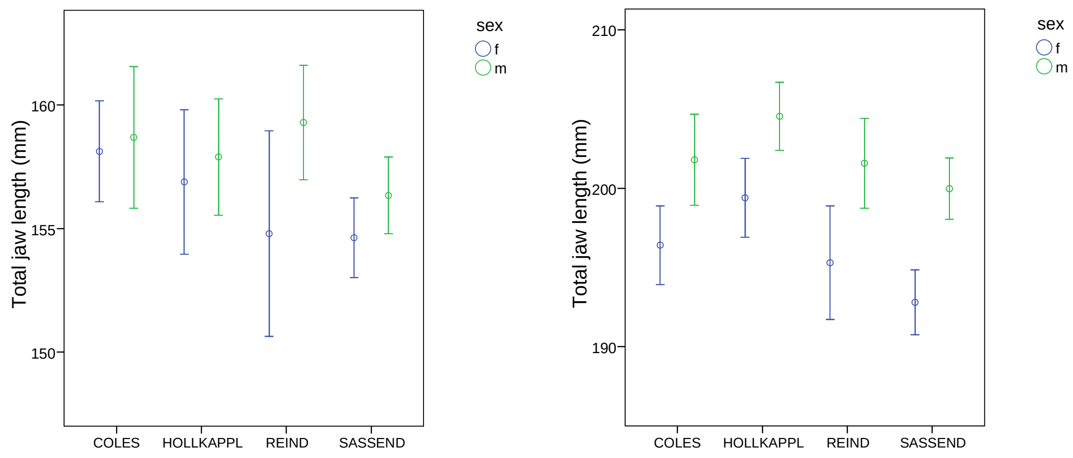

Figure 8. Mean total jaw lengths (± 95% confidence intervals) in Svalbard reindeer calves (left) and yearlings (right) from four hunting areas (other areas excluded because of small sample size). "Hollkappl" is Hollenderdalen (previously Kapp Laila).

3.2. Variation in tooth wear

Although measurements of molar heights are only available from five years in the mid 1990s, some temporal patterns are present (Fig. 9). In particular, molar heights are rather systematically smaller in 1997 than other years (across sex and age classes, and particularly among yearlings). The reason for this is not obvious. Effects of the poor foraging conditions during winter 1996 should have been apparent in poor teeth already in the subsequent autumn of 1996 (which is not the case) but could possibly explain the poor teeth in yearlings in 1997 (i.e. poor prenatal conditions, see above for jaw length growth). Clearly, analysing molar heights (a low-cost procedure) in the remaining samples for which this is possible and age is known would substantially improve the sample size, temporal coverage and, hence, ability to detect climatic signals and variation in tooth wear with age. Assessing changes in tooth wear with age is currently irrelevant (i.e. arguing in a circle) as long as the molar data used are from samples for which ages are estimated based on tooth wear (see sample sizes in Tables 4–6).

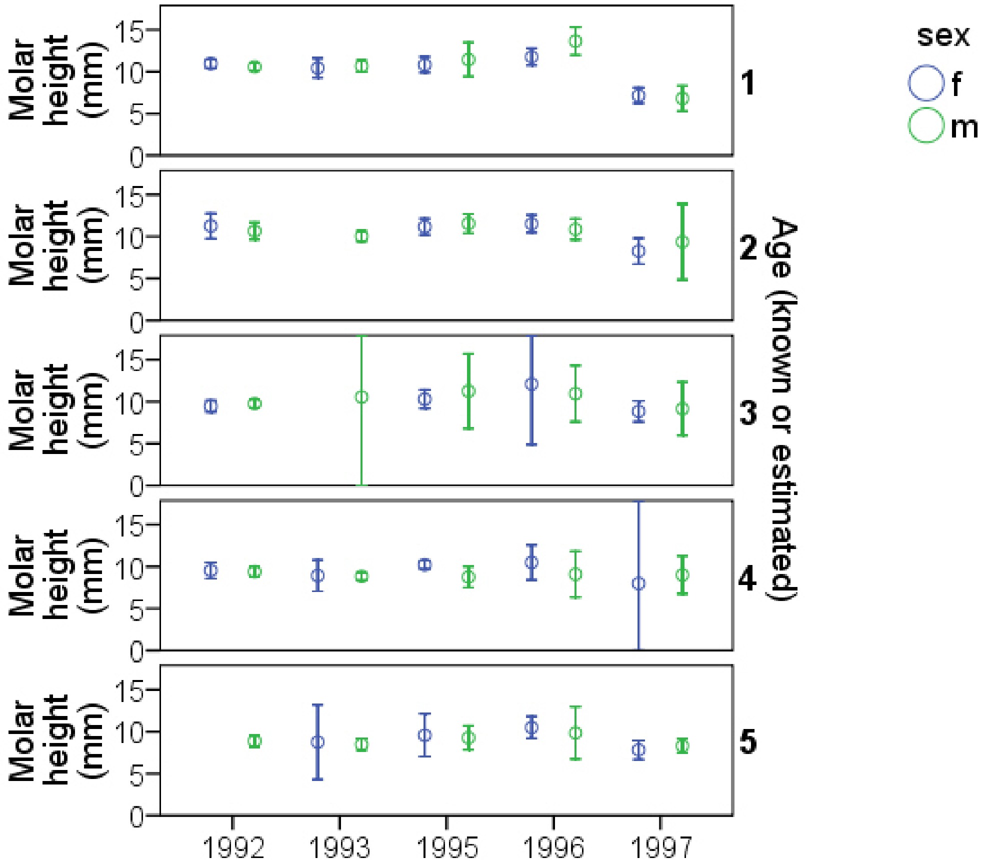

Figure 9. Annual variation in mean (± 95% confidence intervals) height of the left first molar of female and male Svalbard reindeer classified by age (including estimated ages). Older age classes are not shown (small sample size).

3.3. Variation in dressed weights

The data on dressed weights of shot animals are too limited (see Table 5) to allow for proper analysis of temporal variation and potential effects of climate, population density etc. However, some overall patterns can be detected, such as variation in weight with sex and age (Fig. 10), which is generally consistent with the pattern shown above for jaw lengths. Note that estimated ages must be included in order to have an adequate sample size. The apparent negative trend starting from age ~7–10 should therefore be interpreted with caution, although it could indicate senescence. As expected (Skogland 1983), the weights are fairly well correlated with jaw lengths (Fig. 11).

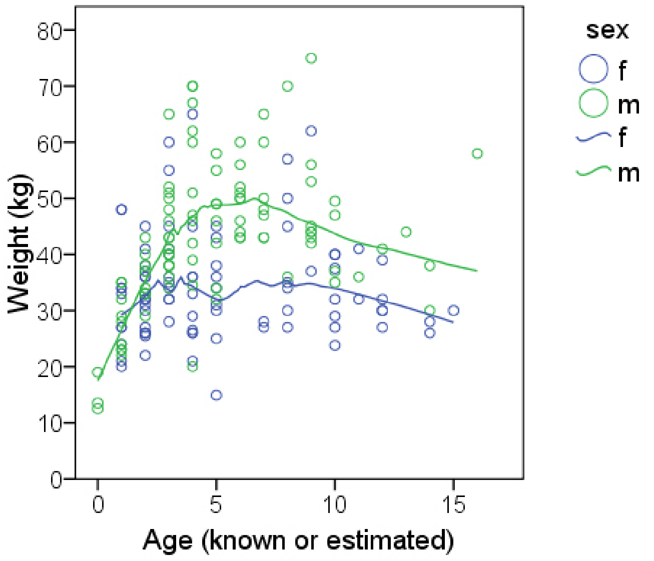

Figure 10. Weights of female and male Svalbard reindeer hunted in 1984, 1986, 1987 and 1994 as a function of age (including estimated ages). The weights are reported as dressed weights but probably also include partially dressed weights (a few obvious outliers were excluded).

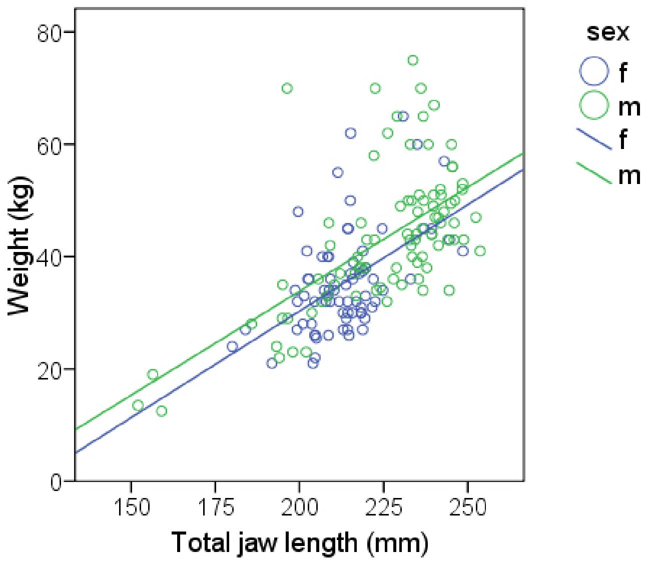

Figure 11. Weights of female and male Svalbard reindeer hunted in 1984, 1986, 1987 and 1994 as a function of the animal's total jaw length. The weights are reported as dressed weights but probably also include partially dressed weights (a few obvious outliers were excluded).

3.4. Age distributions

Because of biased sampling, it is unlikely that the dataset can be used for reliable reconstructions of the “real” population sex-age distributions. Important demographic patterns can however be detected, such as variation in sex ratio among calves and variation in adult age distribution within sexes. Assuming no change in the hunters’ preferences, it is likely that the sex-specific age distribution of shot adult animals adequately reflects the adult age distribution within the population. Large annual variation is evident in the age distribution of both females and males (Fig. 12). The changes can occur either gradually (e.g. the overall increase in age during ~2005–2009) or rather suddenly (particularly in females, e.g. 2004–2005). The median age of adults varies between 2–5 years in females and 2–4 years in males (Fig. 13) and seems to correlate somewhat between the sexes, yet not strongly (Spearman’s $\rho = 0.42$, $n = 12$, $P = 0.175$). How the age distributions relate to e.g. changes in climate, population densities and birth rates, and the potential implications of cohort effects, require complex analyses that are beyond the scope of this report. Note however that, e.g., the low proportion 2-year-olds in 1998/2004/2008 and 3-year-olds in 1999/2005/2009 (etc.) coincides with overall low birth rates (and relatively poor winters) in 1996/2002/2006.

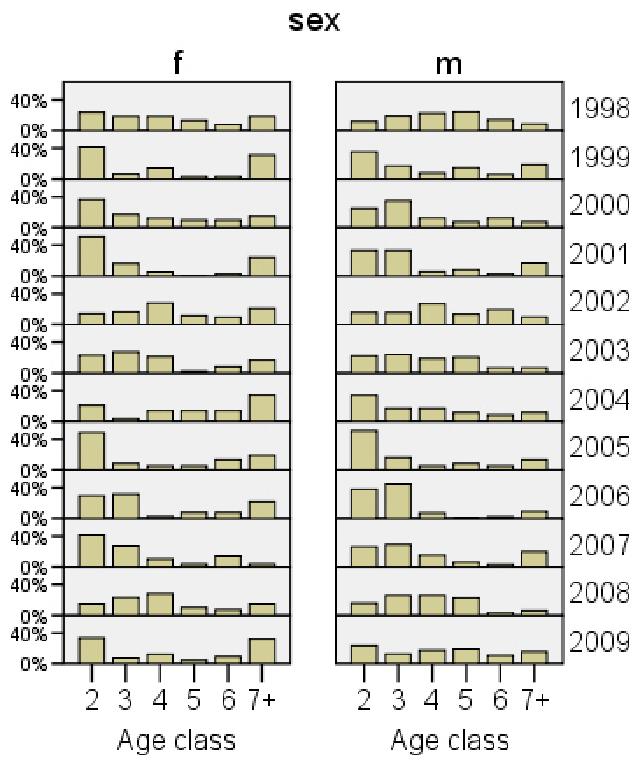

Figure 12. Annual changes in the proportion of different age classes in adult (≥ 2 years) females (left) and males (right) in the material from hunted Svalbard reindeer (only “known ages” included).

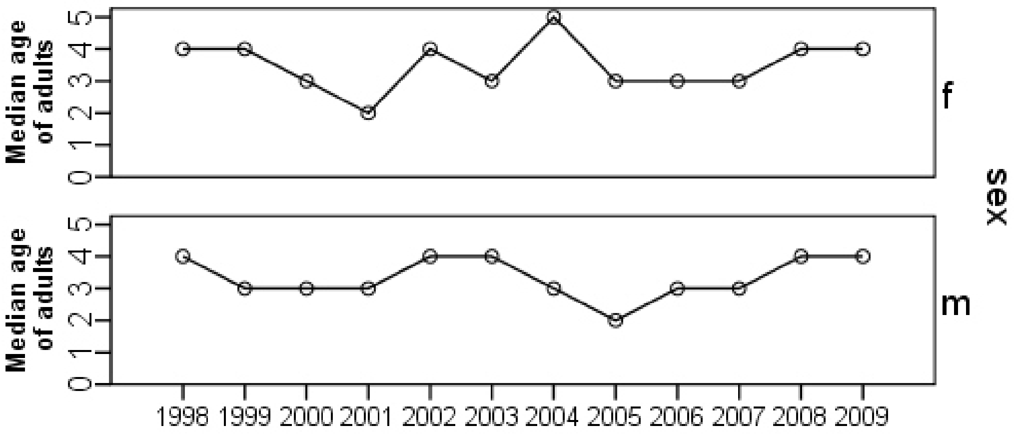

Figure 13. Annual changes in median age for adult (≥ 2 years) females (upper) and males (lower) in the material from harvested Svalbard reindeer (only samples with "known" age included).

3.5. Hunting statistics versus population survey data

Besides the demographic patterns that can be assessed from sex-age determination of shot animals (see examples above), the available databases provide various descriptive hunting statistics that are particularly useful when combined with the summer population surveys performed annually from helicopter by the Governor of Svalbard. The population surveys show a general increase in the number of animals between the late 1990s and the mid 2000s, followed by an overall population decline (Fig. 14a). Comparing the annual number of shot animals with the respective number of counted animals does not show a close relationship ($r = 0.23$, $P = 0.515$; Fig. 14b), but note that excluding 2009 (the outlier) gives a close to significant positive relationship ($r = 0.66$, $P = 0.052$). This is probably due to other factors than variation in the total quota *per se*, as all the hunters that apply (and pass the shooting test) get a permit for one animal.

If the aim of the hunting quotas is to "shoot through" the population, the proportion of e.g. calves among shot animals should lie fairly close to the proportion calves in the population, or possibly higher, as calves are the most difficult animals to spot and thus likely underestimated during counting. The proportion shot calves has however been systematically lower than the proportion calves counted in summer (although positively related; Fig. 14c). The shot versus counted regression coefficient is < 1. Thus, the increase in number of shot calves with number of calves in the population follows an asymptotic curve (Fig. 14d). Regardless of whether these relationships result from the quota settings, hunters' preferences/constraints, or a combination, they should be taken into account in future management and quota settings.

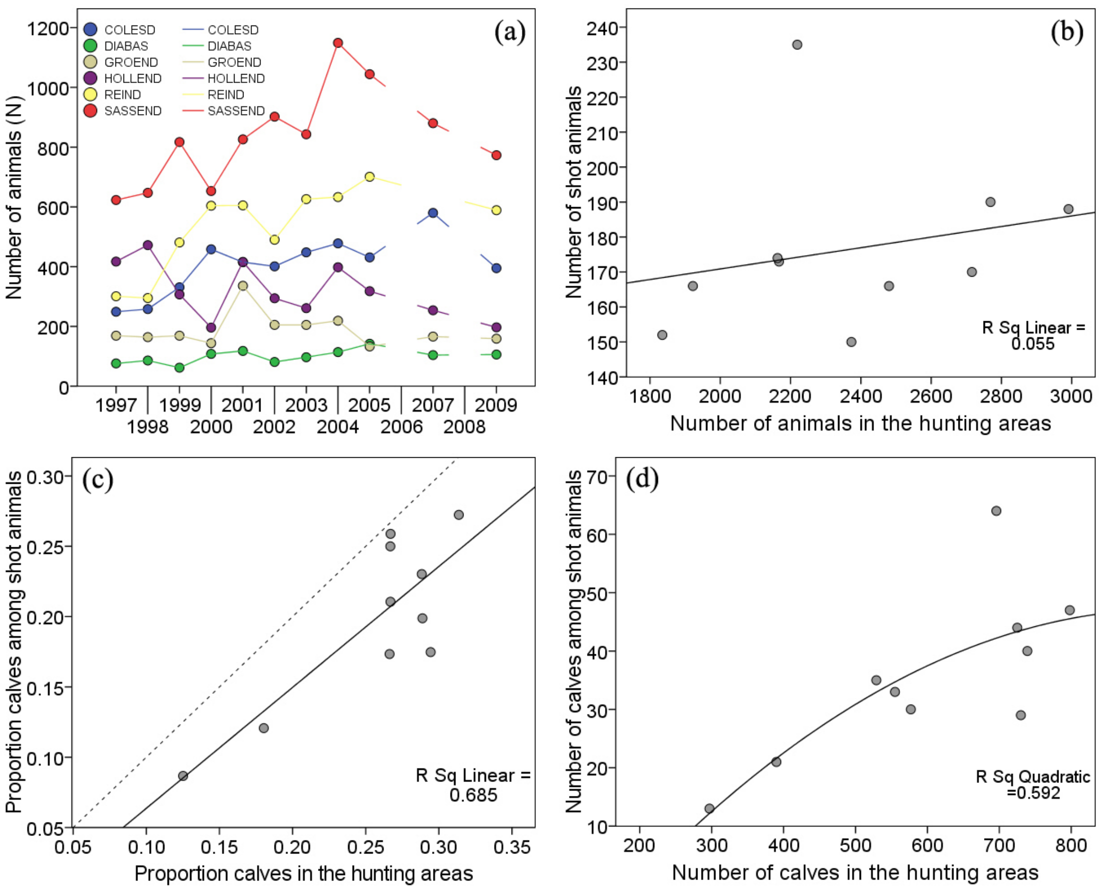

Figure 14. (a) Annual population size estimates in the six hunting areas made from helicopter surveys in summers 1997–2009 (no estimates in 2006 and 2008). Note that varying weather can influence the accuracy of the estimates and that Reindalen 2007 is omitted because of fog and poor visibility. **(b)** Annual number of shot animals fitted as a linear function of the estimated population size. The six hunting areas are pooled. 2007 was omitted because of low counting accuracy in Reindalen. **(c)** Annual proportion calves among shot animals fitted as a linear function of the proportion counted calves (1:1 relationship is displayed as a dashed line). **(d)** Annual number of shot calves versus annual number of counted calves fitted with a quadratic function.

4. Sources of error

- There are several potential sources of error in the dataset that should be taken into account in future analysis and when considering improvements of the sampling procedures. Some of these sources are listed here:
- The different methods of age determination performed by different people should be kept in mind when choosing which samples to be included in an analysis. We consider ages estimated to 0 and 1 year (even by NN) as adequately reliable, owing to the distinct tooth set in these age classes and the high accuracy when compared to “known” age. For many of the approaches listed above, however, it is highly important to avoid substantial systematic or non-systematic errors in age estimates of adults ($\geq$ 2 years), and it is recommended to exclude other age determination categories than 1 and 2 (see *2.3.1. Age determination*). Exceptions from this include analyses where the adult segment can be pooled (for each sex) or approximate ages are sufficient.
- The “dressed” weights are highly uncertain estimates made by NN and probably include partially dressed and undressed weights. Cautious interpretation of the data is needed, and future weight measurements should follow standardised procedures (see below).
- If jaw length measurements other than those performed by V. Veiberg are included in analyses, one should take into account the potential for systematic biases during handling/measuring (e.g. difference between left- and right-handed observers). A comment column in the dataset also indicates that many of the jaw lengths measured by NN are performed on non-boiled samples, which would probably give biased results.
- In several cases, the same id has been used for two or more individuals. If this could not be clarified based on the background data or measurements, these cases were registered with unknown sex and are thus not included in the analyses. However, it is reasonable to assume that other unknown errors also occur in the background data (id, sex, location, year). Although such sources of errors are not easily detected and their extent is unknown, they are likely insignificant when analysing large samples.

5. Recommendations

The material from harvested Svalbard reindeer and associated dataset can be greatly improved both retrospectively and through future sampling:

- Analyses of the remaining material (probably most of the 1991–1993 and 1995–1997 material) will significantly improve the time-series.
- The total collection should be analysed for molar heights, which is currently only measured for fractions of the material.
- One could consider including "dressed weight" as a mandatory part of the report form filled in by the hunters, but this should probably be discussed in advance with the hunters' organisation. A potential way to make this task easier for the hunters is to establish one or two weighing stations, e.g. in the harbour. This has proven to be an efficient tool on the mainland. A clear definition of "dressed weight" is needed to avoid bias and uncertainty. Standardised weight measurements would provide a precise proxy of body condition that over time will have great value both for the hunters, the management and within research.
- We strongly recommend that standardised procedures regarding collection and handling of the material be established.

6. Concluding remarks

In the present report we evaluated the available material and associated dataset from hunted Svalbard reindeer. We have outlined some important areas of application for research and management and discussed potential improvements. The jaw collection located at UiO covers most of the period 1984–2009, yet a significant amount of material is missing, incomplete or currently unavailable. Despite the limited sample size from parts of the study period, we have shown that the time series from the material represents an important source of information about this key stone species and its interaction with the environment. Thus, more detailed analyses integrating local population dynamics will likely improve our understanding of e.g. the effects of population density and climate, including the relative importance of changing conditions during the breeding versus non-breeding season. Furthermore, the effects of different hunting regimes on the population dynamics and structure are unknown, yet assumedly small. We demonstrate examples of how the information available from the hunting statistics, the material database and the annual population surveys can provide an important source of knowledge for the management, e.g. in terms of quota settings.

In order to improve the dataset's applicability within research and management, we recommend standardised procedures for collecting and handling the material. First, a continuous sample processing and analyses of age, jaw length and molar height of all samples should be established on an annual basis. Second, a systematic evaluation of the data and presentation of relevant results should be done on a regular basis. Establishing these routines will improve the relevance of the data series to the management and researchers, clarify areas of potential improvement, and strengthen the motivation among the hunters to perform proper data collection.

7. References

Aanes R, Sæther B-E, and Øritsland NA (2000) Fluctuations of an introduced population of Svalbard reindeer: the effects of density dependence and climatic variation. Ecography 23: 437–443.

Aanes R, Sæther B-E, Smith FM, Cooper EJ, Wookey PA, and Øritsland NA (2002) The Arctic Oscillation predicts effects of climate change in two trophic levels in a high-arctic ecosystem. Ecology Letters 5: 445–453.

Albon SD, Stien A, Irvine RJ, Langvatn R, Ropstad E, and Halvorsen O (2002) The role of parasites in the dynamics of a reindeer population. Proceedings of the Royal Society of London B 269: 1625–1632.

Governor of Svalbard (2009) Plan for forvaltning av svalbardrein. En beskrivelse av mål og status for reinen på Svalbard, og en veileder for forvaltningen og forskningen (in Norwegian). Rapport 1/2009. 49 pp.

Hamlin KL, Pac DF, Sime CA, and DeSimone RM (2000) Evaluating the accuracy of ages obtained by two methods for Montana ungulates. Journal of Wildlife Management 64: 441–449.

Loison A, Cuyler LC, Linnell JDC, and Landa A (2001) Sex, age, condition and tooth wear of harvested caribou *Rangifer tarandus groenlandicus* in west Greenland, 1995–1998. Wildlife Biology 7: 263–273.

Reimers E (1977) Population-dynamics in 2 subpopulations of reindeer in Svalbard. Arctic and Alpine Research 9: 369–381.

Reimers E, and Nordbye Ø (1968) Relationship between age and tooth cementum layers in norwegian reindeer. Journal of Wildlife Management 32: 957–961.

Røed KH (2005) Refugial origin and postglacial colonization of holarctic reindeer and caribou. Rangifer 25: 19–30.

Skogland (1983) The effects of density dependent resource limitation on size of wild reindeer. Oecologia 60: 156–168.

Solberg EJ, Jordhøy P, Strand O, Aanes R, Loison A, Sæther B-E, and Linnell JDC (2001) Effects of density-dependence and climate on the dynamics of a Svalbard reindeer population. Ecography 24: 441–451.

Tyler NJC, Forchhammer MC, and Øritsland NA (2008) Nonlinear effects of climate and density in the dynamics of a fluctuating population of reindeer. Ecology 89: 1675–1686.

van der Wal R, and Hessen DO (2009) Analogous aquatic and terrestrial food webs in the high Arctic: The structuring force of a harsh climate. Perspectives in Plant Ecology, Evolution and Systematics 11: 231–240.

Veiberg V, Mysterud A, Bjørkvoll E, Langvatn R, Loe LE, Irvine RJ, Bonenfant C, Couweleers R, and Stenseth NC (2007) Evidence for a trade-off between early growth and tooth wear in Svalbard reindeer. Journal of Animal Ecology 76: 1139–1148.