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Svalbard reindeer (*Rangifer tarandus platyrhynchus*) antler characteristics reflecting the local environmental conditions

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Abstract

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A new non-invasive method based on picture analysis was used to estimate the conditions in Svalbard reindeer populations. The well-being of an individual subject is often expressed through visual indices. Two distinct reindeer populations were compared based on their antler parameters. Relative antler size and number of tines are variables supposed to reflect correspondingly the environmental conditions of sedentary populations within the growing season. The occurrence areas of two studied populations are distinctly isolated – separated with high mountain ridges, glaciers and fjords. The population in Petuniabukta occupies a sparsely vegetated region with harsh climatic conditions, whereas Skansbukta represents an area with continuous tundra vegetation cover, milder climatic conditions and, consequently, also a longer vegetation season. These environmental factors probably caused significant differences in the relative antler size and number of tines in the studied species. The Skansbukta population exhibited a larger relative antler size and higher number of tines than the population in Petuniabukta (both parameters differed significantly, $p < 0.01$). This difference reflects concisely the different environmental conditions of both locations. A comparison of Skansbukta population antler characteristics between years 2017 and 2018 did not reveal significant changes, most probably due to very similar atmospheric conditions in these two years (in terms of air temperature).

Keywords

antlers, environmental conditions, population characteristics, Svalbard reindeer

Introduction

Svalbard reindeer

The Svalbard reindeer (*Rangifer tarandus platyrhynchus)* (Vrolik, 1829) is a species endemic to the Svalbard region. Comparing to its closest relative species in the continental Norway, the local Svalbard species is smaller, short-legged, (Groves et al., 2011). The shoulder height is approximately 90–100 cm in males, some 20% less than in the Norwegian subspecies (Wollebaek, 1926). The body mass in males is approximately 65 kg in spring and 90 kg in autumn, while the female body mass is approximately 53 kg in spring and 70 kg in autumn (Pedersen, 2018). The

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fat accumulated by the animals during the summer grazing period is then used during the winter months with low forage availability. Males lose 20–25% of their weight during their rutting period in October (Groves et al., 2011).

The Svalbard reindeer was close to extinction due to the extensive hunting in the early 1900ies. The overall population has increased thanks to strict protection measures after 1925 (Reimers, 1983,) and the latest estimation from the 90ies of the last century reports around 10,000 individuals (Tyler, 1993). The local population in Adventdalen, for example, has grown from about 600 individuals in 1975 to around 1,000 in 2007 (Tyler et al., 2008). Svalbard reindeer often stay in small groups of three to five individuals, except during winter, when they can form large feeding groups. Males usually prefer solitude, and they join the herds only during the rutting season. The rutting time begins at the end of September and is over towards the end of October (Wollebaek, 1926; Pedersen, 2018).

The diet of Svalbard reindeer consists of all types of vegetation, mostly the tundra vegetation – dominated by different grass species such as *Deschampsia* and *Poa*, mosses and some vascular plants (Staaland, 1984). Lichens are the main forage plants during winter season, when accessibility of other plants is limited (Hansen et al, 2009). Apart that, the Svalbard reindeer´s diet is complemented with vascular plants, woody plants, herbs and graminoids available under the snow cover (Reimers, 2012).

Antlers

Reindeer (also known as caribou in North America) is the only species from Cervidae that is growing antlers in males and females. This feature is a rather interesting fact in context of the sexual selection and male-male competition that is shaping the evolution of antlers (Plard et al., 2011). The females have developed antler for social reasons but also for defending their food sources during winters. The males exhibit larger and heavier antlers than females. The pedicles begin to grow very early, just in 7–10 days-old animals, and the first set of antlers appears in 4–6 weeks (Groves et al., 2011). The males and females begin to grow antlers from April to July, and clean their antlers of the velvet until far into August.

The reindeer well-being may be correlated with their antler size (both weight and length) and the number of tines as described for reindeers and other species of Cervidae. Because the antlers casting and regrowing each year mean high cost demands, there exists a very close relationship between the energy supplied for the antler growth and the current environmental conditions (see e.g. Andersson, 1994). Vanpé et al. (2007) described a good correlation between the antler size and the body mass on an example of roe deer. Decreased antler size related to harsh climatic conditions in deer has been reported by Pélabon and Van Breukelen (1998), Schmidt et al. (2001) or Mysterud et al. (2005). On this basis, the antler characteristics in reindeer populations have been recognised as a proxy of the population conditions, with certain limitations discussed later. Similar conclusion has also been reported by Thomas and Barry (2005) using the antler mass as a proxy of conditions for each individual.

Factors influencing Svalbard reindeer population

In most animal species, the population dynamics and fitness of individuals living in regions with harsh environmental conditions is usually driven by climatic factors (e.g. Peeters et al., 2017, Hlôška et al., 2016). The well-being of reindeer is a result of a wide range of environmental parameters influencing the reindeer ability to feed during the vegetation season. In general, the food availability and vegetation period length are important factors directly influencing the well-being of each individual. Considering the specific local environmental conditions, in the case of Svalbard reindeer, the main parameters influencing the feeding success in reindeer are: length of the summer vegetation season, total biomass production and atmospheric conditions as a general factor influencing above mentioned parameters. The overall population conditions are also considerably influenced by winter conditions significantly controlling the mortality. Snow depths of 50–70 cm represent the approximate limit for the cratering activity (Laperriere and Lent, 1977), which corresponds to the common snow depths in Svalbard being usually within these thresholds for cratering (Hansen et al., 2010). Therefore, the snow depth is not usually an important factor, as the mean snow depth in the coastal areas of Svalbard is usually less than 0.5 m. The main factor influencing the winter foraging success and mortality level is presence of icy layers within the snow pack. These layers have been recognised having a severe impact even on the domesticated reindeer (e.g. Sokolov et al., 2016). As stated by Hansen et al. (2010), more than 90% of the low-altitude environment in Svalbard could be covered with a thick ice coat on the ground (median thickness 9 cm). This often markedly reduces the numbers of calves surviving to the following summer (Tyler, 1987). Such an extreme climatic event can result in a 80% reduction of the population during winter (Chan et al., 2005). Winter conditions often represent a severe constraint even for populations of domesticated reindeer (Vuojala-Magga et al., 2011) from mainland regions.

The starvation occurs also due to worn out teeth from grazing on sparse vegetation among stones and gravel or on icy surfaces (Pedersen, 2018), which affects mainly the older individuals. Except polar bears (*Ursus maritimus*) which occasionally hunt reindeer (e.g. Derocher et al., 2000; Kavan, 2018) and Arctic foxes (*Vulpes lagopus*) (Eide et al., 2005) which kill new-born calves (Prestrud, 1992), reindeers have no predators unlike reindeers living in other regions (Reimers, 2012).

The density dependent food limitation is the second most important factor controlling the reindeer population characteristics in regions with populations completely recovered from the hunting period. Soldberg et al. (2008)

identified that the fluctuations in Svalbard reindeer population were due to the direct density dependent food limitation and also due to the variation in the winter climate associated with abundant precipitation and icing of the feeding range.

Environmental conditions in the study area

Almost 60% of the area of the Svalbard archipelago is covered by glaciers and ice caps, which makes its terrain rather inaccessible. Together with heterogeneous shoreline and steep mountain ridges, these terrain conditions are perfect for existence of relatively isolated reindeer populations. The topography and other spatial limitations have resulted in relatively isolated and sedentary local populations (Tyler and Øritsland, 1989). Such conditions are typical for the area, where the presented study was carried out.

Two isolated populations of Svalbard reindeer were studied in Billefjorden, central Svalbard (Fig. 1). Observation and monitoring were carried out during the second half of August 2017. The first population is located in the northernmost part of the fjord – Petuniabukta and in its neighbourhood (78°41'21.1"N, 16°32'21.9"E). The second one is rooted just in the mouth of the Billefjorden near Skansbukta – spreading along the coast about 4 km from Skansbukta to Rundodden (78°31'18.1"N, 16°00'23.2"E and 78°29'07.4"N, 15°56'43.3"E respectively). These two localities are only some 25 kilometres distant but isolated by several series of mountain ridges and ice caps, consequently, moving along the coast is not possible because of steep cliffs between the localities.

The first population in Petuniabukta is somewhat spread out in several different valleys around the bay with discontinuous vegetation cover. The valleys are divided by rather steep mountain ridges and many glaciers as well. The average annual air temperature in Petuniabukta in 2013–2015 was –3.7 °C, with a minimum of –28.3 °C (February 2015) and a maximum of 17 °C in July 2015 (Ambrožová and Láska, 2017). Additional information related to the local climate characteristics can be found in Láska et al. (2012). Even though the distance between the localities is just some 25 km, the climate in the Petuniabukta area is significantly colder (approximately 1 °C) shifted to higher continentality, which leads to drier conditions during vegetation season (Przybylak et al., 2014). The vegetation season itself is considerably shorter (by approximately 2–3 weeks) especially due to later dated meltdown of snow cover. This is caused by the permanent sea ice cover during winter blocking the inflow of relatively warm Atlantic water to Petuniabukta, whereas Skansbukta is exposed to warm sea water impact during most of the winter (Nilsen et al., 2008) (Fig. 2). Longer vegetation season with higher temperatures and precipitation leads to higher amount of more nutritious vegetation in Skansbukta region compared to Petuniabukta. There have been carried out numerous studies on the vegetation in the Petuniabukta locality – especially thanks to the presence of research facilities established in the Pyramiden town or Petuniabukta itself. The vegetation studies launched as early as before the World War II (Walton, 1922; Acock, 1940) have been proceeding until now (e.g. Prach et al., 2010; Prach et al., 2012 or Těšitel et al., 2014).

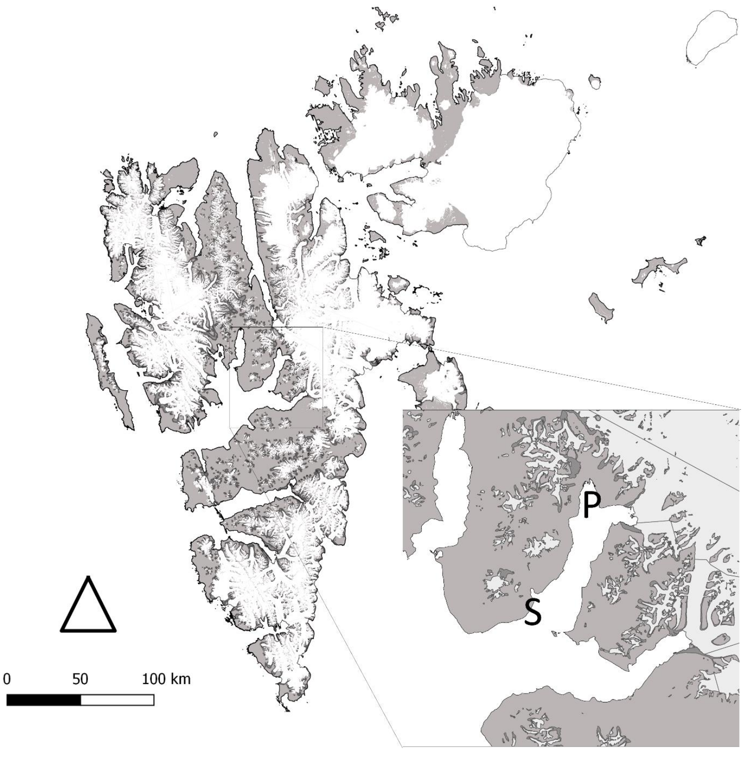

Fig. 1. Location of study area in central Svalbard, P indicates Petuniabukta, S stands for Skansbukta.

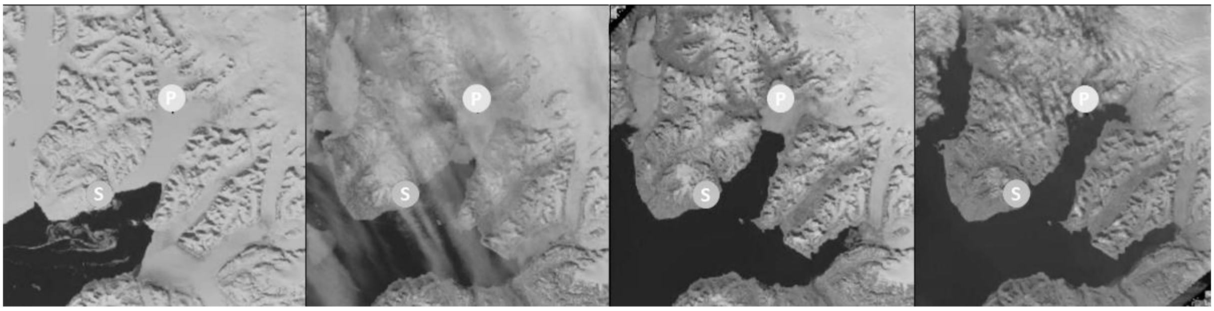

Fig. 2. Landsat_7 images illustrating sea ice breakup, that affects onset of vegetation season and climate conditions in general, image from 12 May 2002, 13 June 2002, 22 June 2002 and 11 July 2002 (modified from USGS, 2018, available at: https://earthexplorer.usgs.gov/; accessed 13 August 2018). Petuniabukta area marked with "P", Skansbukta with "S".

However, there is lack of detailed information on the vegetation of Skansbukta. The comparison of the vegetation characteristics between the two localities is therefore based on the data with a low spatial resolution from the Svalbard vegetation map (Elvebakk, 2005) and a work by Jónsdottir (2005). Although the two above mentioned studies are helpful, visual comparison can be easily made from vegetation map provided by the Norwegian Polar Institute Svalbardkartet online database (NPI, 2018). Based on the NPI database, the prevailing vegetation type in Skansbukta is classified as "dry rich vegetation on slopes and terraces", whereas the most abundant vegetation type in Petuniabukta is classified as "polar desert and extreme vegetation".

Objectives

The study intends to demonstrate how the different environmental conditions may affect conditions of the two relatively isolated populations of Svalbard reindeer. This has been done by implementing a simple distant method working with the antler characteristics as a proxy for their fitness. The population in Skansbukta experiencing more favourable environmental conditions is supposed to be in better physical state which should be reflected in its antler characteristics. Apart from the comparison between the two populations, the Skansbukta population was monitored again in 2018 and the inter-annual changes related to the climatic conditions were discussed as well. We hypothesize that the reindeer population characteristics are reflected in the visual signs such as antlers. These are dependent on the environmental conditions where the population has been settled.

Material and methods

Observation of reindeer

The observations of reindeer were made directly in the field during the second half of August 2017, both in the case of Petuniabukta and Skansbukta. The same observations were repeated towards the end of August 2018 in Skansbukta. All observed individuals were photographed in their natural habitats with a 300mm tele-objective. The individuals in Petuniabukta area were scattered throughout several distinct locations in smaller groups, consisting typically of around 5 individuals (the largest group of 9). All the individuals observed in Skansbukta were located in one relatively homogeneous region, without significant spatial differences in occurrence distribution.

All individuals were photographed several times to ensure a high-quality pictures with a possibility to measure the relative size of antlers and to count the number of tines. Nevertheless, for each populations, the image analysis working with photos taken from different angles exhibited an obvious measurement error which was random and similar in both populations. This error was minimised by selecting (if possible) for each individual the photos in upright position, facing towards the photographer. All the photographs were processed manually to obtain information on each individual. All individuals were subsequently cross checked – to avoid multiple counting of the same animals moving across Petuniabukta – one group moved between the two neighbouring valleys during August. Cross checking of photographs was not necessary in case of Skansbukta, where a single day survey was carried out.

Measurement of relative antler size and number of tines

For each individual its relative shoulder height and antler length were measured from a photo. The absolute measures were not taken in the field, as such an approach would require to observe the individuals fixed for at least several seconds. Even in such a case, the measurement error would be probably too large. Antler length was considered as a proxy for antler size. Relative antler size (RAS) was then calculated as a ratio between the antler length and shoulder height. The process of estimation of RAS is illustrated in Fig. 3. The measurement error was estimated on a series of 5 photographs of 5 different individuals. Expressed through the standard deviation, the measurement error was 0.024 of RAS (i.e. ±4.5%). The number of tines (NT) was counted as well. It was not always possible to differentiate between the males and females; therefore, this fact has not been taken into account in the analysis.

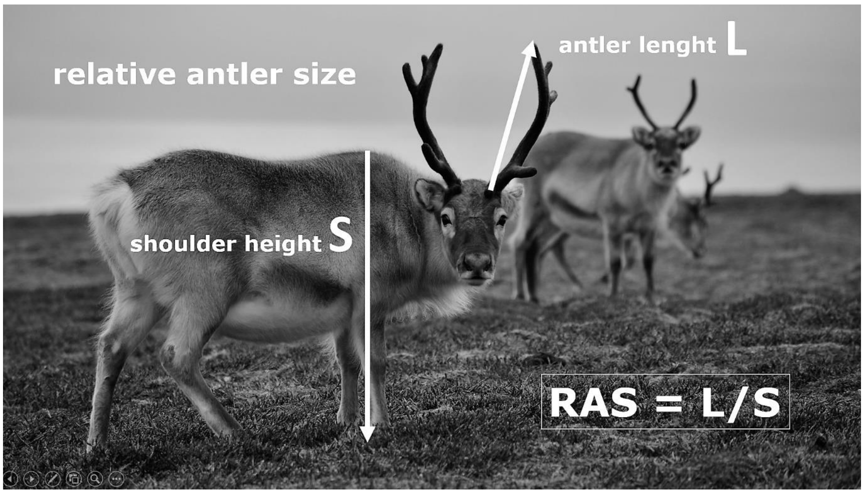

Fig. 3. Estimation of relative antler size from a photo.

The antler characteristics of the two populations (Skansbukta and Petuniabukta) measured in 2017 were compared between each other to asses the differences between the localities. Other comparison was done in the case of the Skansbukta population where the antler characteristics were compared between the years 2017 and 2018.

Results and discussion

Skansbukta and Petuniabukta populations in 2017

The total number of 159 individuals were observed and documented from which 65 individuals were found in Petuniabukta and 94 in Skansbukta. There were recorded 39 calves which makes 25% of the whole observed set. Rather important difference in proportion of calves in the population was found between the two localities. There were 21 calves in Petuniabukta (32%) whereas only 18 in Skansbukta (19%). The generally harsher winter conditions in Petuniabukta can lead to a biased sex ratio towards more females resulting in the higher proportion of calves (Peeters et al., 2017) in the Petuniabukta population comparing to Skansbukta. The statistical analyses presented in the following text have been applied for both populations, under including and excluding the calves, to avoid the bias made by the uneven distribution of calves in the two populations.

Relative antler size

The average RAS value was 0.37 for both groups together. However, significant differences were found between the two populations. The average RAS values comprising calves were 0.31 and 0.41 for Petuniabukta and Skansbukta, respectively. A similar pattern could be found when excluding calves from the analysis. The RAS value in the case of Petuniabukta was 0.42 and 0.49 in the case of Skansbukta. The average values of both RAS parameters were significantly different ($p < 0.01$) using the t-test (Howell, 2014). The cumulative probability of RAS in both populations is illustrated in Fig. 4. The RAS in Skansbukta was higher with the exception of calves, where the difference was not so pronounced and could be probably attributed to an earlier birth.

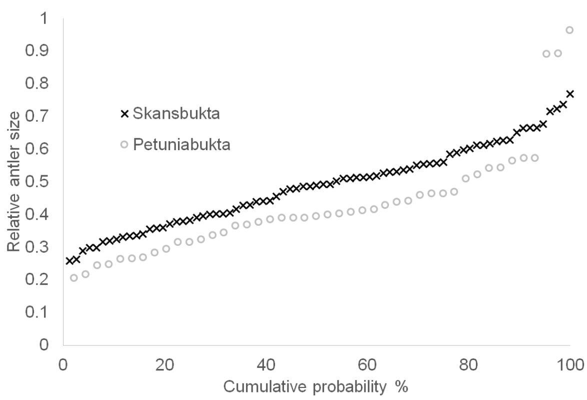

Fig. 4. Comparison of Skansbukta and Petuniabukta population characteristics based on relative antler size cumulative probability (excluding calves).

Number of tines

The average number of tines (NT) was found to be 3.58 for the whole dataset. The difference between the two populations followed the pattern of RAS. The NT values obtained for Petuniabukta and Skansbukta were 2.81 and 4.12 including calves; whereas 3.76 for Petuniabukta and 4.95 for Skansbukta when excluding calves from the analysis (both significantly different with $p < 0.01$). The NT cumulative probability for both populations is presented in Fig. 5 and shows a similar pattern as the RAS. The group of well-developed individuals with NT 7–10 was not present in the population. The exception was the 3 individuals with a high NT and RAS. The overall population parameters are summarised in Table 1.

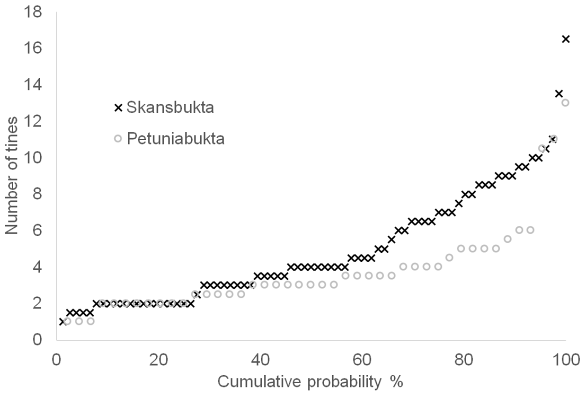

Fig. 5. Comparison of Skansbukta and Petuniabukta population characteristics based on number of tines cumulative probability (excluding calves).

Differences between the populations

Significant differences were found between the two studied populations (both parameters significantly different with $p < 0.01$). The reindeer population in Svalbard is, in general, growing (Pedersen, 2018) with the size controlled mainly by winter conditions leading to starvation (Reimers, 2012), and the population density should not be a limiting factor for the antler characteristics in this population. Thus, the environmental conditions constitute the main factor influencing the population fitness. Alendal et al. (1979) reported differences in Svalbard reindeer populations probably due to dissimilarities in their food quality and feeding conditions caused by the climate. It has been shown that the Petuniabukta population occupying climatically harsher environment (as deduced from Nilsen et al., 2008, Przybylak et al., 2014 for climate and from Elvebakk, 2005; Jónsdottir, 2005 for vegetation) has on average a significantly lower number of tines and smaller relative antler size than the population in Skansbukta. The antler size seems obviously dependent on age, too. There has been observed an overall positive correlation between age and antler size (Thomas and Barry, 2005), with the maximum antler size at an age of about 14–16 years. Therefore, our results reflect both the population fitness and the population age structure. However, the two populations as a whole should follow the rather close correlation between the antler size and environmental conditions expected by Andersson (1994). The influence of age and environmental conditions cannot be distinguished without having precise age data on each observed individual, which requires a physical examination. Comparison of both populations (Fig. 6) probably indicates a lacking group of older well-developed individuals with RAS between 0.6–0.8 and NT between 7–10. This might be associated to a general lower abundance of forage during the summer season, shorter vegetation season or harsh winter conditions (e.g. Pélabon and Van Breukelen, 1998, Schmidt et al., 2001, Mysterud et al., 2005) causing starvation and possible higher mortality in this group of older individuals.

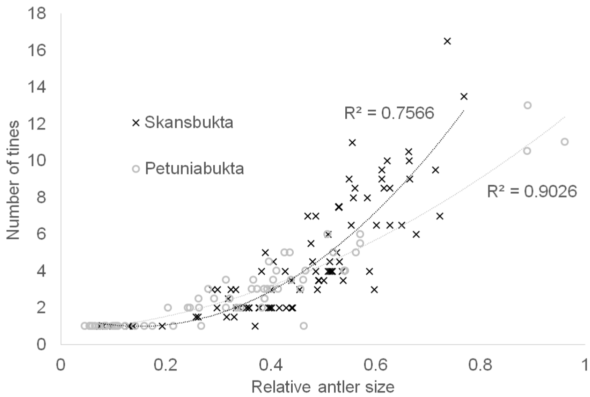

Fig. 6. Comparison of Skansbukta and Petuniabukta population characteristics based on relationship between number of tines and relative antler size.

Skansbukta population in 2017 and 2018

In total, 101 individuals were observed on 28 August 2018 in comparison with 94 in year 2017. Observation was made the same day of the year and covered the same area from Skansbukta to Rundodden. This ensured the comparability of the results obtained. As mentioned earlier, the average number of tines in 2017 was 4.95 (excluding calves) and the average relative antler size was 0.49 (excluding calves). The average number of tines in 2018 was 4.26 and the average relative antler size was 0.47 (excluding calves). Both figures do not differ significantly when using a t-test ($p > 0.2$). The absence of significant inter-annual difference in the antler parameters in this population is in good correspondence with climatically very similar years 2017 and 2018. The average summer (June, July, August) temperature was 5.6 °C in 2017 and 5.9 °C in 2018 (data taken from UNIS Adventdalen weather station). The winter conditions exhibited a similar pattern, including a few

Table 1. Basic parameters of populations of Petuniabukta and Skansbukta with differences in relative antler size and number of tines

Locality	Individuals		Calves		Relative antler size		Number of tines	
	Number	%	Number	%	All	Excluding calves	All	Excluding calves
Petuniabukta	65	40.9	21	32.3	0.31	0.42	2.81	3.76
Skansbukta	94	59.1	18	19.2	0.41	0.49	4.12	4.95
Total	159	100	39	24.5	0.37	0.46	3.58	4.51

melting events during the late winter/early spring. Regarding the similar climatic conditions during the two years, it is no surprise, that the antler parameters did not differ between 2017 and 2018.

Conclusions

A novel simple distant non-invasive method for assessing population well-being was introduced and tested. The method is rather robust and it can be used during regular annual reindeer monitoring – carried out for example in Adventdalen (as reported by Pedersen, 2018). The two populations compared in the study exhibited significant differences, probably due to the effects of different environmental conditions. On the other hand, the population in Skansbukta was proven relatively stable, without significant changes between 2017 and 2018.

The recent changes in the Arctic climate, driven by the global climate change (Comiso and Hall, 2014) can have long-term implications for the local reindeer populations (Mallory et al., 2018) especially through more frequent and abundant rain on snow events (Albon et al., 2017). These phenomena can be assessed also with the help of this method. Such an approach can bring a new information concerning the long-term trends observed presently only in terms of population size. The reindeer antler characteristics can serve as a useful proxy for assessing the environmental conditions at specific sites and also for comparison of the local atmospheric conditions on the interannual scale. The new method is supposed to have important implications in assessing the well-being of the local populations, the mutual effects of herbivore phauna and vegetation on specific localities, and it can be also implemented in more general ecological studies in which the effect of reindeer on its environment and vice versa plays an important role.

It would be, however, useful to validate the findings obtained in this study by comparing distantly measured antler parameters with more detailed data measured directly on the individuals (weight, size, sex, age) to implement and fully approve the methodology. At the current stage, the interpretation of the results is based on the assumption that environmental and atmospheric conditions are the main factors influencing the antler parameters. The density dependent food limitations are considered to have a minor effect in the region where the population probably has not been fully recovered to its pre-hunting level.

Acknowledgements

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