



Wild reindeer winter migratory patterns (Hardangervidda, Norway): what resilience under climate change?

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In subarctic areas, global warming has strong consequences on ecosystems (IPCC, 2014). Reindeer (*Rangifer tarandus* L. 1758) is a northern ungulate with a subarctic distribution. Its long-distance seasonal migration between forests and altitudinal forbes and grasses is particularly important for ecosystem structures and functions. During winter, reindeers move on shorter distances. Little is known about the links between climatological variability and migration of herbivorous. We test these relationships during the winter season, to assess the adaptability of reindeer to climate irregularity, increasing with global warming.

7 to 8 reindeers individuals have been equipped with GPS-collar in Hardangervidda plateau, Southern Norway, during 3 years (2007-2010), with a 3 hours repetitiveness. Datasets from Cagnacci et al. 2013, have been downloaded from Datadryad portal. We aggregated GPS locations for the whole surveyed population and on a daily basis. In winter, the Northern Atlantic Oscillation is the most prevalent teleconnection (Rødsvik Kolloen, 2015). We downloaded daily NAO index dataset (NOAA-NCEP portal), standardized by the 1981-2010 period. During 2007-2010 winters, NAO anomalies are ranging from positive (+0.7), slightly negative (-0.1) to strongly negative (-2.4), corresponding to three types of weather conditions. We also acquired (Norwegian Meteorological Institute) daily minimal, mean, maximal temperatures, rainfall and snow depth, from two meteorological stations located less than 10km to reindeer's vital areas (Høydalsmo, 590m; Rauland, 715m). We processed datasets using Spearman correlation matrix to test the links between climatology and reindeer locations. We further checked if these correlations are consistent with reindeer ecology (e.g. reindeer' seasonal and diurnal behavior) and biogeography (movements into reindeer' vital area).

Results shows significant relationships between reindeers' GPS location, NAO values and climatic records. The more the NAO is positive, the more GPS track logs tends to be southerner or westerner (11 significant correlations/13, $p < 0,005$). As expected, positive anomalies of NAO are strongly correlated with mild and wet weather (17 positive relationships between NAO and temperatures over 19 significant relationships, $p < 0,005$; 11 positive relationships over 12 for NAO/precipitations, with $p < 0,005$). These results suggest that positive NAO phases are related to milder and wetter conditions, themselves related to movement patterns comparable to spring migration, initially toward calving areas. Reindeers moves on the opposite direction with increasing snow depth (significant correlations, $p < 0,005$), toward the direction of their winter migration. When snow depth shows anomalies, significant correlations ($p < 0,005$), of same directions, are found between reindeer locations, NAO anomalies and snow depth. Reindeers present a disturbed behavior in the following situations: very low snow depth (November 2007 and 2008), very deep snow (>120 cm, February 2008), thawing-freezing periods (December and February 2009, February 2010).

During unusual winter conditions, reindeers' partial migrations might follow the same climate driver compared their seasonal long-distance migration, showing its adaptability to climate irregularity. Anomalies in snow depth and density, make lichen grazing difficult, disturbing reindeer spatial behavior while its energy balance is negative during this season. Such anomalies are increasing in frequency and intensity with global warming, questioning the resilience of the ungulate.