Long-term population dynamics of Eurasian reindeer: trends, synchrony, and role of large-scale climate

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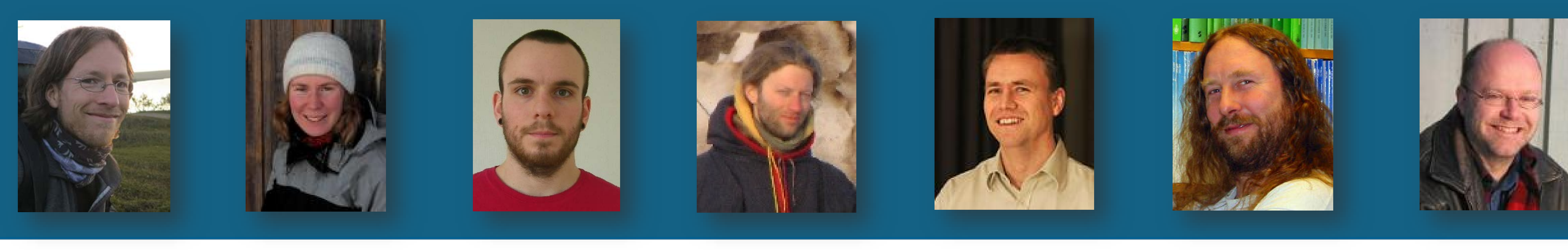

Objective

The scope of our study was to examine the **effects of large-scale climate on reindeer population dynamics** at a large spatial scale, using for the first time long-term datasets (covering a period up to 70-year long) collected from more than half of the species' circumpolar range.

Take home message

1) Climate has **not** been **a main, common force** driving population dynamics across Eurasia in the past seven decades
2) **Socio-economic** history of each country and reindeer husbandry system, together with predators, diseases and local weather, have likely exerted stronger impacts

1. Background and aims

In the Arctic, temperature is increasing two to three times faster than in other parts of the world *[1]*. Precipitation is also expected to increase, potentially in the form of extreme events *[2]*.
Reindeer (*Rangifer tarandus*) can counterbalance the effects of climate change by limiting the growth of plants that would otherwise flourish at higher temperatures *[3]*. Moreover, reindeer exert an essential ecological role in Arctic ecosystems and are an integral part of the livelihood of several indigenous people of the north.

Due to the **ecological and social importance of reindeer** in the Arctic, it is crucial to understand if/how the species is affected by climate.

We **aimed to**:
1) analyze the trends in reindeer population dynamics over the last 70 years
2) evaluate if reindeer populations fluctuated in a synchronous manner
3) determine the influence of large-scale climate on each population

2. Methods

To address the three tasks of our study we:

a) Ran linear regression models with reindeer abundance as response variable and time as predictor variable to assess temporal **trends** in population dynamics of each population (fig. 1)

b) Calculated **synchrony in population growth rates** (estimated as $\ln(N_t) - \ln(N_{t-1})$, where N_t = population abundance at time t) (Table 1)

c) Ran univariate regression models with growth rate (calculated as $(\ln(N_t) - \ln(N_{t-1}))/\ln(N_{t-1})$) as response variable and large scale climate indices as predictor variables. The indices we used were the **North Atlantic Oscillation** (NAO) index, the **Arctic Oscillation** (AO) index, and the **North Pacific** (NP) index (Table 2)

3a. Trends

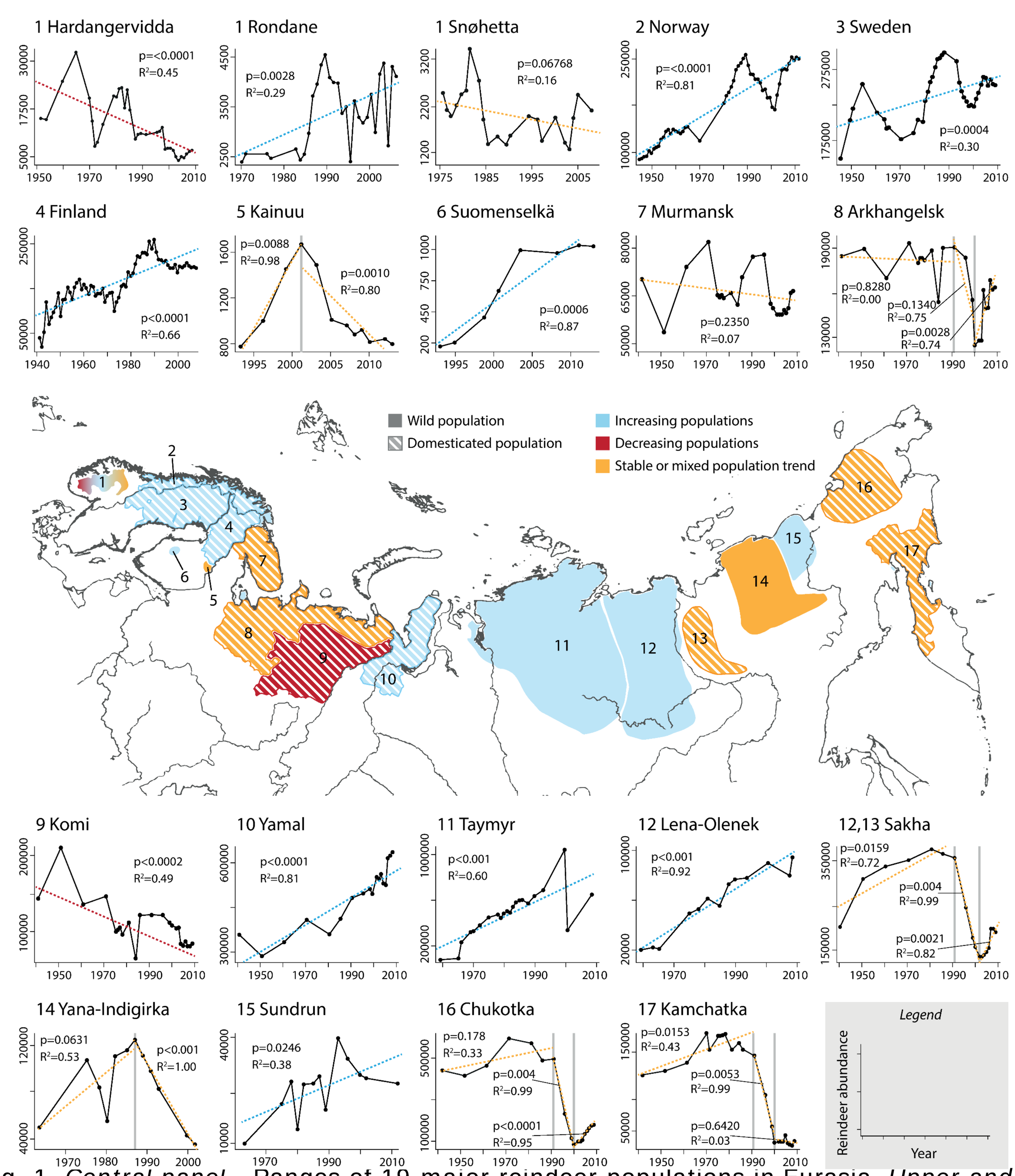

Fig. 1. *Central panel* - Ranges of 19 major reindeer populations in Eurasia. *Upper and lower panels* - Plots representing the time series of available data for each population. Each plot number corresponds to a range in the map and is followed by the name of the population. The color-coded lines in the plots represent the trend in the time series. Reindeer abundance data were all collected from public sources.

3b. Synchrony

Table 1. Pearson correlation coefficient values indicating synchrony among reindeer population growth rates. Statistically significant values are highlighted in bold. Abundance time series were paired and reduced to include only years in which data were available for both populations in the pair before calculating growth rates.

			Semi-domesticated										Wild						
			F			R							F			R			
			Norway	Sweden	Finland	Murmansk	Arkhangelsk	Komi	Yamal	Sakha	Chukotka	Kamchatka	Hardangervidda	Rondane	Snøhetta	Lena-Olenek	Yana-Indigirka	Sundrun	Taymyr
Semi-domesticated	F	Norway	1.00																
		Sweden	**0.45**	1.00															
		Finland	**0.40**	0.10	1.00														
	R	Murmansk	0.26	-0.31	-0.39	1.00													
		Arkhangelsk	0.37	0.15	0.12	0.20	1.00												
		Komi	**-0.37**	0.07	0.34	-0.03	**0.52**	1.00											
		Yamal	**0.63**	-0.63	-0.48	**0.73**	0.24	-0.32	1.00										
		Sakha	**0.55**	0.25	**0.67**	-0.04	**0.40**	0.25	-0.25	1.00									
		Chukotka	**0.54**	0.16	0.12	**0.37**	**0.46**	-0.04	0.16	**0.66**	1.00								
		Kamchatka	0.37	0.33	**0.22**	0.20	0.28	-0.12	0.09	**0.61**	**0.84**	1.00							
Wild	F	Hardangervidda	0.21	0.23	0.19	-0.19	-0.18	-0.36	**-0.72**	**0.39**	0.18	0.00	1.00						
		Rondane	0.14	0.02	0.16	-0.05	0.27	0.10	0.15	0.26	0.16	-0.15	-0.01	1.00					
		Snøhetta	-0.39	-0.01	-0.28	0.12	0.31	0.37	-0.90	0.40	0.41	-0.05	0.03	-0.23	1.00				
	R	Lena-Olenek	0.25	-0.11	-0.02	NA	NA	NA	NA	NA	NA	0.07	-0.58	NA	0.61	1.00			
		Yana-Indigirka	**0.60**	**0.93**	-0.08	NA	NA	NA	NA	NA	NA	NA	-0.01	**0.78**	-0.84	NA	1.00		
		Sundrun	0.03	0.06	-0.37	NA	NA	NA	NA	NA	NA	NA	-0.07	-0.09	-0.27	NA	**0.66**	1.00	
		Taymyr	0.05	-0.09	**-0.30**	**-0.81**	-0.38	-0.23	NA	NA	NA	-0.23	-0.23	-0.32	0.30	0.68	-0.55	-0.29	1.00

3c. Large-scale climate

Table 2. Relationship between population growth rates (response) and large-scale climate indices (NAO, AO, and NP: predictors). Reported results are based on univariate regression models. A plus sign denotes a positive relationship between predictor and response variable; a minus sign denotes a negative relationship; a blank cell denotes no significant relationship. The grey shadings indicate that the predictor variable is: not lagged (lightest), 1-year lagged, or 2-year lagged (darkest). F = Fennoscandia: R = Russia.

			NAO	AO	NP
Semi-domesticated	F	Norway	+		
		Sweden			
		Finland			
	R	Murmansk			
		Arkhangelsk			
		Komi			
		Yamal			
		Sakha	-		
			-	-	
		Chukotka	-		
		Kamchatka			
Wild	F	Hardangervidda			
		Rondane			
		Snøhetta			
	R	Lena-Olenek			
		Yana-Indigirka			
		Sundrun			
		Taymyr			+
					+

4. Discussion

1) Trends in reindeer population dynamics were very heterogeneous (fig. 1), probably because not only climate but also strong socio-economic factors were involved in shaping the dynamics of some populations (e.g. the collapse of the Soviet Union [4])

2) Only synchrony between Norway, Sakha, Chukotka (Table 1) may have been triggered by a large-scale climate phenomenon (since only those populations were affected by the same index, Table 2)

3) The dynamics of only four populations were explained by climate indices (Table 2)

Globally, reindeer as a species do **not** seem to be **at immediate risk** of extinction, because of the asynchrony in the dynamics of most populations and the weak effect of large-scale climate.

Acknowledgements

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