I inledningen kommer jag förklara varför fåglar kan vara viktiga bytesdjur etc. Frågan är hur mycket jag behöver repetera I metoddelen för att rättfärdiga de variabler jag har valt.

Birds can be important alternative prey especially during low years in the lemming cycle (Elmhagen *et al.* 2000).

**Methods**

**The study area**

This study was conducted in Helagsfällen, Jämtland county (≈ 62°54′ N, 12°27′ E), which is the southernmost of three geographically isolated arctic fox subpopulations in Sweden (Dalén *et al.* 2006). The Helags population covers an area of 1920 km2 (står 3400 km2 i Norén et al 2016, vad gäller?) ((Angerbjörn *et al.* 2013) and is mostly comprised of typical Fennoscandian mountain tundra. Productivity is low and the ground surface is characterised by grass heath, dry heath, fens, bogs, rocks and firn (källa behövs).

Intense conservation actions have been carried out on the Helags population since 1999, including support feeding at some dens, red fox culling, yearly den inventories and ear tagging of individual arctic foxes (Angerbjörn *et al.* 2013). Therefore, the 68 known dens can be considered to be all that are present in the area (jag har 78 i mina filer). Much due to these conservation efforts, the population increased from four breeding individuals in 2000 to 58 in 2015 and virtually all reproductive dens have been recorded every summer (Norén *et al.* 2016, Hasselgren *et al.* 2018). Winter active dens have also been recorded by the Jämtland county administrational board. Arctic fox demography and ecology is highly influenced by cyclic rodent prey populations, mainly Norwegian lemming (*Lemmus lemmus*) and voles (Meijer *et al.* 2013). Since the initiation of the conservation actions there have been five rodent population peaks (Hasselgren *et al.* 2018).

**Den parameters**

To estimate prey abundance, six dens have been extensively studied since 2000 with snap-trapping of rodents (see Le Vaillant *et al.* (2018) for methods) and 10 km bird and tracks transects around each den. The bird and tracks transects were divided into four 2.5 km lines with the den in the centre. Sometimes the transects were divided into shorter lines if topographical features did not allow for a straight line. The lines were placed in areas that were representative of the environment around the den. Visual observations of birds and/or bird sounds were recorded and the distance (in metres) and angle from the line to each bird was estimated. Species was determined if possible. Live and dead rodents, fresh ptarmigan and hare droppings and lemming and stoat nests were also recorded. For each of these observations, the distance (in centimetres) and angle to the line was estimated.

I also measured den characteristics on five of the six prey-inventoried dens and five additional dens. Four out of the five prey-inventoried dens are frequently used by reproducing arctic foxes. The five additional dens are seldom or never inhabited. In late April and early May 2018 I recorded snow depth at 10 points with a 2 metre radius from the estimated centre of the den. At the same points I measured soil temperature at 2 cm depth. I also measured snow-free area and number of open burrows. In late June and early July I returned to the same ten dens and measured the area, slope angle and direction of the den using a hand held compass. I also counted the number of open burrows and measured soil temperature at 10 cm depth at 10 points at 2 m radius from the estimated centre of the den.

**Ptarmigan inventories**

I estimated ptarmigan abundance around the same ten dens using the Wildlife Triangle Scheme (Lindén *et al.* 1996, Hellström *et al.* 2014) in two separate surveys conducted in late April to early May and in late June to early July 2018. Visual observations of ptarmigan, calls, droppings and snowtracks were counted on 12 km triangle shaped transects around each den. The triangles were placed with the den in the centre. If steep terrain did not allow for a central placement of the den the triangle was placed with the den in a corner. The species was determined for each observation if possible, otherwise genus was recorded. GPS -coordinates were recorded with each observation. Distance to visual birds was measured with a Nikon Laser Rangefinder PROSTAFF 3I and angle was measured using a hand held compass. Distances to droppings along the transects and unseen calling birds were estimated. The triangles were divided into 4 km corners with 2 km sides, and abundance index was measured as the number of tracks/droppings/calls/visual observations and standardised to 10 km per triangle corner.

**Den parameter estimation using geographic information systems**

All geographic information system (GIS) computations were calculated in QGIS 3.0 Girona software and RStudio version 1.1.383 (Rstudio, Inc.). Elevation of dens was calculated using 2 metre elevation raster (GSD-Höjddata, grid 2+, source: Lantmäteriet, downloaded 2018 – 05 - 31). This can be an important factor since invasive red foxes can force arctic foxes to retreat to higher elevations (Herfindal *et al.* 2010). Since a few dens are located near the Swedish - Norwegian border the topographical features of interest were added for both sides of the border. As a proxy for waders I used proximity to and area of streams, lakes and bogs around each den since many shorebirds are common in wet habitats (Cunningham *et al.* 2016). I chose a 1500 m radius around each den since reproducing foxes act as central place foragers because they have to bring prey back to the cubs (Zapata *et al.* 1998, Gallant *et al.* 2014). Territories are roughly 45 and 16 km2 around each den for males and females respectively (Landa *et al.* 1998), but female territories can be even smaller if there is plenty of food around the den ((Angerbjörn 1997). I calculated distances from dens to streams and lakes and total water cover within the 1500 m radius from the dens using Fastighetskartan Hydrografi Vektor, source: Lantmäteriet, downloaded 2018 – 06 – 07 for the Swedish side. Total area of bogs within a 1500 m radius from the dens was calculated using Fastighetskartan Markdata Vektor source: Lantmäteriet, downloaded 2018 – 08 – 07 for the Swedish side. For the Norwegian side N50 Kartdata, Source: Kartverket, downloaded 2018 – 06 – 08 was used for both analyses.

Distances from dens to treeline were calculated using Vegetation Fjällkedjan Vektor, source: Lantmäteriet, downloaded 2018 – 06 – 08 for the Swedish side and N50 Kartdata, Source: Kartverket, downloaded 2018 – 06 – 08 for the Norwegian side. Groups of trees that were not connected to continuous lowland forest were excluded, since red foxes expand into the tundra from boreal forest (Norén *et al.* 2017). Probability of lemming presence during increase- and peak years at a 1500 metre radius around each den was calculated using a raster model based on primary productivity (500 x 500 metre scale), elevation (50 metres), and slope aspect (which includes the slope’s angle in degrees, north-east direction, profile and tangential curvature) developed by Le Vaillant *et al.* (2018). With the same model, the proportion of favourable lemming habitats within a 1500 m radius around each den was also calculated. The maximum mean probability of lemming presence during increase years for all the pixels (pixel size = 48.5 x 43.8 m) around a single den was 0.53. Therefore, I set a lemming presence probability of > 0.265 (0.53/2) as favourable lemming habitat and lemming presence probability of < 0.265 as unfavourable lemming habitat within each pixel.

**Statistical analyses**