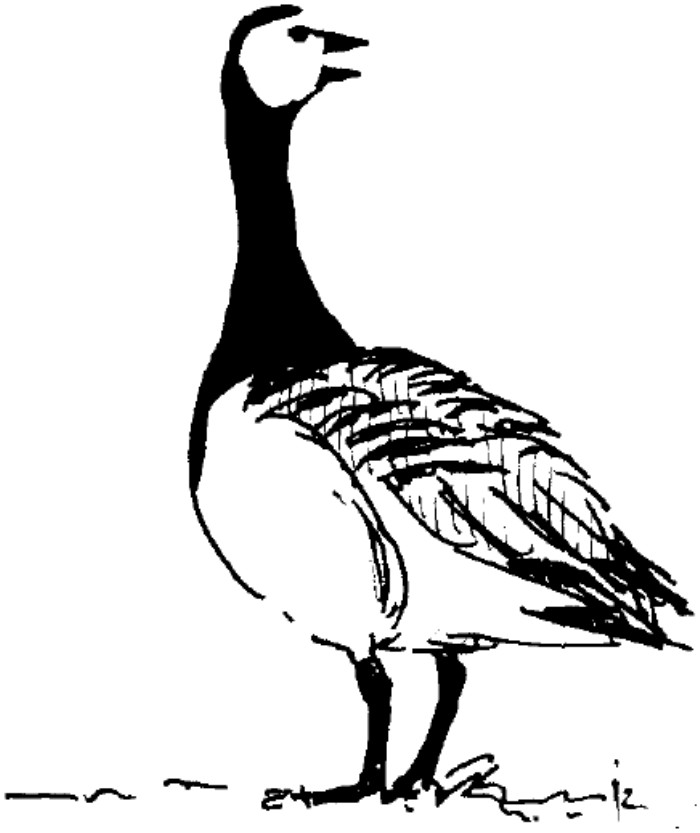
Barnacle geese (Branta leucopsis) in interaction networks

In comparison to the interaction network of the Brent goose (*Branta bernicla*)



Bachelor thesis (2013)

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Cover image from Loonen *et al.* 1997

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Abstract

There has been a lot of research on migrating bird species. Two model species for migrating birds are the Barnacle geese (*Branta leucopsis*) and the Brent geese (*Branta bernicla*). A lot is known about their foraging, migrating and breeding behavior. Most studies focused only on a specific interaction during a specific time of the year. By putting all this information of different interactions and different areas together it is possible to make an interaction network for the whole flyway route of the geese.
Brent geese are declining in numbers, while Barnacle geese numbers are growing.
Because habitats are overlapping, it could be that, due to competition, the Barnacle geese have a share in the decline of the Brent geese. By comparing the interaction network of Barnacle and Brent geese it is possible to gain an insight into interactions between the two species. The analysis of the flyway route of the Barnacle geese shows that they only share the Wadden Sea wintering area with the Brent geese. It could be possible that the Barnacle geese, which are bigger and in increasing numbers, are "pushing" the Brent geese from their foraging areas. However, the Brent geese were already declining before the Barnacle arrived in the Wadden Sea area. At the moment it seems that the increasing Barnacle geese numbers do not have a direct effect on the numbers of Brent geese.

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Introduction

There has been a lot of research on migrating bird species. Birds migrate because the quality of the locations where they forage and breed are not optimal throughout the year (Berthold 2001). It is beneficial for migratory birds to migrate to another area with better resources when their old residence lost its suitability. In spring migratory birds travel north to breed on the northern hemisphere. When winter commence there is less food available. At that moment it is more beneficial for the birds to migrate south to places where the circumstances are better (Berthold 2001). Migration carries high costs. There is a high risk on being predated (including by humans) and there is a high mortality rate because of exhaustion (Alerstam *et al*. 2003). Two model species for migrating birds are the Barnacle geese (*Branta leucopsis)* and the Brent geese (*Branta bernicla*). The population of Brent geese is declining. Their young production is low since 1990 (Engelmoer 2001). Engelmoer insinuates that the Barnacle geese could have an effect on the decline of Brent geese. It could be that, due to competition, the Barnacle geese have a share in the decline of the Brent geese. There is a lot of ongoing research on the Barnacle and the Brent geese. A lot is known about their foraging, migrating and breeding behavior. Those studies focused only on a specific interaction during a specific time of the year. By putting all this information of different interactions and different areas together it is possible to make an interaction network for the whole flyway route of the geese. This already has been done by Wimke Fokkema for the Brent geese (see: Fokkema, Introductory essay). The intention of my study is making an interaction network for the Barnacle geese and comparing this with the interaction network of the Brent geese. By comparing the interaction network of Barnacle and Brent geese it is possible to gain an insight into interactions between the two species. First in this thesis the Barnacle geese will be introduced. Then an interaction network will be made for the different areas (breeding, stop over and wintering areas). Those interaction networks will be compiled to one overall interaction network which will be compared to the overall interaction network of Brent geese. All this will be discussed at the end of this thesis. Such a comparison of interaction networks along the flyways of two different species has never been done before.

The Barnacle goose (*Branta leucopsis*)

The Barnacle goose is part of the genus *Branta*. This genus consists of goose species which have dominantly black plumage. This distinguishes them from the *Anser* species, which have dominantly grey plumage. The Barnacle goose is a small goose species. Its body is 55-70 cm long (Whitehead 1978), its wingspan is 130-140cm and its body mass is between 1.21 and 2.23kg (Dunning 1992). They have a white face, a black head, neck and upper breast. Their belly is white and their wings are grey. The goose is a herbivorous species, its diet consists of grasses, aquatic plants, leaves (del Hoyo *et al*. 1992), mosses (Kear 2005a) and herbs (mainly white clover *Trifolium repens)* (Peberdy 1991). They also forage on agricultural lands during stop overs (Jonker *et al.* 2010) and during winter (del Hoyo et al. 1992).
Barnacle geese are migratory birds (del Hoyo et al. 1992). There are three Barnacle geese populations; One breeds in Novaya Zemlya and winters in the Netherlands (the Russian population), one breeds in Svalbard and winters in Solway Firth (the Svalbard population) and one population breeds in eastern Greenland and winters in Schotland (the Greenland population) (Owen & Norderhaug 1977). The geese are present on their breeding sites from May/June to August/September (Kear 2005a), where they breed in small colonies (Madge and Burn 1988). The geese have high site fidelity, which means they come back to the same breeding grounds every year (Phillips *et al.* 2003) and even to the same nesting sites (Johnsgard 1978). They breed on cliffs (Johnsgard 1978), semi-desert tundra, wetlands, meadows, mudflats, near fjords and on coastal islands (Kear 2005a). When the adults are done breeding they moult for a period between July and August near the breeding grounds. This lasts for approximately 3 to 4 weeks (Scott and Rose 1996). In September the geese will travel back to their wintering grounds. They travel via stop-over sites (Madge and Burn 1988) and arrive begin-October (Kear 2005a). In winter the geese graze in flocks, often feeding on grasslands and salt-marshes and roosting on water (Madge and Burn 1988). When spring commence again they will travel back to their breeding grounds. This begins in April or May. They travel via spring staging areas where they rest and fatten up for 20 to 30 days before they continue their migration to their breeding grounds (Kear 2005a). In the past, barnacle geese and their eggs were exploited by humans (Kear 2005a). Nowadays the species is protected by European law. Still the species may be disturbed by farmers who try to protect their grasslands from overgrazing (Cope *et al.* 2003). In Svalbard the Barnacle goose also suffers from nest predation by Arctic foxes (*Vulpes lagopus*) (Madsen *et al.* 1992).
The worldwide population of Barnacle geese is increasing. The Svalbard population of Barnacle goose increased from 300 individuals in 1940 to 12,100 individuals in 1988. This growth rate slowed down since 1980 (Owen&Black 1989). In the winter of 2004/2005 the total estimate of Barnacle geese on Svalbard was 26,500 individuals (Norwegian Polar Institute). This increase can also be found in the numbers of geese wintering in the Netherlands. Since 1995 the number of wintering Barnacle geese in

the Dutch Wadden Sea has been increasing (Engelmoer 2001). See *fig. 1*.

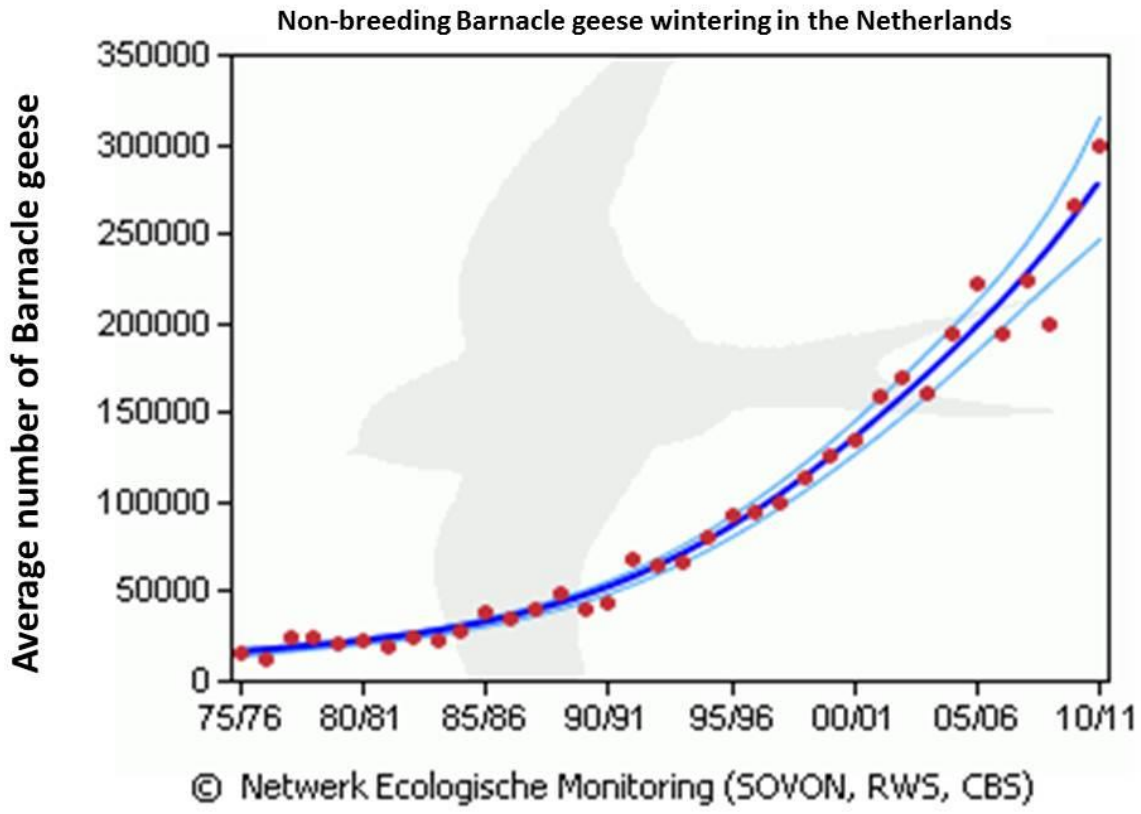

Figure 1: The increasing number of Barnacle geese over the years in the Netherlands. Graph from Sovon.

The increase of Barnacle geese could be explained by the increasing quality of the fields they graze on in winter and spring staging areas. Grasslands are artificially fertilized which has improved the grasslands significantly. The fertilized grasslands are a seemingly unlimited supply of food for the geese (Loonen *et al.* 1998). Most goose species have been expanding their feeding ranges with grasslands during winter (Madsen *et al.* 1987). Together with a decreasing hunting pressure, the overall reduction of hunters and the establishment of nature reserves the mortality of Barnacle geese decreased (Ebbinge 1991).

In the next chapters the interactions of vegetation, predation, competitors and Barnacle geese will be described for each important area along the flyway of the Barnacle geese. These will be illustrated in interaction networks. First the flyway of the Svalbard Barnacle goose population will be discussed and then the flyway route of the Russian Barnacle goose population. The flyway of the Greenland Barnacle goose population will not be discussed in this essay because lack of information.

Wintering area - England (Solway Firth)

Solway Firth is an estuary that forms the west coast border between England and Scotland. The coastline is characterized by rocky shores with mudflats. Some parts of the area are used for hill farming but most of the area consists of grass-dominated salt-marsh (Owen *et al.* 1986). Solway Firth is part of the flyway route of the Svalbard Barnacle goose population. The population has its breeding grounds in Svalbard and spends the winter in Solway Firth (see *fig 2.*) (Owen et al. 1986).

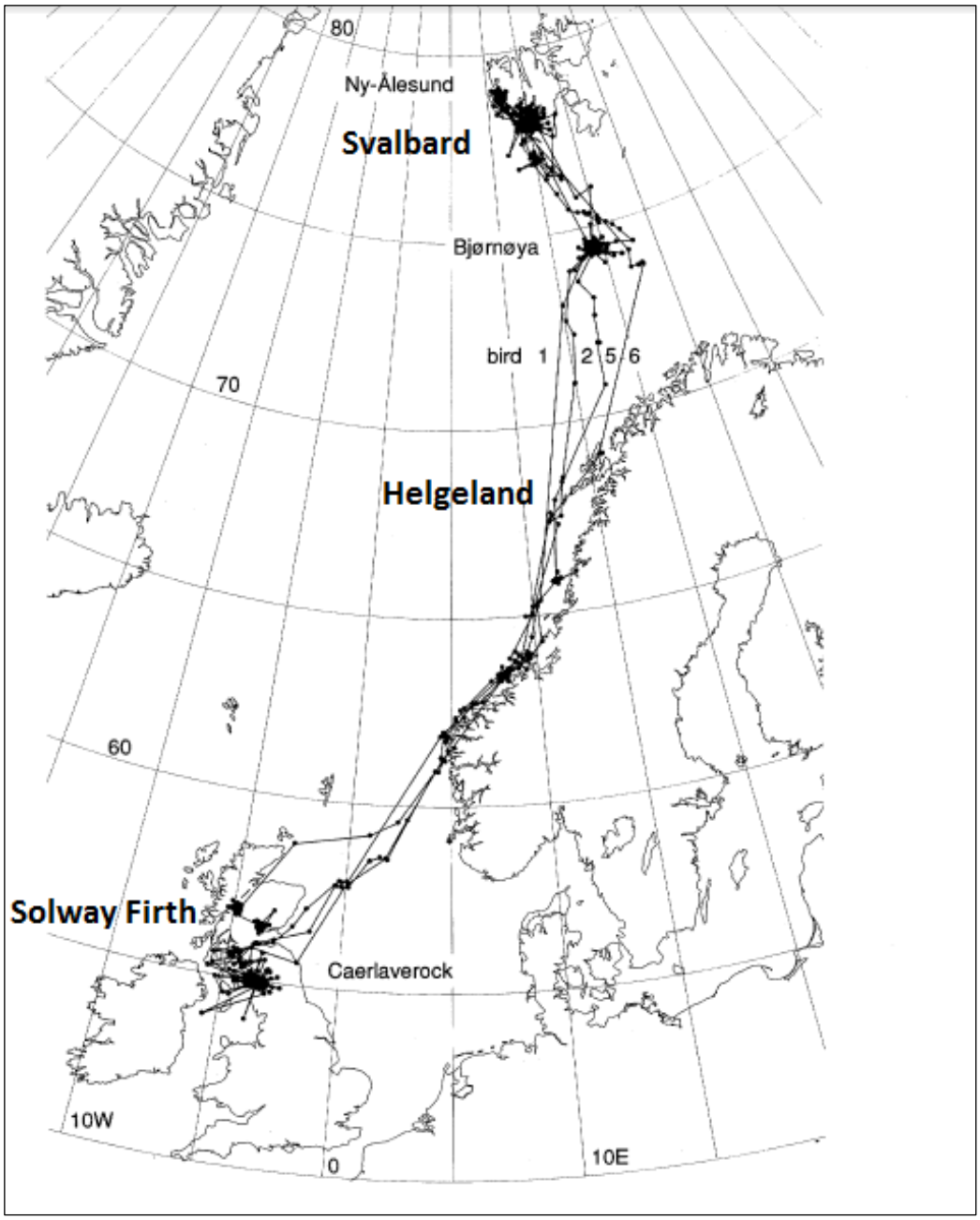

Figure 2: The flyway route of the Svalbard Barnacle geese population. The geese have their breeding grounds in Svalbard and they winter in Solway Firth. Figure from Butler *et al.* 1998.

The areas in Solway Firth where the geese like to winter are fragmented because of claimed land by farmers, industrial sites and areas which are not suitable for foraging. The salt-marsh is not always available because of the tidal dynamics of the estuary. Each salt-marsh area is adjoined with sandbanks, where the Barnacle geese like to roost at night (Owen *et al.* 1986).

The Svalbard population is closed, which means there is almost no exchange of individuals with other Barnacle populations (Owen 1982). There were only 300 individuals present in the Solway Firth area in 1948. They started to recover when the wintering (in 1954) and breeding grounds (in 1955) became protected (Owen & Norderhaug 1977). Around the turn of the century there were 6000 wintering barnacle geese present in Solway Firth. Since then the numbers only increased. In recent years counts go up to 33,000 individuals per year (RSPB, Royal Society for the Protection of Birds). This increase is attributed to the decline in hunting activities (Owen 1984) and the protection of breeding and winter areas (Owen & Norderhaug 1977). The arrival date of the geese on the wintering grounds stayed the same through years. The first geese arrive around 20-30 September and the whole population is present around mid-Octobre. They depart from Solway Firth around mid-April back to their breeding grounds in Svalbard (Owen *et al.* 1968). The increasing number of Barnacle geese on the pastures around Solway Firth caused conflicts with the local farmers who rely on their lands as a resource of food for their stock (Owen & Black 1990). Studies found that the yield of pasture fields during summer reduces significantly when it was grazed upon by geese (Percival & Houston 1992). Farmers are performing scaring-practices to get rid of the geese from their land. Studies have shown that geese avoid areas which are disturbed by human activities (Owen 1973).

There are several reserves established for the Barnacle geese around Solway Firth. The reserves consist of; The Caerlaverrock National Nature Reserve (NNR), The Wildfowl&Wetland Trust (WWT) Caerlaverock reserve, the Royal Society for the Protection of Birds (RSPB) Campfield Marsh reserve, RSPB Mersehead and RSPB Kirkconnel Merse (Cope *et al.* 2002). These reserves did reduce the conflicts with geese around the pasture areas (Owen & Black 1990), but the Barnacle geese still forage in non-reserve areas. A scheme named the Barnacle Goose Management Scheme (BGMS) was established in 1994 for removing the conflict between farmers and geese in the best interest of both groups (Cope *et al.* 2002). The aim of the BGMS is "support farming practices that help integrate productive farming with the conservation of barnacle geese''. The BGMS compensate farmers in return for reducing scaring practices. At the moment the reserve fields still consists of a higher density of geese than non-reserve areas, however this difference seem to reduce. Factors like differences in biomass of grass on pastures (Bautista *et al.* 1995), reseeding fields (Percival 1993) and the primary productivity of food sources (Ydenberg & Prins 1981) might contribute in increasing geese on the pasture fields (Cope *et al.* 2002).

The reserves are mainly intended for Barnacle geese, which involves the minimization of human disturbances but also the removal of sheep from September to April. On non-reserve fields sheep act as competitors with the geese for resources.
In the Caerlaverrock reserve there are grazed and un-grazed salt-marshes by sheep. In the grazed area are *Festuca rubra*, *Juncus gerardii* and *Trifolium repens* dominant (Owen *et al.* 1986). The *Trifolium repens* density is related to vegetation height and so the grazing intensity (Owen 1973). The stolons of *Trifolium repens* forms the main part of the geese diet. The ungrazed salt-marsh consists of the above named species. The lower parts of the salt-marsh also consist of *Puccinellia maritima* and *Armeria maritima* (Owen *et al.* 1986).

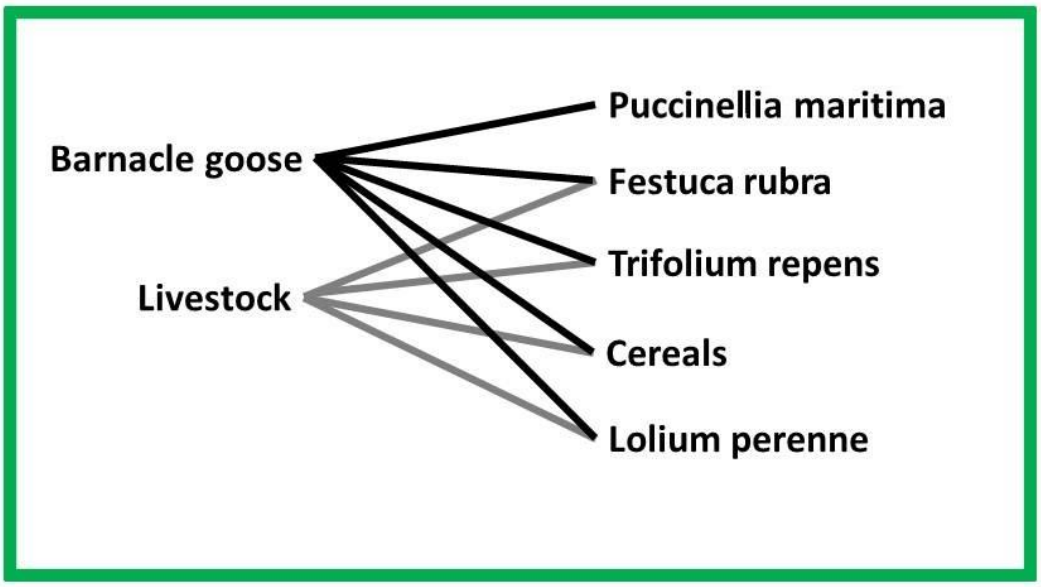

Figure 3: Interaction network (simplified) in Solway Firth.

Stopover - Helgeland

The Svalbard Barnacle geese pause on spring staging areas (or stop over sites) during their migration to the breeding grounds. The energetic costs during migration are very high because of the long distances they have to travel. Since breeding is energetically costly (Clausen et al. 2003), it is beneficial to pause at a spring staging area to recharge and regenerate body mass. This decision has a positive effect on the breeding performances (Madsen 2001). Often the breeding grounds are still covered in snow which results in low food availability (Prop & de Vries 1993). By building body reserves at the spring staging areas the geese are able to rely on their body reserves when their breeding area is still covered in snow (Madsen 2001). The timing of migration towards the spring staging and breeding areas can be explained by the 'green wave hypothesis' (van der Graaf *et al.* 2006). When spring arrives a 'green wave' of growing plants arises which follows the melting snow northwards. The geese benefit from high quality food by following the green wave (van der Graaf *et al.* 2006). An example of a spring staging area is the Helgeland district, an archipelago 50 km from the coast of western Norway. Part of the Svalbard population of Barnacle geese uses this site as a stopover. On the archipelago island the geese feed on *Festuca rubra* and *Puccinellia maritima*. Because of the increasing numbers of Barnacle geese and the decline in food quality over the years the geese are forced to forage on the mainland of Norway. On the mainland the geese forage on cultivated lands. There they feed on *Festuca rubra, Poa spp*. and *Phleum pratense*. The geese prefer Phleum because of higher protein content and a faster growing rate. The number of geese foraging on cultivated lands is higher when the area is grazed upon by sheep (Black *et al.* 1991).
There is an increase of White-tailed eagles (*Haliaeetus albicilla*) in the Baltic area. This avian predator feeds on geese (Jonker *et al*. 2010). The geese take predation danger into account when they decide where to forage. By deciding to leave earlier or skip the stop over area caused that birds did not take the full advantage of foraging on the available resources (Pomeroy *et al.* 2006).

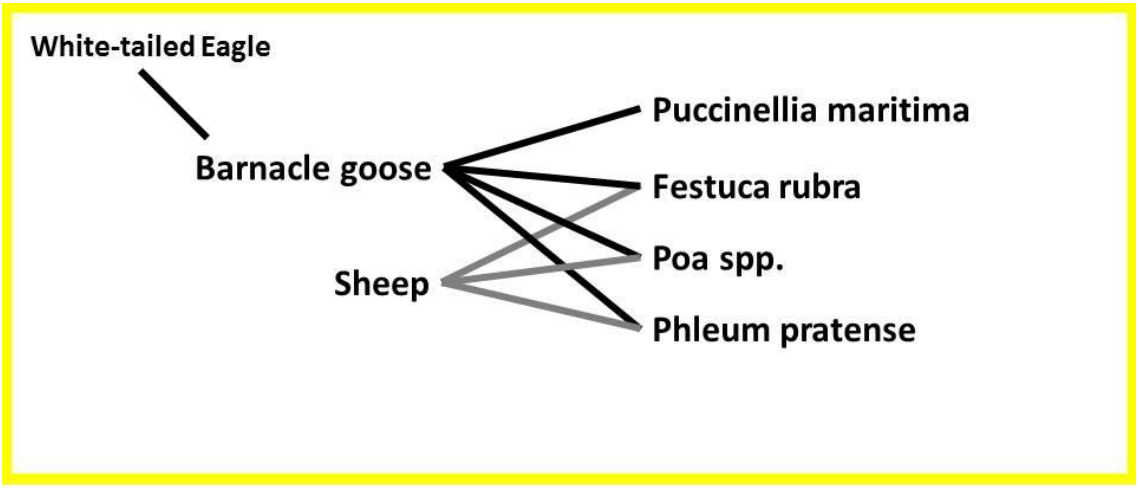

Figure 7: Interaction network (simplified) in Helgeland.

Breeding area - Svalbard

Svalbard is an archipelago which lies 600 km above Scandinavia in the Arctic Ocean. It consists of several rocky islands with mountains and glaciers. This area is used by the Barnacle geese as breeding area. The geese are present on the breeding areas from May to June for moulting and breeding (Kear 2005a). The population which breeds in Svalbard (and winters in Solway Firth, discussed earlier) is the smallest of the 3 groups. In 1973 the Svalbard population represented with 70,000 individuals about 6.3% of the world population (Ebbinge *et al.* 1975). Before 1950 were only a few hundred Barnacle geese breeding in the Svalbard area. After the protection of the wintering grounds in Solway Firth the number of individuals started increasing (Owen & Norderhaug 1977). Recent counts (2004/2005) gave an estimation of 26,500 individuals breeding Barnacle geese on Svalbard (Norwegian Polar Institute).
The Svalbard area consists mainly out of the vegetation type tundra. This tundra is dividable in the following areas: fjellmark (Elvebakk 1985), polar semi-desert (Bliss 1981), wet moss-meadows and mudflats (Prop & de Vries 1993). Fjellmark covers 70% of the area, which makes it the most common vegetation type. Fjellmark is covered with dicotyledons, low shrubs, liches and mosses. Moss-meadows (covers 8% of the area) consist of thick moss carpet with grasses (*Dupontia fisheri*) or sedges (*Carex subspathacea*). On the mudflats some *Puccinellia phryganodes* can be found (Prop & de Vries 1993).

Species of plant	**Eatable parts for Barnacle geese**
Equisetum variegatum	Branches
Salix polaris	Buds
Cerastium arcticum	Seed heads and fresh flowers
Saxifraga oppositifolia	Entire plant
Saxifraga caespitosa	Entire plant
Cochlearia officinalis	Entire plant
Polygonum viviparum	Entire plant
Dupontia fisheri	Green shoots
Carex subspathacea	Green shoots

Table 1: A list of eatable plants found in Prop & de Vries 1993.

At Svalbard the snow melts away during spring. This happens in a fixed sequence; where respectively the crests of the beach ridges and the peaks of the outcrops become snow free, then the gravel deserts and mudflats, and finally the moss-meadows. Because of this the food availability is dependent of the snow melting sequence. Some species of plants appear immediately when the snow disappears. *Cerastium arcticum, Saxifraga oppositifolia* and *Saxifraga caespitosa* are only available short after the snowmelt. *Equisetum variegatum* is also soon available but is quickly depleted because of the intensive grazing of the geese. When the snow is retreated completely the goose have access to the rest of the vegetation. Mosses seem to be an inexhaustible food supply, but it seems that geese prefer them more

when the roots are still anchored in the snow. In this way geese are able to scrape off the green nutritious parts of the moss, while the dead lower parts stay behind (Prop & de Vries 1993). Snow cover is the most important factor why the geese forage on the different vegetation types in different periods (Owen & Norderhaug 1977).
The Barnacle geese share their breeding area with the Pink-footed geese (*Anser brachyrhynchus*). This geese forages on the following species of plants: *Eriophorum scheuchzeri , Pedicularis hirsuta ,Alopecurus borealis , Bistorta vivipara , Carex spp., Dupontia spp., Calamagrostis stricta , Equisetum arvense , Luzula spp. and Poa spp.* (Anderson *et al.* 2012). Some of the plants they feed on overlap with the diet of the Barnacle goose (see *table* 1).
There are a few predators present in the Svalbard area which predate on geese. The goslings of both species of geese are predated by the Arctic fox. The Arctic fox is a scavenger and the only terrestrial predator of the Barnacle goose. Next to predating on Lemmings (*Lemmus spp.),* Ptarmigan (*Lagopus mutus)*, sea birds and marine invertebrates, the fox predates heavily on breeding Barnacle geese and Pink-footed geese (Prestrud 1992). The Lemming is the main food source of the Arctic fox. Lemmings show cyclic fluctuations in abundance. There numbers show a peak every 3-5 years. Therefore the Arctic fox also shows fluctuations in population number (Macpherson 1969). Arctic foxes predate mainly on the goslings of the geese. Therefore the foxes play a major role in the population dynamics of the geese. When there are many foxes present and predating on the breeding geese the population growth slows down (Loonen *et al.* 1998). The fox is only a threat to the goslings when they are walking on the mainland. When the goslings just hatched they could be predated by the Glaucous Gull (*Larus hyperboreus)* (Loonen *et al.* 1998) or the Arctic Skua (*Stercorarius parasiticus*) (Prop *et al.* 1984).
A relatively new threat for the Barnacle geese is the Polar bear (*Ursus maritimus*)(see *fig. 5)*. This predator started predating on goose eggs and chicks (Drent & Prop 2008). This change could be a result of the changing climate. Normally Polar bears would hunt for seals. But due to the melting ice caps it is possible they have shifted their hunting grounds to the mainland, where the geese are breeding (Rockwell *et al.* 2011).

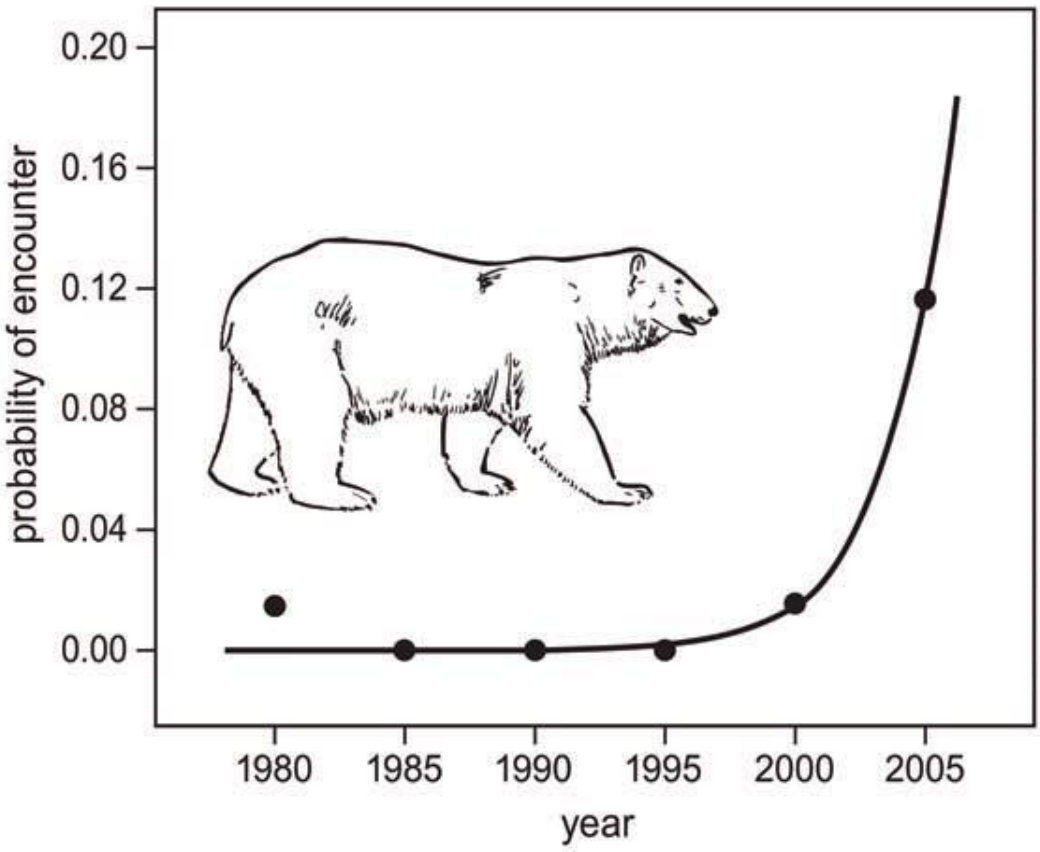

Figure 5: The probability of encountering a Polar bear in Svalbard. Figure from Drent & Prop 2008.

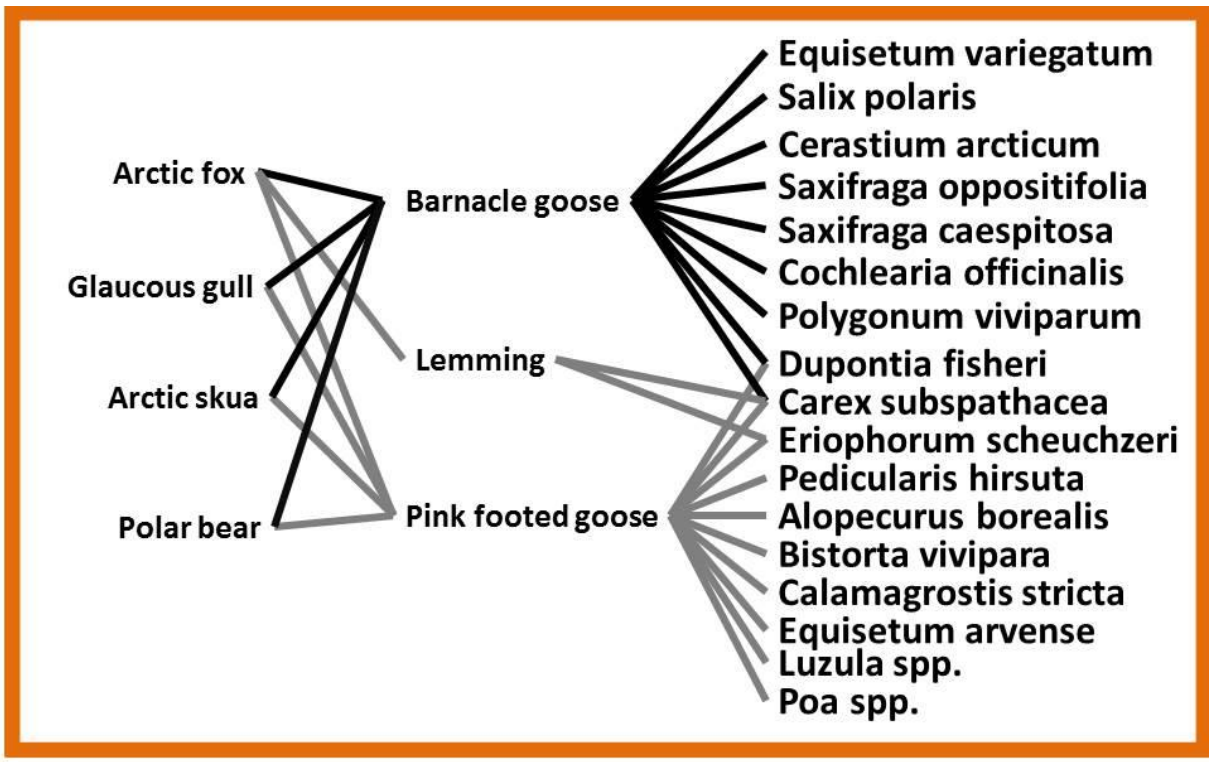

Figure 6: Interaction network (simplified) in Svalbard.

Wintering area - Wadden Sea

The Wadden Sea is an intertidal zone which lies along the Northwestern coast of Europe between the Frisian Islands and the mainland. The Wadden Sea area forms a shallow water area with tidal flats and wetlands. It is a unique area worldwide. For many species of birds it is an important wintering and stopover area. The area is protected by the UNESCO's World Heritage List (Wadden Sea world heritage).
The Wadden Sea area is an important wintering site for the Barnacle geese. A lot of research has been done on the Barnacle geese in this area. During the winter Barnacle geese forage on the pasture grasslands along the coasts of the Islands and the mainlands of the Wadden Sea (Engelmoer *et al.* 2001). The Wadden sea is part of flyway route of the Russian Barnacle geese. They have their stopover in the Baltic area and breed in and around Novaya Zemlya (van der Graaf *et al.* 2006). See *fig 8.* for the flyway route.

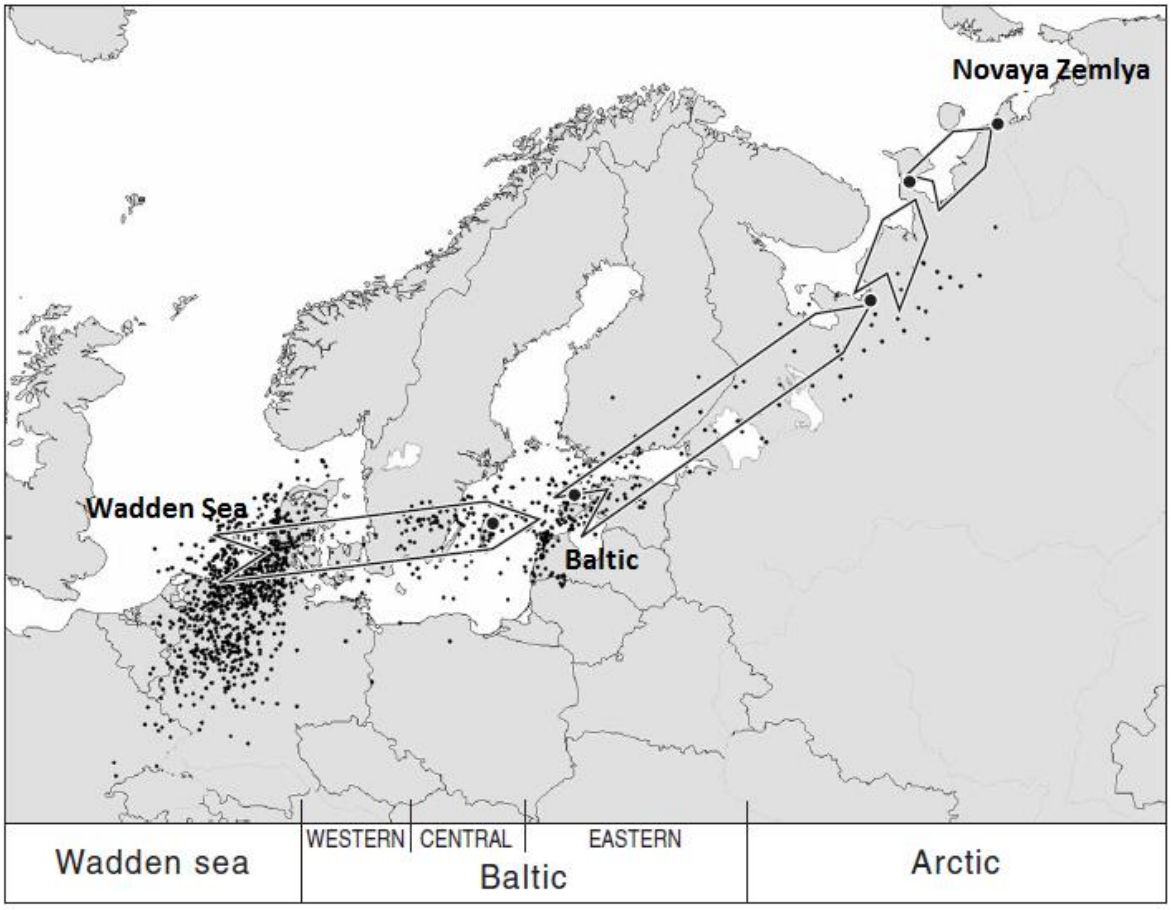

Figure 8: The flyway route of the Russian Barnacle geese population. The geese have their breeding grounds in the Novaya Zemlya area and they winter in the Wadden Sea area. Figure from Eichhorn *et al.* 2006.

During winter the Barnacle geese like to feed on pasture lands (Bos & Stahl 2003). When spring commence a switch between habitats occur. The geese shift from foraging on pasture lands to foraging on salt-marshes (Rowcliffe *et al*. 2001). Pasture land is of lower forage quality than salt-marshes (Vickery *et al*.1995, Rowcliffe *et al*.

2001). Salt-marshes start later with plant production than pasture lands (Prins & Ydenberg 1985). It seems that spring staging barnacle geese switch to salt-marshes when the nitrogen content of plants in the salt-marsh is the same as on the pasture lands (Prins & Ydenberg 1985). This could explain the shift from pasture lands to salt-marshes during spring.

Foraging on pastures has long not been possible. For example on the Wadden Sea island Schiermonnikoog the farmers were allowed to extrude the geese from their pasture lands. Since the year 2000 the farmers stopped with scaring practices in exchange of a compensation for the damages on their lands (Bos & Stahl 2003). This gave the geese the opportunity to forage longer on the grassland if necessary.

The Barnacle geese feed mainly on *Lolium perenne* and *Poa spp.* on the pastures *(*Bos & Stahl 2003). They feed mainly *Festuca rubra* and *Puccinellia maritima* on the salt-marshes*.*

The Barnacle geese is not the only grazing herbivore on the pastures and salt-marshes in the Wadden Sea. They have to share their foraging grounds with Brent geese *,* hares (*Lepus europaeus*) and cattle. Geese influence hares negatively (van der Wal *et al.* 1998), since the geese are depleting the foraging grounds. Contrariwise, the presence of hares does not influence the geese (Stahl *et al*. 2006). Cattle are influencing the geese positively, because they make the foraging grounds suitable for grazing geese. The cattle keep the vegetation short which keeps the plants in a qualitively better state (Olff *et al.* 1997).

The Brent geese are also foraging on the pastures and salt-marshes. Not much is known yet about the effects the two species of geese have on each other.

The Brent have partially the same diet as the Barnacle geese (*Puccinelia maritima, festuca rubra, Poa spp* and *Lolium spp*), but they also forage on *Plantago maritima, Triglochin maritima* and *Zostera noltii*. Brent geese are able to forage on saline environments because they have larger salt glands, which give them higher salt tolerance. Barnacle geese try to avoid foraging on environments which are too saline (Stahl *et al*. 2002).

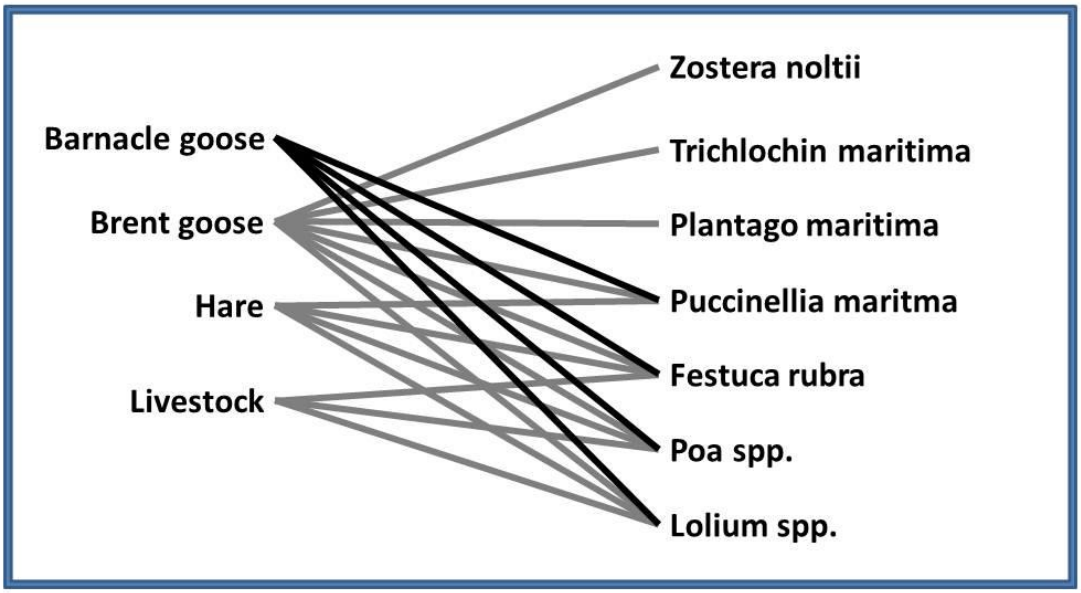

Figure 9: Interaction network (simplified) of the Wadden Sea area.

Stopover – Baltic & Breeding area – Novaya Zemlya

Novaya Zemlya is the breeding area for the population Russian Barnacle geese. They winter in the Wadden Sea and have their stopover in the Baltic area (see *fig1.*) (Ganter *et al.* 1999). Novaya Zemlya is characterized by barren lands, tundra's, mountains and glaciers. During their migration towards the Novaya Zemlya breeding grounds the Barnacle geese follow primarily the coastlines (van der Graaf *et al.* 2006). Traditionally they stop at the Baltic Sea area, which can be divided in 3 staging sites: The Western, the central and the eastern Baltic. The geese seem to have a preference for the eastern Baltic area. Observations suggest that the White Sea area is hardly used as a stopover by Barnacle geese (Eichhorn *et al.* 2006). The geese like to forage on *Festuca rubra* on the salt-marshes. If they forage on the pastures they feed mainly on *Phleum pratense*. White-tailed eagles are an increasing threat for the foraging goose in the Baltic areas. In the eastern Baltic area are 28 known White-tailed eagle territories and the number is still growing (Jonker *et al.* 2010).
Once the geese restored their body reserves they fly further to their breeding area in Novaya Zemlya. In the past their breeding area was restricted only to Novaya Zemlya and the Vaigach islands. Now, they are also breeding in the Archangelsk region (west from Novaya Zemlya) (van der Jeugd et al. 2003), along the coasts of the Baltic sea (Larsson *et al.* 1988) and a small part of the geese stay behind on their wintering grounds in the Netherlands (Ouweneel 2001). The past few years up to circa 3000 pairs of breeding Barnacle geese have been counted in and around the Novaya Zemlya area. The number of moulting individuals (so including 1 year olds, non-breeders and failed breeders) can go up to 10,000 individuals (van der Graaf *et al.* 2004). The Barnacle geese share their habitats in this area with small numbers of White-fronted geese (*Anser albifrons*) and Bean geese (*Anser fabalis*) (van der Graaf et al. 2004) Because they are in such small numbers I assume they are not competing with the Barnacle geese. Perhaps the increasing number of Barnacle geese is influencing the other populations of geese.
The Barnacle geese mainly forage on *Puccinellia phryganodes* and *Carex subspathacea* at the breeding sites (van der Graaf *et al.* 2006). Animals which predate on the (goslings of) Barnacle geese in the Novaya Zemlya area are great Skuas (Rockwell et al. 2011), Arctic fox and the Polar bear (Drent & Prop 2008). These predators are discussed earlier in the chapter "Interaction network Svalbard".

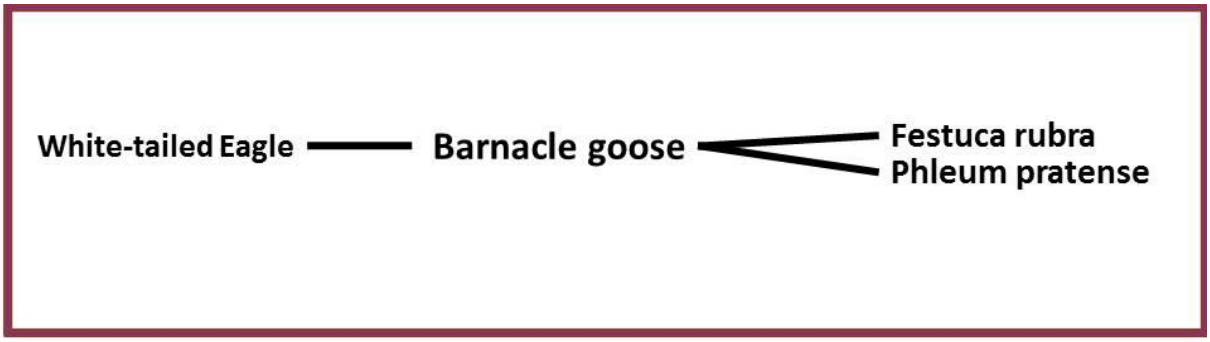

Figure 10: Interaction network (simplified) of the Baltic area.

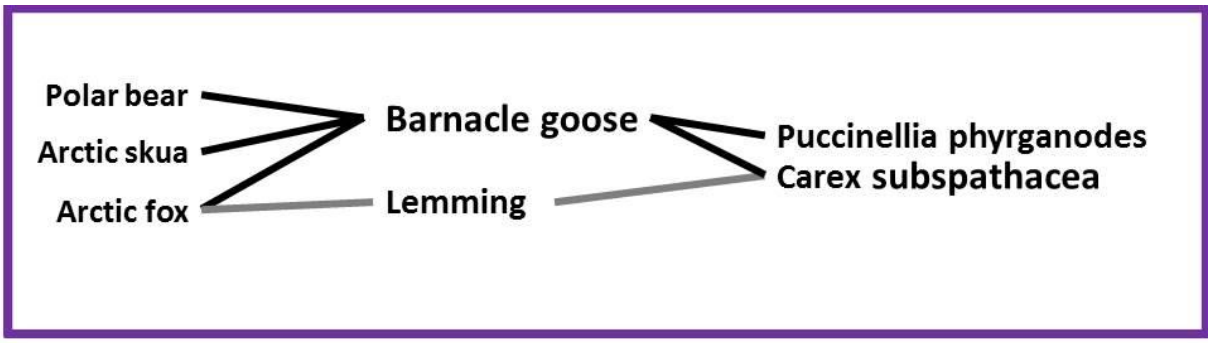

Figure 11: Interaction network (simplified) of the Novaya Zemlya area.

Overall interaction network Barnacle geese vs. overall interaction network Brent geese

An overall interaction network of the described interactions discussed earlier has been made (see *fig. 12*). The interactions focused mainly on the Barnacle goose, which means that not all interactions of every species are described. For example: not all preys of the Arctic fox are illustrated, only the ones which have a direct or indirect influence on the Barnacle geese. The interaction network of the Barnacle geese can be compared to the interaction network of the Brent geese. The interaction network of the Brent geese is illustrated in *fig. 13*, this figure is from Wimke Fokkema's introductory essay. By comparing these two interaction networks it shows that the Brent and Barnacle geese have only one staging area in common, namely the Wadden Sea area. The Russian (not the Svalbard) Barnacle geese winter in the Wadden Sea area, while Brent geese use this as a spring staging area (Engelmoer *et al.* 2001). Brent geese are coastal birds, they strictly forage on salt-marshes or pastures not far from the coast. Barnacle geese on the other hand, can also be found on pastures more land inwards. Barnacle geese are able to digest lower quality food because they have a longer digestion track which makes them able to digest more cellulose (Prop & Vulink 1992). Because of the changing environment Brent geese have fewer options in foraging areas than the Barnacle geese. Brent geese prefer to forage on *Zostera marina*, which is an aquatic plant which grows along coastlines. Because of diseases, harvesting and the closure of the "Afsluitdijk" a major part of the *Zostera marina* disappeared from the Wadden Sea. This forced the Brent geese to forage on the salt-marshes and compete with the Barnacle geese for food (Engelmoer *et al.* 2001). In figure 12 and 13 shows that some parts of both diets overlap. Brent tend to forage on lower salt-marsh areas, since they can withstand salt better because they have bigger salt-glands compared to the Barnacle geese (Stahl et al. 2002). This is reflected in the interaction network, it shows that the Brent geese forage on more salt resistant plant species than the Barnacle geese (for example *Zostera marina* and *Salicornia europaea*).

The Barnacle geese are bigger than the Brent geese. The increasing number of Barnacle geese could be "pushing" the Brent geese to the edges of the salt-marshes, where is less food. Also, the Barnacle geese have longer beaks which could give them an advantage when foraging. Barnacle geese arrive earlier on the foraging grounds which give them the opportunity to forage first. By the time the Brent geese arrive the vegetation could be too short for them to reach properly (see: Fokkema, Introductory essay).

The Barnacle geese fly almost the same route as the Brent geese to the breeding grounds. The Brent geese have a stopover in the White Sea area, while the Barnacle geese pause slightly more south, in the Baltic. Also, Brent geese have their breeding grounds further north than the Barnacle geese. The Brent geese choose to fly further north, to Siberia, while the circumstances seem to be the same in the Novaya Zemlya

area where the Barnacle geese breed. This could be an example of the Brent geese trying to avoid the Barnacle geese.
The interaction networks show that the only place where the Barnacle geese could have a direct negative effect on the Brent geese is in the Wadden Sea area. There are no interactions between the two goose species along their flyway route. If future research concludes that the decline of Brent is not directly linked to the increasing wintering Barnacle geese in the Wadden Sea area then the cause could be found in the differences between the staging and breeding areas of both species. The variation in the Lemming cycle could be an explanation for the declining numbers of Brent geese. If there are enough Lemmings present the predators will (the Arctic fox for example) predate on the Lemmings and leave the geese alone. When the Lemmings are (almost) absent the predators will predate on the geese populations (Summers 1986).

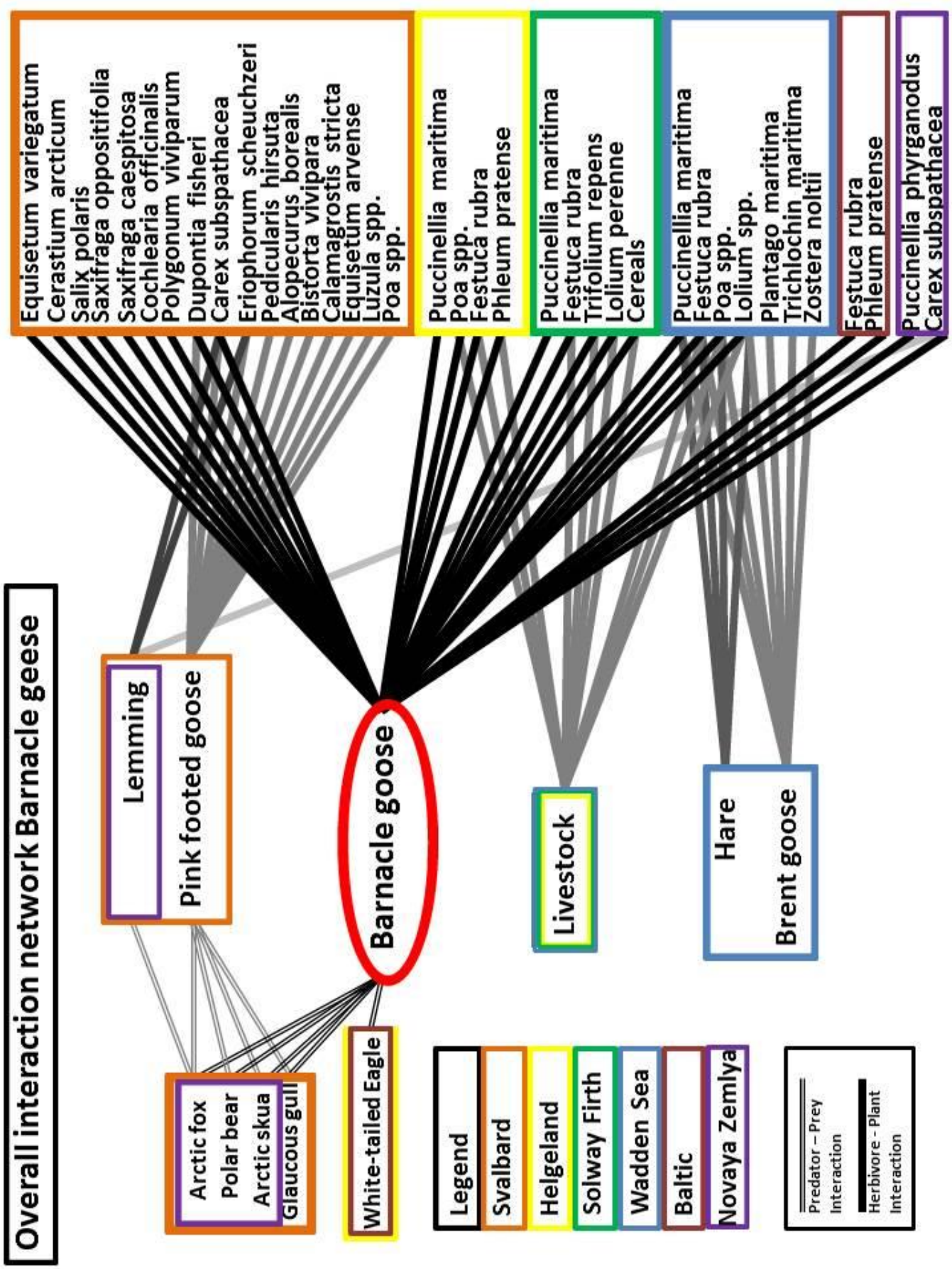

Figure 12: The overall interaction network of the Svalbard and the Russian Barnacle geese populations illustrated in one figure.

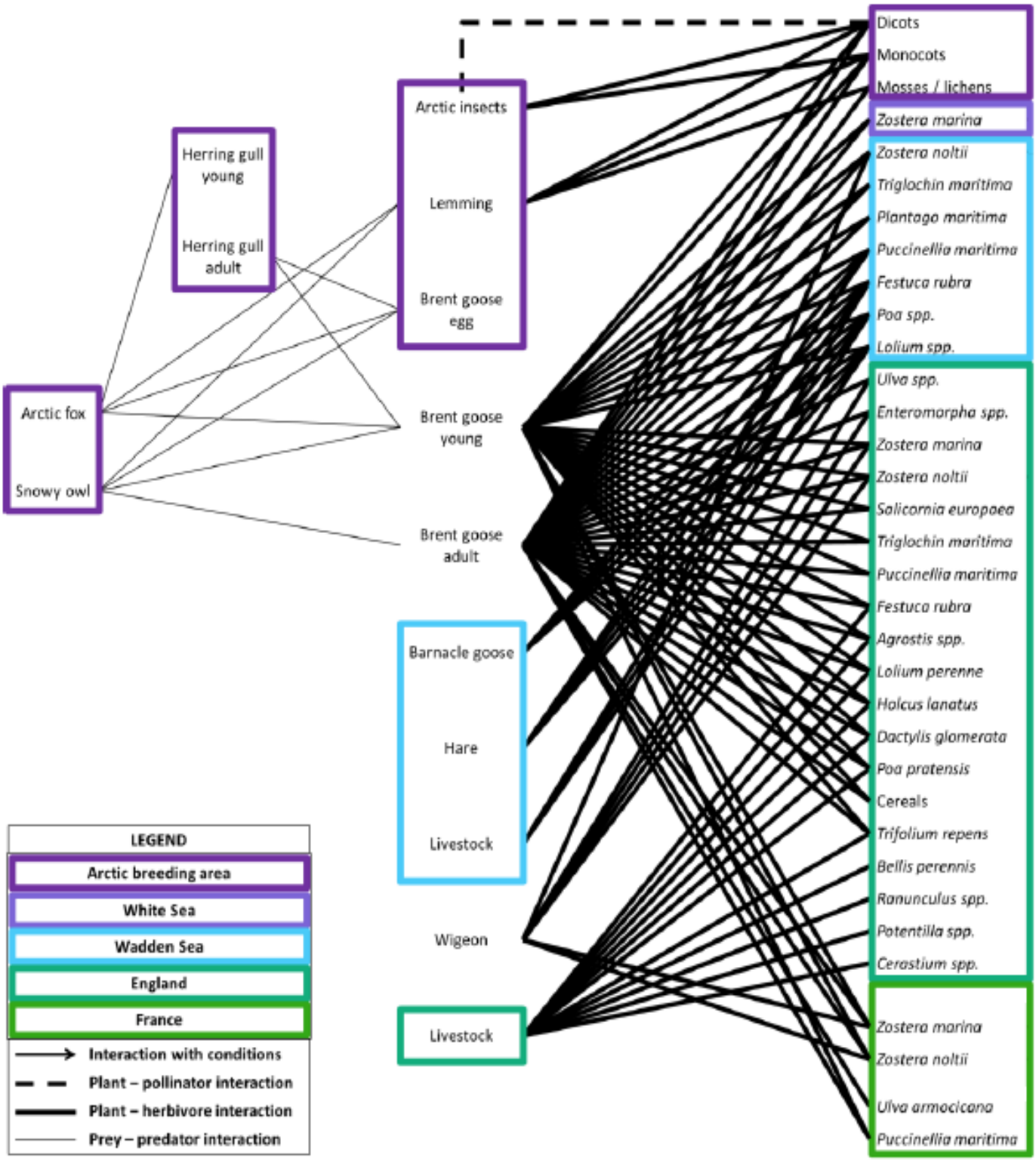

Figure 13: The overall interaction network of the Brent geese. Figure from Wimke Fokkema's introductory essay.

Discussion

In this thesis the interaction network of the Barnacle geese was compared with the interaction network of the Brent geese. The flyway routes of two different populations of Barnacle geese (the Svalbard and the Russian population) were described. Only the Russian population had an interaction with the Brent geese population. Next to comparing the Barnacle with the Brent geese it is also possible to compare the two different Barnacle geese populations. The first thing to notice is the fact that the Svalbard population has its wintering, staging and breeding area almost exclusively on islands. Compared to the Russian Barnacle geese population the Svalbard population has to travel longer distances across the sea. Traveling over sea might have the advantage of encountering less avian predators. However, when traveling over land the geese have to withstand less bad weather conditions. Probably the advantages and disadvantages of the two different flyway routes cancel each other out. If we look at the different diets along the two flyway routes we see that those are practically the same for the wintering, staging and breeding areas. Also the predators correspond in the different areas. The Barnacle geese search for the most optimal conditions for their survival. Finding almost the same conditions along both flyway routes could support this thought.

The analysis of the flyway route of the Russian Barnacle geese shows that they only share the Wadden Sea area with the Brent geese. If the number of Brent geese is declining because of direct (or indirect) competition with Barnacle geese it must be taking place in the Wadden Sea. According to Engelmoer *et al.* 2001 the Brent geese is having a low young production since 1990. The Barnacle geese arrived in 1995 in the Wadden Sea area and they started foraging on the salt-marshes in 1998. This means that years before the arrival of the Barnacle geese in the Wadden Sea Brent geese numbers were already declining! Even when there were no interactions between the two species there was a decline in Brent geese numbers. This could be an indication that Barnacle geese are not the cause of the declining Brent geese. This does not rule out the possibility of Barnacle geese maintaining this decline in Brent geese numbers in the future.

Summers 1986 points out that the decline of Brent geese could be linked to the Lemming cycle (Low Lemming numbers means high predation by predators on Brent geese). The interaction networks show that the Barnacle geese also have to share their breeding areas with Lemmings. Barnacle geese seem to be less influenced by the Lemming cycles than Brent geese, since their numbers are not declining. An explanation could be the fact that Barnacle geese breed in a different area, where the predation pressure is different. Or maybe the Barnacle geese have a better strategy in defending their nests against predators. There is a possibility that Lemming population size is not linked to the breeding success of Brent geese, but that both factors are linked by an independent factor (Owen 1987). This proposition could also explain the seemingly different reaction on fluctuating Lemming cycles by both goose species.

Studies show that the Barnacle geese are increasing, but how will this event evolve in the future? The changing climate brings relatively new predators like the Polar bear to their breeding grounds and the changing climate could disturb their annual cycle. Are the geese able to adapt to these changes and maintain their population growth, or do they have to struggle like the Brent geese for their survival? At this point it seems that Barnacle geese are able to adapt better to the changing environment. They are not strictly bound to the coast like the Brent geese. There are already examples of Barnacle geese who choose to breed in the Netherlands by which they avoid the exhausting migration and the predators in the north. This number is increasing each year (Sovon).

References

- Alerstam, T., Hedenstrom, A., Akesson, S. 2003 Long-distance migration: evolution and determinants. Oikos 103, 247–260.
- Anderson, H. B., Godfrey, T. G., Woodin, S. J. & van der Wal, R. 2012. Finding food in a highly seasonal landscape: where and how pink footed geese Anser brachyrhynchus forage during the Arctic. SpringJournal of Avian Biology 43: 415–422.
- Bautista, L. M., Alonso, J. C., Alonso, J. A. 1995. A field test of ideal free distribution in flock-feeding common cranes. J Anim Ecol. 64:747–757.
- Berthold, P. 2001. Bird migration: A general survey. USA:Oxford University Press.
- Black, J. M., Deerenberg, C. & Owen. M. 1991. Foraging behaviour and site selection of barnacle geese Branta leucopsis in a traditional and newly colonized spring staging habitat. Ardea 79:349–358.
- Bliss, L.C. 1981. North American and Scandinavian tundras and polar deserts, pp. 8-25. In: Bliss, L. C., Heal, O. W. & Moore, J. J. (eds.). Tundra ecosystems: a comparative analysis. Cambridge Univ. Press. Cambridge, UK.
- Bos, D. & Stahl, J. 2003. Creating new foraging opportunities for Dark-bellied Brent Branta bernicla and Barnacle Geese B. leucopsis in spring insights from a large-scale experiment. Ardea 91(2): 153-166.
- Butler, P. J., Woakes, A. J. & Bishop, C. M. (1998). Behaviour and physiology of Svalbard Barnacle Geese Branta leucopsis during their autumn migration. J. Avian Biol. 29: 536 -545.
- Clausen P., Green, M. & Alerstam, T. 2003. Energy limitations for spring migration and breeding: the case of Brent geese Branta bernicla tracked by satellite telemetry to Svalbard and Greenland. Oikos 103: 426–445
- Cope, D. R., Pettifor, R. A., Griffin, L. R., Rowcliffe, J. M. 2003. Integrating farming and wildlife conservation: the Barnacle Goose Management Scheme. Biological Conservation 110: 113-122.
- Cope, D.R., Pettifor, R.A., Griffin, L.R., & Rowcliffe, J.M. 2002. Integrating farming and wildlife conservation: the Barnacle Goose Management Scheme. Biological Conservation 110: 113–122.
- Del Hoyo, J., Elliot, A. & Sargatal, J. (Eds). 1992. Handbook of the birds of the world. Volume1. Barcelona, Spain: Lynx Edicions. 696 pp.
- Drent, R. H. & Prop, J. 2008. Barnacle goose Branta Leucopsis survey on Nordenskiödkysten, west Spitsbergen 1975-2007: breeding in relation to carrying capacity and predator impact. Circumpolar Studies 4: 59-83.
- Dunning Jr., J.B. 1992 CRC Handbook of Avian Body Masses. CRC Press.
- Ebbinge, B. S. 1991. The impact of hunting on mortality rates and spatial distribution of geese wintering in the Western Palearetic. Ardea. 79: 197-210.
- Ebbinge, B.S., Canters, K. & Drent, R. 1975. Foraging routines and estimated daily food intake in barnacle geese wintering in the northern Netherlands. Wildfowl 26: 5-19.
- Eichhorn G., Afanasyev V., Drent R.H. & van der Jeugd H.P. 2006. Spring stopover routines in Russian Barnacle Geese Branta leucopsis tracked by resightings and geolocation. Ardea 94(3): 667–678.
- Elvebakk, A. 1985. Higher phytosociological syntaxa on Svalbard and their use in subdivision of the arctic. Nordic Journal of Botany 5: 273-284
- Engelmoer, M., J. Taal, E. Wymenga, and R. Kuipers. 2001. Aantalsafname bij de Rotgans Branta bernicla langs de Friese waddenkust. Limosa 74:41-56.
- Fokkema, W. Introductory essay. 2012. PhD project October 2011 – September 2015

- Ganter B., Larsson K., Syroechkovskiy E.V., Litvin K.E., Leito A. & Madsen J. 1999. Barnacle Goose Branta leucopsis. In: Madsen J., Cracknell G. & Fox A.D. (eds) Goose populations of the Western Palearctic. A review of status and distribution, 19: 271–283. Wetlands International, Wageningen, The Netherlands. National Environmental Research Institute, Rønde, Denmark.
- Johnsgard, P. A. 1978. Ducks, geese and swans of the World. University of Nebraska Press, Lincoln and London.
- Jonker, R.M., Eichhorn, G., van Langevelde, F., Bauer, S. 2010. Predation Danger Can Explain Changes in Timing of Migration: The Case of the Barnacle Goose. PLoS ONE 5(6): e11369.
- Kear, J. 2005. Ducks, geese and swans volume 1: general chapters; species accounts (Anhima to Salvadorina). Oxford University Press, Oxford, U.K
- Koffijberg, K., Voslamber B. & van Winden E. 1997. Ganzen en zwanen in Nederland: overzicht van pleisterplaatsen in de periode 1985-94. Sovon, Beek-Ubbergen.
- Larsson, K., Forslund, P., Gustafsson, L. & Ebbinge, B. S. 1988. From the high Arctic to the Baltic: the successful establishment of a Barnacle Goose Branta leucopsis population on Gotland, Sweden. Ornis Scand. 19: 182–189.
- Loonen M. J. J. E., Oosterbeek, K. & Drent, R. H. 1997. Variation in growth of young and adult size in Barnacle Geese *Branta leucopsis:* evidence for density dependence. Ardea 85: 177-192.
- Loonen, M. J. J. E., Tombre, I. M. & Mehlum, F. 1998. Development of an arctic barnacle goose colony: interactions between density and predation. Norsk Polarinstitutt Skrifter 200: 67-79.
- Loonen, M. J. J. E., Tombre, I. M. & Mehlum, F. 1998. Development of an arctic barnacle goose colony: interactions between density and predation. Norsk Polarinstitutt Skrifter 200: 67-79.
- Macpherson, A. H. 1969. The dynamics of Canadian arctic fox populations. Can Wildl Serv Rep Ser no. 8
- Madge, S., Burn, H. 1988. Wildfowl. Christopher Helm, London.
- Madsen, J. 1987. Status and management of goose populations in Europe, with special reference to populations resting and breeding in Denmark. Dan. Rev. Game Biol. 12(4): 1-76.
- Madsen, J. 2001. Can geese adjust their clocks? Effects of diurnal regulation of goose shooting. Wildlife Biology 7:213–222.
- Madsen, J., Bregnballe, T., Hastrup, A. 1992. Impact of the Arctic Fox Alopex lagopus on nesting success of geese in south-east Svalbard, 1989. Polar Research 11(2): 35-39.
- Olff, H., De Leeuw, J., Bakker, J.P., Platerink, R. J., Van Wijnen, H. J. and De Munck, W. 1997. Vegetation succession and herbivory in a salt marsh: changes induced by sea level rise and silt deposition along an elevational gradient. Journal of Ecology 85:799-814.
- Ouweneel, G. L. 2001. Snelle groei van de broedpopulatie Brandganzen Branta leucopsis in het deltagebied. Limosa 74: 137–146.
- Owen, M. & Black, J. M. 1989. Factors affecting the survival of Barnacle Geese on migration from the breeding grounds. 1. Anim. Ecol. 58: 603-618.
- Owen, M. & Black, J. M. 1990. Barnacle Geese. In: I. Newton (ed.). Lifetime reproductive success in birds. Academic Press, Oxford.
- Owen, M. & Norderhaug, M. 1977. Population dynamics of Barnacle Geese breeding in Svalbard, 1948-1976. *Ornis Scand*. 8:161-174.
- Owen, M. 1982. Population dynamics of Svalbard barnacle geese 1970-1980. Aquila 89: 229 -247.
- Owen, M. 1984. Dynamics and age structure of an increasing goose population - the Svalbard Barnacle Goose. Nor. Polarinst. Skr. 181:37-47.
- Owen, M. 1987. BRENT GOOSE BRANTA-BERNICLA-BERNICLA BREEDING AND LEMMINGS - A REEXAMINATION. Bird Study 34:147-149.
- Owen, M., 1973. The management of grassland areas for wintering geese. Wildfowl 24: 123±130.
- Owen, M., Black, J. M., Agger, M. K. and Campbell, C. R. G. 1986. The Use of the Solway Firth, Britain, by Barnacle Geese Branta leucopsis Bechst. in Relation to Refuge Establishment and Increases in Numbers. Biological Conservation 39:63-81.
- Peberdy, K. 1991. The use of grazed saltmarsh by Branta leucopsis (barnacle goose) in relation to refuge establishment and management. In: Finlayson, C. M.; Larsson, T. (ed.), Wetland management and restoration, pp. 95-107. Swedish Environmental Protection Agency, Solna.
- Percival, S. M. 1993. The effects of reseeding, fertiliser application and disturbance on the the use of grassland by barnacle geese, and the implications for refuge management. Journal of Applied Ecology 30: 437–443.
- Percival, S.M. & Houston, D.C. 1992. The effect of winter grazing by barnacle geese on grassland yields on Islay. Journal of Applied Ecology 29: 35-40.
- Phillips, R. A., Cope, D. R., Rees, E. C. and O'Connell, M. J. 2003. Site fidelity and range size of wintering Barnacle Geese Branta leucopsis. Bird Study 50,161 -169.
- Pomeroy, A. C., Butler, R. W., Ydenberg, R. C. 2006. Experimental evidence that migrants adjust usage at a stopover site to trade off food and danger. Behav. Ecol. 17: 1041-1045.
- Prestrud, P. 1992. Food habits and observations of the hunting behaviour of Arctic Foxes, Alopex lagopus, in Svalbard. Canadian Field-Naturalis 106(2): 225-236.
- Prins, H.H.T. & Ydenberg, R. C. 1985. Vegetation growth and a seasonal habitat shift of the barnacle goose (Branta leucopsis). Oecologia 66 : 122 - 125.

- Prop, J. & de Vries, J. 1993. Impact of snow and food conditions on the reproduc- tive performance of Barnacle Geese Branta leucopsis. Ornis Scand. 24: 110-121.
- Prop, J.& Vulink, T. 1992. Digestion by barnacle geese in the annual cycle: the interplay between retention time and food quality. Functional Ecology 6: 180-189.
- Prop, J., van Erden, M. R. & Drent, R. H. 1984. Reproductive success of the Barnacle Goose Branta leucopsis in relation to food exploitation on the breeding grounds, western Spitsbergen. Nor. Polarinst. Skr. 181: 87-117.
- Rockwell, R. F., Gormezano, L. K. & Koons, D. N. 2011. Trophic matches and mismatches: Can polar bears reduce the abundance of nesting snow geese in western Hudson Bay? Oikos 120: 696-709.
- Rowcliffe, J. M., Watkinson, A. R. & Sutherland, W. J. 2001. The depletion of algal beds by geese: a predictive modeland test. Oecologia 127: 361-371.
- Scott, D. A.; Rose, P. M. 1996. Atlas of Anatidae populations in Africa and western Eurasia. Wetlands International, Wageningen, Netherlands.
- Stahl, J., A. J. Van Der Graaf, R. H. Drent, and J. P. Bakker. 2006. Subtle interplay of competition and facilitation among small herbivores in coastal grasslands. Functional Ecology 20:908-915.
- Stahl, J., Bos, D. and Loonen, M. 2002. Foraging along a salinity gradient - The effect of tidal inundation on site choice by Dark-Bellied Brent Geese Branta bernicla and Barnacle Geese B-leucopsis. Ardea 90:201-212.
- Summers, R. W. 1986. BREEDING PRODUCTION OF DARK-BELLIED BRENT GEESE BRANTA-BERNICLA-BERNICLA IN RELATION TO LEMMING CYCLES. Bird Study 33:105-108.
- Van der Graaf A. J., Feige, N., van derJeugd, P. J., Leito, J., Larsson,K., Ye. Litvin, K., Drent, R. H., & Stahl, J. 2006. Breeding range expansion of Actic geese facilitated by changesin human land use? In: van der GraafA.J.,Geese on a Greenwave: Flexible migrants in a changing world. Proefschrift, RijksuniversiteitGroningen, Haren.
- Van der Graaf, A. J., Lavrinenko, O. V., Elsakov, V., van Eerden, M. R. & Stahl J. 2004. Habitat use of barnacle geese at a subarctic salt marsh in the Kolokolkova Bay, Russia. Polar Biol. 27: 651–660.
- Van der Jeugd, H. P., Gurtovaya, E., Eichhorn, G., Litvin, K. Ye., Mineev, O. Y. & van Eerden M. R. 2003. Breeding Barnacle Geese in Kolokolkova Bay, Russia: number of breeding pairs, reproductive success, and morphology. Polar Biol. 26: 700–706.
- van der Wal, R., van de Koppel, J. & Sagel, M. 1998. On the relation between herbivore foraging efficiency and plant standing crop: An experiment with barnacle geese. Oikos 82: 123-130.
- Vickery, J. A., Sutherland, W. J., Watkinson, A. R., Lane, S. J., & Rowcliffe, J. M. 1995. Habitat switching by dark-bellied brent geese Branta b. bernicla (L.) in relation to food depletion. Oecologia 103: 499-508.
- Whitehead, P., Soothill, E. 1978 Wildfowl of the World. London: Peerage Books.
- Ydenberg, R. C., Prins, H. H. T. H. 1981. Spring grazing and the manipulation of food quality by barnacle geese. Journal of Applied Ecology 18: 443–453.