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Habitat complementation in urban barnacle geese: from safe nesting islands to productive foraging lawns

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Since the first breeding in the Helsinki area (60°N, 20°E) in 1989, barnacle geese (*Branta leucopsis*) have increased drastically. In 2010, the number of nesting geese was estimated at 1440 pairs while the post-breeding population was 8400 individuals. The Helsinki area was clearly an open niche for this arctic species. Geese nested in the relatively natural archipelago and broods used urban lawns for foraging. This behaviour may indicate that by nesting on small islands geese avoid predation by terrestrial mammalian predators and by moving to urban lawns broods decrease predation risk by avian predators. Furthermore, during the autumn, geese foraged on urban lawns and in cultivated fields and roosted in coastal waters. The use of post-breeding habitat is again likely linked with predator avoidance. We suggest that the successful establishment of the barnacle geese is due to a combination of high brood production and low predation rate, and this is possible to achieve by using the landscape in a complementary manner.

Introduction

At present, half of the human population lives in urban areas (United Nations 2010). This means that globally more and more landscapes are under heavy anthropogenic influence, which can be problematic for many species. At the same time, however, urban ecosystems are structurally the most complex mosaics of vegetative land cover and multiple land uses of any landscape (Foresman *et al*. 1997). In landscapes of patchy habitats, such as urban areas, species may need to move between patches, for example, for foraging and breeding, and hence individuals use resources complementarily to fulfil their life cycle (Dunning *et al*. 1992, Pope *et al*. 2000). Eybert *et al*. (1995) stated that landscape complementation involves a species requiring at least two different resources provided by habitats within the same season, and that resource patches need to be near each other. In cities, potential biodiversity benefits can be gained through landscape complementation. Land uses in urban green areas could synergistically interact to support biodiversity when the green areas are clustered together in different combinations (Colding 2007). Landscape complementation may not only provide increased habitat availabil-

ity for species, but also promote other important ecosystem processes (Melles *et al*. 2003).

Distributions and abundance of bird populations are changing especially as a consequence of human impact (e.g. Helle and Järvinen 1986, Virkkala 1991, Herzon *et al*. 2008). Usually changes in breeding ranges of bird populations are gradual: expansion or decline often occurs little by little (Hagemeir and Blair 1997). The barnacle goose (*Branta leucopsis*) is an example of a species which has successfully occupied a new breeding area in the Baltic, over 2000 kilometres away from its traditional breeding grounds in the Russian arctic region (Larsson *et al*. 1988, Svensson *et al*. 1999). The first breeding in the Baltic was recorded in Sweden in 1971, and now (2010) the number of breeding barnacle geese is 5000 pairs (Larsson *et al*. 1988: Kjell Larsson in litt.). In Finland, the population grew during 1985–2010 to 3000–3500 pairs. Over a third of these geese breed in the urban habitats of Helsinki alone (Väänänen *et al*. 2010).

The breeding ecology of these urban geese has not been studied much since most of the Baltic barnacle goose research has focused on Gotland and Öland in Sweden or on Estonia, where geese breed in comparatively natural habitats (e.g., Larsson *et al*. 1988, Larsson and Forslund 1994, Leito and Tuur 2008). Here, our aim is to reveal how barnacle geese have adapted to different parts of the urban landscape in the Helsinki area, which in many parts is under substantial anthropogenic influence. We first present a short overview of population trends among the barnacle geese in our study area. Secondly, we focus on habitat use of barnacle geese from the nesting period to the post-breeding phase. Finally, we discuss the factors behind the successful establishment of barnacle geese in the Helsinki area.

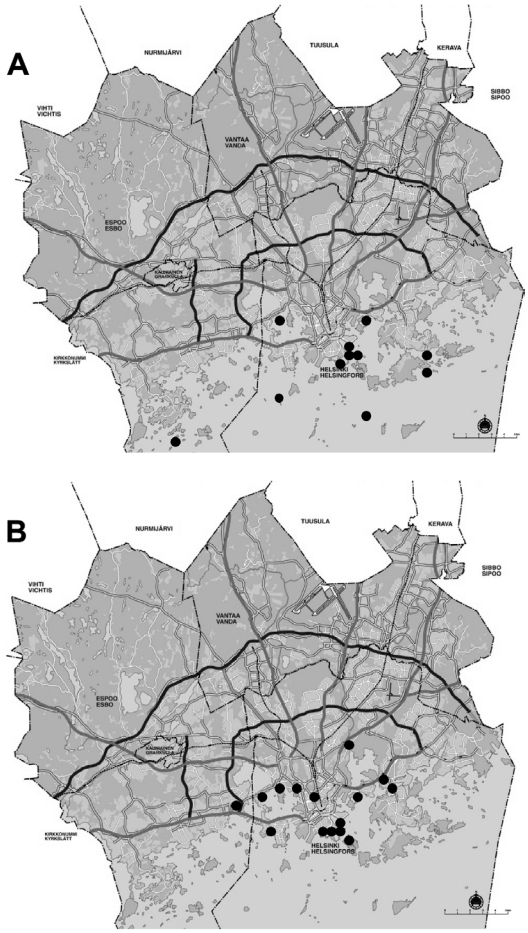

Fig. 1. (**A**) Distribution of barnacle goose colonies (> 20 pairs) in the archipelago of Helsinki in 2010. (**B**) Distribution of barnacle goose brood-rearing areas (> 10 broods of each) on shore lawns of the Helsinki area in 2010. Reproduced with permission from kaupunkimittausosasto of the city of Helsinki.

Material and methods

Study area

Our study area was the Helsinki metropolitan area (60°N, 20°E) in Finland, which includes the cities of Helsinki, Espoo, Vantaa, Kirkkonummi and Sipoo (Fig. 1A). The study area consisted of a relatively natural archipelago with a few hundred islands and islets. In addition, we collected data from urban lawns and cultivated fields in areas with high anthropogenic influence.

Barnacle goose counts

Since the first breeding observation in 1989 (Väisänen *et al*. 1998) the number of breeding pairs of barnacle geese in the Helsinki area was counted annually. Breeding pairs were censused in late April. The islands and islets in the archi-

pelago were checked by a boat. The counting area consisted of those islands and islets with no or few buildings. Nesting barnacle geese pairs were rather easy to find because the male goose is visible when guarding the incubating female. Veli-Matti Luostarinen monitored the breeding population. Brood counts were done annually, during July, on certain urban lawns accessible to broods. Brood counting areas included lawns on both the mainland and some islands near the mainland.

The post-breeding Barnacle goose population in the Helsinki area was monitored since 1989 during September, before the autumn migration of arctic barnacle geese (Russian population). The arctic barnacle geese migrate through the south coast of Finland usually during October and often do not stay in areas close to Helsinki (Solonen *et al*. 2010). The post-breeding geese were monitored in the morning at 08:00–10:00 with the help of numerous bird watchers. At 08:00, the geese were already in their foraging areas, where they typically fed for a few hours. Geese seldom changed their foraging area in the morning. Later during the daytime, geese flew to their roosting areas. So, the risk of counting the same birds in two areas was small.

In 1989–1999, the barnacle geese were easy to count because they stayed mainly in one or two flocks. Later on, the monitoring was organized so that all known foraging areas contained at least one bird counter or more in most favoured foraging areas (> 1000 geese/morning annually). In 2000–2009, 20–30 voluntary birdwatchers carried out the monitoring.

Voluntary bird watchers selected suitable monitoring areas from our list of potential foraging areas e.g., through the internet discussion forum of the local ornithological society. During the morning counting period, some counters monitored 2–5 of the nearest foraging areas. In many cases, the same counters counted geese year after year in the same areas. We also used a bird watching tower to monitor geese leaving roosting sites (Laajalahti) at dawn. Bird watchers marked flight directions and flock sizes of geese in the morning. Using that information we could better avoid counting the geese twice.

Roosting areas were monitored during dawn and dusk in September. The geese flew to the foraging areas early in the morning, and back to the roosting sites at dusk. In many cases, the geese were monitored first at dusk and then during the following dawn to make sure that they remained in the same place the whole night.

Monitoring foraging areas

For mapping the use of foraging habitat, we collected data on barnacle goose foraging sites and flock size from different foraging areas in the Helsinki area during 1997–2009. We used the data collected from 1 August to the end of September (before the autumn migration of Arctic Russian barnacle geese). In 1997–2000, the data were collected as part of a barnacle goose project at the University of Helsinki. In later years, we also used a large dataset collected by Tringa (ornithological society for the Uusimaa province in southern Finland). The data were collected via the Internet using the Tiira bird observation database maintained by BirdLife Finland.

When the barnacle goose population in the Helsinki area began to expand, bird watchers were very interested in to contribute to the monitoring of geese. Thus, we have accurate data on the flock sizes and distribution of barnacle goose foraging areas during 1989–2005. Over the last five years, when barnacle geese became very common on urban lawns and in fields in the Helsinki area, bird watchers were not always interested in counting the individuals of all flocks. We thus assume that during these years, large flocks were still well documented but counts of small flocks (100–500 geese) may not be as explicit as in earlier years.

Results

Nesting areas and population growth

Barnacle geese bred in large areas in the Helsinki area archipelago (Fig. 1A); broods, on the other hand, sought urban lawns (Fig. 1B). The four largest goose colonies in 2010 consisted of 235, 175, 87 and 70 nesting pairs. In 2010, a goose colony deserted one nesting island, which a red fox (*Vulpes vulpes*) occupied during the winter.

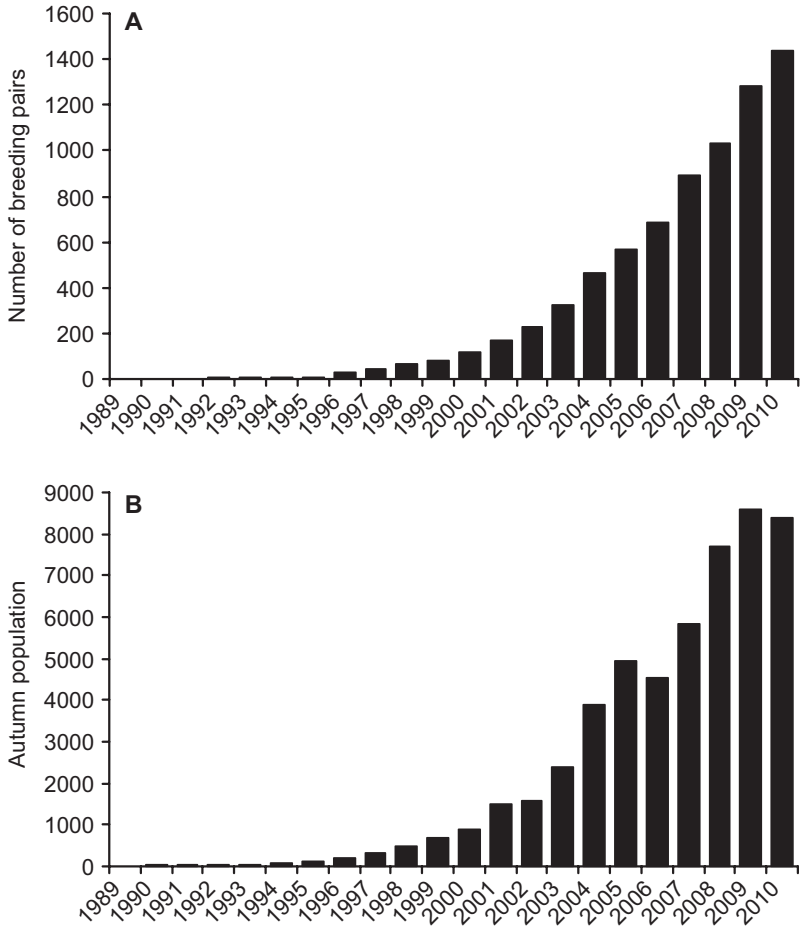

Fig. 2. (**A**) Number of nesting pairs of barnacle goose in the archipelago of the Helsinki area in 1989–2010. (**B**) Post-breeding number of barnacle goose on urban lawns and in cultivated fields in the Helsinki area in 1989–2010.

In the previous summer, 22 goose pairs bred on this island, and also in earlier years geese used this island regularly for nesting.

In the Helsinki area, the population of barnacle geese increased from 1 to 1440 breeding pairs during 1989–2010 (Fig. 2A). Early on, the goose population grew only slightly, but after 1995 population growth was rapid (Fig. 2A). During 1996–2003, the annual growth of the breeding population in Helsinki was on average 47% per year. After 2003, growth slowed down to an average of 22.5% per year.

Brood rearing habitats

During the study period, we found 15 urban lawns where at least 10 broods foraged (Fig. 1B). Over the past few years, all of those lawns were regularly used as brood rearing areas of barnacle geese. Twelve of these foraging areas were situated on mainland shores. Only three were located on islands where geese also nested. Broods usually foraged very close to the shore line (seldom more than 50 metres from the nearest shore line).

Post breeding stage

The size of post-breeding barnacle goose population followed the trend of the breeding population (Fig. 2). During autumn, barnacle geese were widely distributed around the Helsinki area (Fig. 3). Originally, the goose flock used only one urban lawn in Espoo (Fig. 3). Over the years, the geese rapidly enlarged their foraging grounds (Fig. 3). In 1997, 2000, 2003, 2006 and 2009, the

Fig. 3. Distribution of barnacle goose foraging areas from 1 August to the end of September in three-year intervals during 1997–2009. Highest number of geese monitored in current autumn in each foraging areas is divided into 6 classes (*see* above). Reproduced with permission from kaupunkimittausosasto of the city of Helsinki.

farthermost foraging area was 0.3, 1.5, 3.5, 10.5 and 15 km, respectively, from the nearest shore of the Baltic Sea. During recent years, geese foraged on all suitable (large and sufficiently open) lawns and in cultivated fields. In addition, the flock size increased steadily (Fig. 3).

Barnacle geese in the Helsinki area used three roosting areas during the post-breeding

period (Fig. 4). Roosting sites were situated in the archipelago, two in sheltered eutrophic bays (Laajalahti and Vanhankaupunginlahti) and one in an islet group (Fig. 4). Over 5000 geese rested in each of those roosting areas during September before the autumn migration of arctic geese. We did not observe geese in the foraging areas or on dry land on the mainland during the nights.

Fig. 4. Distribution of barnacle goose roosting areas during September in the 2005–2010 period. Reproduced with permission from kaupunkimittausosasto of the city of Helsinki.

Discussion

The spectacular increase of barnacle geese in the coastal areas of the Baltic Sea is a curious phenomenon. Apparently there was clearly an open niche for this arctic species in the Baltic Sea. The increase has followed an exponential population growth curve which is typical when a population is not yet affected by regulating factors (Larsson *et al*. 1988). Density-dependent effects of reproduction have taken place, however, in the largest colonies in Sweden, and the number of fledged young per breeding pair has drastically declined (Larsson *et al*. 1988, Larsson and Forslund 1994, Larsson and van der Jeugd 1998, Black *et al*. 2007). A population growth model of Larsson *et al*. (1988) shows that in the beginning the observed increase of the goose population required immigration. The population of barnacle geese in our study area also has increased rapidly. The growth rate of our population is almost identical to that of the one found in Sweden (Larsson *et al*. 1988, Larsson and Forslund 1994).

The landscape of Helsinki has appeared to be suitable for barnacle geese, and they have been able to use the landscape in a complementary manner. The geese change their habitats throughout the breeding season: they use different habitats during nesting, brood rearing and the post-breeding season. In each phase, the habitat patches are situated so close to each other relative to the mobility of the birds that goslings or flying juvenile birds could easily move between patches in search for vital resources (Wiens 1989, Dunning *et al*. 1992). The islands and islets are essential for goose nesting since they give protection from terrestrial mammalian predators. Predation is one factor strongly affecting birds in urban settings (Jokimäki & Huhta 2000, Rodewald *et al*. 2011). Many waterbirds seek protection against predation by nesting on small islands surrounded by open water and by nesting in colonies (Götmark and Andersson 1980, Burger 1984, Väänänen 2000). The red fox and raccoon dog (*Nyctereutes procyonoides*) rarely visit the islands of the Helsinki archipelago. Only occasionally, these predators occupy an island and cause large nest losses to waterbirds (Veli-Matti Luostarinen unpubl. data). In our study area, barnacle geese nested in colonies of up to over 200 pairs. Gulls, such as the common tern (*Sterna hirundo*) and common gull (*Larus canus*), also nested within those colonies (Veli-Matti Luostarinen unpubl. data). In colonies, geese can probably avoid predation by the American mink (*Mustela vison*) (*see* Nordström *et al*. 2002). However, the colony does not help much against larger terrestrial predators. During our study, a red fox once occupied a nesting island of barnacle geese. Consequently, the geese deserted this breeding island, indicating that the barnacle goose is very sensitive to the presence of a predator. In Russia, arctic barnacle geese nest in colonies on cliff ledges or on small islands beyond the reach of mammalian predators (e.g. Madsen *et al*. 1999). We acknowledge that we do not have much data on predation risk caused by terrestrial predators in our study area. However, our findings are in line with the earlier studies

addressing predator avoidance of the barnacle goose during the breeding season in the Western Palearctic (Madsen *et al*. 1999).

After broods hatch, they move to areas containing short grass, which resemble their original open arctic feeding grounds (Madsen *et al*. 1999). During the brood period when geese cannot fly, it is important that feeding lawns are near water where the ducklings can seek safety when facing predators (*see* also Eybert *et al*. 1995). The long shore line of Helsinki is beneficial since the broods are able to use many lawns in the vicinity of water. In waterfowl, duckling mortality is highest during the first two weeks (Ball *et al*. 1975, Orthmeyer and Ball 1990). In Sweden, the gosling losses to gulls (*Larus marinus*, *L. argentatus* and *L. fuscus*) are up to 90% of birds under the age of three weeks (Larsson and van der Jeugd 1998). This indicates that after a high population increase, the predation rate of goslings may also increase. In Estonia, predation by white-tailed eagles (*Haliaetus albicilla*) has probably caused the decrease of barnacle geese population (Leito and Tuur 2008). The potential predation risk of goose broods in the archipelago of Helsinki area is high as well. In the Finnish archipelago, large gulls are very common and the numbers of white-tailed eagles has increased (Solonen *et al*. 2010). It is probably very profitable for barnacle goose broods to move from the archipelago to urban shores. In urban areas, the intensity of predation is sometimes, but not always, high (Gering and Blair 1999, Jokimäki and Huhta 2000, Shochat *et al*. 2006). These earlier studies mainly focused on nest predation, but the important urban avian nest predators, such as corvids, may not be so effective with goose broods which are concentrated in flocks (Valcarcel and Fernández-Juricic 2009).

Brood production of barnacle geese has been high and relatively stable in the Helsinki area whereas in Russia, brood production of barnacle geese varies dramatically (Madsen *et al*. 1999, Väänänen *et al*. 2010). Due to predation by the arctic fox (*Alopex lagopus*), nesting success of barnacle geese is dependent on the status of the arctic fox population and, ultimately, of the alternate prey, lemmings (*Lemmus sibricus* and *Dicrostonyx torquatus*) (Syroechkovsky *et al*. 1991).

In our study, those barnacle geese which are capable of flying can cover much wider areas and forage on lawns up to 15 km from the shore. During the recent years, the flying distance between foraging areas and coastal shore has gradually increased along with the population increase. Nowadays, the barnacle geese of the Helsinki area already occupy all suitable foraging areas near the shore. They can easily fly further inland or to rural coastal areas, but then they may gradually lose protection from humans. White-tailed eagles avoid the vicinity of humans, and geese foraging outside urban areas may face larger predation risk. Model of Jonker *et al*. (2010) show that increased number of white-tailed eagles has a strong effect on reduced staging duration of the barnacle goose in Estonia during the spring migration. Thus, the increased predation danger caused by white-tailed eagles may also reduce the attractiveness of foraging sites outside the Helsinki area for barnacle geese.

We presume that barnacle geese could not have established themselves so successfully in the Finnish archipelago without human influence. Captive barnacle geese of the Korkeasaari Zoo in Helsinki attracted the first wild barnacle goose pair to breed in Korkeasaari, and in addition, the Korkeasaari Zoo introduced 54 barnacle geese into nature during 1987–1990 (Väisänen *et al*. 1998). These individuals became to breed with wild barnacle geese in archipelago around Korkeasaari (Väisänen *et al*. 1998). This introduction has evidently an important role in urbanization of barnacle goose in the Helsinki area. A natural Finnish archipelago offers a good number of islands and islets suitable for nesting. However, in the Gulf of Finland there are not many natural high-quality foraging habitats for brood rearing close to our study area. Open meadows in the archipelago close to Helsinki are situated patchily, and in addition, they are usually very dry in June–July during the brood rearing period. Thus, the number of natural foraging areas in the archipelago outside urban areas definitely is a limiting factor for the barnacle goose in the Gulf of Finland. Van der Jeugd *et al*. (2009) stated that barnacle geese have not completely adapted to the environmental circumstances that prevail in the Baltic Sea, and lay too late to fully exploit the peak in food availability and quality. Barnacle goose broods in the Helsinki area can avoid this problem by using urban lawns, which

are irrigated during droughts. The quality and abundance of the grass growing in urban lawns and meadows apparently remains high because they are regularly mown (*see* Virkajärvi 2004 and reference therein). To decrease nest predation risk, geese do not nest on mainland, where they are faced with a high predation risk from medium-sized mammalian predators. To avoid predation by avian predators, geese lead broods to urban shore lawns where avian predators are scarcer than in the natural archipelago. Broods roost on small islets near shore lawns to avoid nocturnal terrestrial mammalian predators, such as the red fox. During the post-breeding season barnacle geese may reduce predation risk by foraging in the daytime in urban areas and roosting in coastal waters. We conclude that barnacle geese have solved bottlenecks during nesting, brood rearing and the post-breeding period by using habitats in a complementary way.

In the future, both the quality and quantity of shore lawns may become a limiting factor for the barnacle goose population in the Helsinki area. In some areas signs of over-grazing are visible, and shore meadows have been colonized by common silverweed (*Argentina anserina*) and common selfheal (*Prunella vulgaris*) which are not suitable food plants for the barnacle geese young (Väänänen *et al*. 2010). The numbers of shore line lawns for goslings may become limiting in future, whereas juveniles can forage in fields situated even further inland than they have done so far.

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