Impact of land use on breeding bird populations – a case study of Vuosaari harbour construction

Rauno Yrjölä

Department of Biosciences, Ecology and Evolutionary Biology,
P.O. Box 65, 00014 University of Helsinki, Finland
LUOVA, Doctoral Programme in Wildlife Biology Research

Helsinki 2016

Academic dissertation
to be presented, with the permission of the Faculty of Biological and Environmental Sciences of the University of Helsinki, for public criticism in Auditorium 1041, Biocentre 2, Viikinkaari 5, Helsinki on 25th November 2016 at 12-16.

CONTRIBUTIONS

The following table shows the contributions of authors to the original articles. The authors are referred to by their first initials, and the articles by their roman numerals.

	I	II	III	IV
Original idea	RY	RY	RY	RY
Design	RY	RY	RY	RY
Methods	RY	RY, AL, AT	RY, AT	RY, JR, HP
Data collection	JS, RY	HS, AT, JV, RY	JS, HS, AT, JV, RY	ML
Analyses	RY	AL, AT, RY	RY, AT	JR, RY, HP
Writing	RY, JS	RY, AL, AT	RY, AT	RY, JR, HP

AL = Aleksi Lehikoinen, ML = Matti Luostarinen, JR = Jukka Rintala, HP = Hannu Pietiäinen, JS = Jarkko Santaharju, HS = Hannu Sarvanne, AT = Antti Tanskanen, JV = Jorma Vickholm, RY = Rauno Yrjölä

Supervised by:
Doc. Hannu Pietiäinen, Department of Biosciences, Ecology and Evolutionary Biology, P.O. Box 65, FI-00014 University of Helsinki
Prof. Antero Järvinen, Kilpisjärvi Biological station, P.O.Box 17 (Arkadiankatu 7), FI-00014 University of Helsinki

Thesis advisory committee:
Doc. Aleksi Lehikoinen, The Helsinki Lab of Ornithology (HelLO), Finnish Museum of Natural History, P.O. Box 17, FI-00014 University of Helsinki
Prof. Jari Niemelä, Department of Environmental Sciences, P.O. Box 65, Viikinkaari 1, FI-00014 University of Helsinki

Reviewed by:
Doc. Esa Lehikoinen, Unviersity of Turku, Finland
Dr Llouis Brotons, Forest Technology Centre of Catalonia, Spain

Examined by:
Doc. Raimo Virkkala, The Finnish Environment Institute, Natural Environment Centre/Biodiversity, P.O.Box 140, FI-00251 Helsinki

ISBN 978-951-51-2631-3 (paperback)
ISBN 978-951-51-2632-0 (PDF)
Unigrafia, Helsinki 2016

INDEX

LIST OF ORIGINAL ARTICLES

The thesis consists of the summary and the following papers, which are referred to in the text by their Roman numerals:

I. Yrjölä, R. A. & Santaharju, J. L. M. 2015: The Impact of Road Construction on a Community of Farmland Birds. - *Annales Zoologici Fennici* 52:33-44.

II. Yrjölä, R.A., Tanskanen, A., Sarvanne, H., Vickholm, J. & Lehikoinen, A. 2016: Can common forest bird species tolerate disturbances in neighbouring areas? A case study from Vuosaari Harbour, southern Finland. - *(manuscript)*.

III. Yrjölä, R.A., Tanskanen, A., Sarvanne, H., Vickholm, J. & Santaharju, J.L.M. 2016: Impacts of human activities on populations of wetland birds. A case study from Vuosaari Harbour, southern Finland - *Annales Zoologici Fennici 53: 241-254*.

IV. Yrjölä, R. A., Rintala, J.A., Pietiäinen, H. & Luostarinen, V.M.O. 2016: Effects of harbour and ship channel construction on breeding seabirds - *Ornis Svecica (accepted manuscript)*.

ABSTRACT

Urbanization in general and the spread of industrial construction into natural areas can seriously reduce animal populations. The effects often reach beyond the actual point of impact. In this thesis, I used breeding birds to investigate the impacts of the construction of Vuosaari harbour, ship channel and road connections on bird populations of nearby area. We monitored bird populations in Natura 2000 area and seabird breeding islets during the construction of the new Vuosaari harbour (Helsinki, Finland) in 2001–2011. The study area is located in Helsinki, northeast of the district of Vuosaari. With more than 10 million tonnes of yearly cargo traffic, the new Vuosaari Harbour is the third largest harbour in Finland (www.finnports.com). The harbour was built less than 300 m from Porvarinlahti Bay at Natura 2000 area, and a railroad bridge was built to cross Porvarinlahti Bay.

We compared the bird populations before, during and after construction to evaluate whether the changes observed were linked with the construction work in the nearby harbour area. Population trends were calculated by using TRIM and Mann-Kendall statistics, GLMM and GAMM statistics were also used to model the effects of distance to harbour, different island types and subareas, for example.

Our results indicate that in the Österängen agricultural area the number of species and territories increased during and after construction, with more territories located closer to the road than before the road was constructed. Thus, road construction resulted in at least a momentary positive impact on bird populations. New grass and bush areas and even large rocky outcrops clearly benefited some species such as the threatened northern wheatear. The bird populations declined slightly several years later, probably the as a result of habitat succession.

In the forest areas, the population trends of 23 boreal forest bird species were significantly positively correlated with population changes in wider areas in southern Finland. Although the population trends were slightly weaker in the Natura 2000 sites compared with the general situation of southern Finland, this difference was not statistically significant.

In the Natura 2000 wetlands he numbers of species and territories varied between years and subareas, but we found no clear impacts of harbour construction on bird population trends. The bird population changes in neares bay, Porvarinlahti, were not more negative in comparison with those of the two other bays. We found that the waterfowl reproduction success was very poor, and that the number of small predators may be reason for that. The more

predators were hunted, the less waterfowl nestlings were observed at the same year.

The archipelago seabird study revealed that the population trends of most species showed no substantial differences between the monitored islets near the construction area and the reference islets. One of the most drastic negative effects was observed for the black-headed gull *Larus ridibundus*, of which a legally destroyed colony was buried under the landfills of the harbour construction. The trends of ruddy turnstone *Arenaria interpres* and great black-backed gull *Larus marinus* populations were more negative in the monitored than in the reference areas. These were the only species with statistically more negative trends in monitored islets.

In the surrounding archipelago, the barnacle goose *Branta leucopsis*, mew gull *Larus canus* and black-headed gull clearly increased during the study years. The European herring gull *Larus argentatus* decreased distinctly, which was probably caused by the removal of individuals from the rubbish dumps around Helsinki.

In conclusion, the numbers of species and territories varied between years and subareas, but we found no clear impacts of harbour construction on bird population trends. Although the population trends were slightly lower in the Natura 2000 sites compared with the general situation of southern Finland, this difference was not statistically significant. Our results indicate that despite the construction work demolished bird populations at the construction site, the impact of the harbour construction work had only limited impact on population trends of birds in the Natura 2000 site. Perhaps other more general factors such as climate and changes in the non-breeding grounds were likely a more important driver of local bird dynamics.

This monitoring project has shown how difficult it is to estimate possible negative impacts caused by a single construction project. Before the project started, biologists said that severe negative impacts are possible, and according to the so called precautionary principle construction of Vuosaari harbour should not be allowed. Monitoring lasted ten years, and we couldn't see any clear significant negative impacts caused by construction. However, reviewers of our manuscripts have pointed out that we only have studied one harbour and the number of territories of most species was comparatively small, especially the number of Birds Directive species. Question remains, are these kinds of long lasting monitoring programs really useful, or are they just waste of time and money? Have we learned something useful for the future?

Key words: Birds, Impacts, Construction, Wetlands, Population dynamics, Conservation, Biodiversity, Land use changes, Monitoring, Seabirds, Harbour, Ship channel, Ecology, the Gulf of Finland, northern Europe.

1 INTRODUCTION

A new harbour for Helsinki was planned already in the mid-1960s, but it took about thirty years before the Vuosaari harbour project was implemented in 1992, when the city authorities began planning of the area. The EIA (Environmental Impact Assessment) procedure of the project was initiated in 1994. The Helsinki City Council accepted the construction protocol for the harbour in 1996 (Heikkonen 2008).

The planning of the harbour encountered much opposition. During the harbour project, many environmental studies were conducted because the harbour was located next to a Natura area. Finland joined the European Union (EU) in 1995 and diversified environmental legislation with new demands developed rapidly. The effects of harbour construction on Natura values were investigated using monitoring programmes. Monitoring programmes include monitoring of the watershed, fisheries, plant populations, ground and surface waters and bird populations (Koskimies 2001, Heikkonen 2008). The objective of these programmes was not only to prevent possible significant changes, but also to document the information obtained from the project.

Although the results of monitoring just one harbour construction cannot be generalized, the results of the monitoring programmes are higly interesting: construction demolished bird populations at the construction site, but were there negative impacts on the nearby areas? In this thesis, the Vuosaari harbour construction is considered as a case study of human impacts and general urbanization.

1.1 URBANIZATION AND HUMAN IMPACT

Vuosaari harbour is just one huge construction site, but it can be seen as part of the urbanization process. One of the main reasons for the new harbour was the fact that the city of Helsinki wanted to build new houses to old harbour areas near the city center, apartments for new citizens. This has now happened.

During the recent decades, the ecological effects of urbanization and other human activities on nature have been widely studied (Niemelä 2011, McDonnell *et al.* 2009). Generally, productivity and amount of resources, predation, heterogeneity of the abiotic environment, disturbance and climatic variation are among factors that influence species richness and population densities in local areas (Townsend *et al.* 2003). The sphere of influence of urbanization and the direction and size of the effect on animals may vary, depending on habitat type and the scale of human activities. Some species are also more sensitive than others.

Urbanization can lead to specific behaviour. It has been shown that low-frequency songs lose their potency in noisy urban conditions, and birds use higher voices in urban environment (Slabbekoorn & Peet 2003, Slabbekoorn *et al.* 2012, Halfwerk *et al.* 2011a), to get their message through the environmental noise. The same phenomenon has been observed with frogs living near roads (Parris *et al.* 2009).

Man-made structures, like roads, electric wires and wind turbines have been in the focus of intensive research. The effects of harbour construction have not been studied widely. The reason for this is surely the fact that the harbours are big infrastructure projects and they are built only occasionally. Many of the publications concerning harbours examine the effects of harbours in the water ecosystem (Dauvin *et al.* 2010, Smith *et al.* 2010). The dredging of the ship channels increase sedimentation and that has a strong impact on benthic fauna and the chemical composition of water.

1.2 IMPACTS OF TRAFFIC CONNECTIONS

Many studies have showed that roads, man-made structures and human disturbance may affect bird populations. Such structures include roads, windmills, high buildings, lighthouses, electric wires etc. (Avery 1979, Reijnen & Foppen 1995b, Forman, R.T.T. & Alexander, L.E. 1998, Forman & Alexander 1998, Trombulak & Frissell 2000, Coffin 2007, Fahrig & Rytwinski 2009, Krijgsveld *et al.* 2009, Grecian *et al.* 2010). The ecological effects of roads and other infrastructure on animal populations have been analysed worldwide in several studies and summary publications (Coffin 2007, Parris & Schneider 2008, Fahrig & Rytwinski 2009, Benítez-López *et al.* 2010, Rytwinski & Fahrig 2013). Commonly mentioned negative factors are noise, disturbance, habitat change, collisions with structures or vehicles, environmental pollution etc. Trombulak and Frissell (2000) summarized the most important ecological effects of road construction as mortality due to road construction, mortality caused by collision with the vehicles, modification of animal behaviour, alteration of the physical and chemical environment, the spread of exotic species, and an increased use of areas by humans Trombulak & Frissell 2000).

The impact of roads differs between species and taxonomic groups. Generally, larger mammal species with lower reproductive rates, and greater mobilities, were more susceptible to negative effects of roads (Rytwinski & Fahrig 2012). Especially bird species with large territories and active movements across roads are in danger compared with other bird species. Among vertebrates, especially slow small mammals, amphibians or tortoises which live near roads are in danger (Hoskin & Goosem 2010, McCall *et al.* 2010, Langen *et al.* 2012, Rytwinski & Fahrig 2012).

Amphibian densities near roads are generally lower than in the surroundings. This can be caused by increased mortality caused by the traffic or by the fact that traffic noise disturbs the males' display calls (Hoskin & Goosem 2010). It has also been noticed that the behaviour of some species will be different near the road. Roads form a serious threat to amphibians because the mortality of amphibians near busy road sections is high (Bouchard *et al.* 2009). Depending on the species, the effect of the road extends to different distances, from few hundred metres to more than kilometre (Eigenbrod *et al.* 2009). In small mammals the impact of roads may be different than in amphibians. Species diversity and population densities are nessessarily not lower near the roads. In one study along a desert road, only two species of small mammals out of 13 were not observed near the road. Population densities of the rest of the 11 species were at the same level or even higher in comparison with more distant areas (Bissonette & Rosa 2009). This is probably a result of the fact that road sides developed into suitable habitats for small mammals.

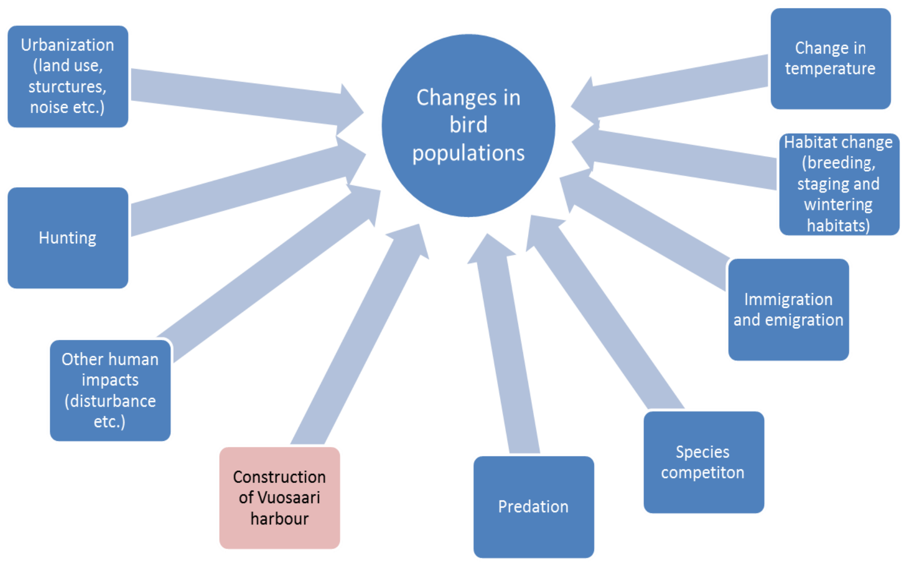

Fig. 1. Examples of different factors causing changes in bird populations.

1.3 SOURCE-SINK POPULATIONS AND ECOLOGICAL TRAPS

Pulliam first described sources and sinks in population regulation (Pulliam 1988, Pulliam & Danielson 1991), and many authors later showed that populations with poor reproduction may remain stable if new individuals arrive in the area from source populations (Liu *et al.* 2011).

Individuals make choices between suitable breeding places and mortality or disturbance rate. A new habitat may attract individuals, but their mortality near a road may be higher or their breeding success lower than in more natural habitats, as in the pied flycatcher study in Finland (Kuitunen *et al.* 2003). Individuals find themselves in an ecological trap.

In a study in the Netherlands, the willow warbler *Phylloscopus trochilus* males that did not succeed in breeding near a highway moved more frequently and farther away than successful males (Foppen & Reijnen 1994). If there are surplus individuals nearby, they can occupy abandoned territories. The roadside hedgerows and trees increase the mortality of some passerine bird species caused by road, especially during the breeding season (Orłowski 2008).

Increasing noise reduces bird numbers (Goodwin & Shriver 2010, Reijnen & Foppen 1995a). In a study of eight breeding birds in Virginia, the occurrence of two species clearly correlated with traffic noise levels. Species were ten times less likely to be found in noisy than in quiet plots. The explanation was that traffic noise was masking the voice of those species(Goodwin & Shriver 2010). In agricultural grasslands in the Netherlands, 7 out of 12 species that could be analysed showed reduced densities adjacent to a road (Reijnen *et al.* 1996). The results of many studies have suggested that traffic noise is the main negative effect causing the population decrease near roads (Reijnen & Foppen 1994, Parris & Schneider 2008), and direct mortality and pollution are considered sometimes unimportant (Reijnen & Foppen 1995a). However, in another study authors showed that in fact traffic mortality may be the prevailing factor behind decreased bird densities (Summers *et al.* 2011).

Contrary to previous studies, studies in forested areas in Sweden and Finland do not have documented negative effects of roads , or negative effects have been overcome by positive effects, such as new roadside habitat or edge effects (Kuitunen *et al.* 1998, Helldin & Seiler 2003). When populations increase, poor-quality areas may also be occupied, often by young and inexperienced individuals. This can prevent the determination of the real effects of construction (Paper I). Poor breeding success may have been replaced by individuals which come from other areas. In the Vuosaari project bird populations near the harbour road increased, probably because of new roadside habitat. The new environment increased bird populations near the road, at least for some years. Generally, roadside vegetation has a strong influence on animal species composition and on the width of the road-effect zone (Forman & Alexander 1998, Forman & Deblinger 2000, Reijnen *et al.* 1996).

1.4 HARBOUR CONSTRUCTION

In the Finnish context, the construction of the Vuosaari harbour was a big construction project (Heikkonen 2008). The total area of the harbour and the adjoining area is 200 hectares (0.93% of Helsinki land area), of which 115 hectares belong to the closed harbour area. Alltogether 90 hectares of sea area were filled with sand and rocks. Large amounts of unsuitable ground masses were moved from the area. A total of 6 million m^3 of clay and mud were dredged away and 12 million m^3 of corresponding fillings were made. The total length of the piers is 3.4 km.

The lenght of the new ship channel which leads to the harbour is 32 km. Its minimum width is 200 m and the secured depth is 12.5 m. The lenght of the new road section of Ringroad III leading to the harbour is 2.5 km and there is a 1.5 km long tunnel which goes under Labbacka forest and Porvarinlahti bay. A new railway connection was also built. The total length of the electrified cargo railway is 19 km, 14.1 km of which is tunnels. In the Natura area, the track goes through the hill of Labbacka forest in the tunnel, and then crosses Porvarinlahti along a bridge.

During the construction work attention was paid to local breeding birds. Strong noise and disturbance (building, blastings, dredgings), were not allowed near the bird areas during the nesting time. The building of the railway bridge over Porvarinlahti bay was also done outside the breeding season.

A 1.3 km long noise barrier was built on the eastern edge of the harbour to reduce the adverse effects of the harbour noise on the nearby Natura area. The spreading of muddy water, soil particles and the possible impurities from the dredgings were prevented by wearing the so-called silt curtain around the harbour water area.

Fig. 2. Dredging of mud and clay at harbour site.

Fig. 3. A rocky hill before it was removed and used as building material.

Fig. 4. A 1.3 kilometre long wall was built at the edge of the harbour to reduce noise and visual disturbance at Natura 2000 area.

Fig. 5. The railway bridge over the Porvarinlahti Bay was built during winter time to avoid disturbing birds.

Fig. 6. Final port area, after the port was opened.

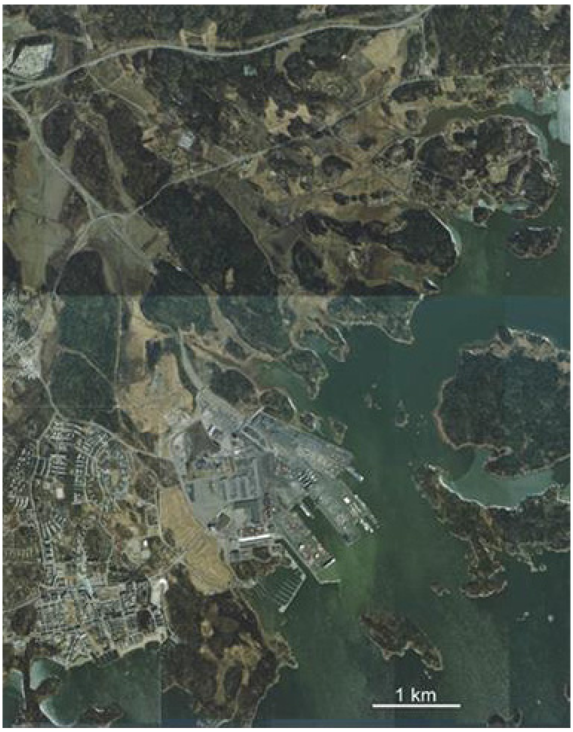

Fig 7. Aerial photo of the area after the Vuosaari Harbour was finished.
© National land survey of Finland and the City of Helsinki.

1.5 ENVIRONMENTAL ASSESSMENT AS A TOOL IN PLANNING

Most of the studies of the impact of human activity on environment have been conducted in Europe and North America. Environmental Impact Assessments (EIAs) were first formally established in the USA in 1969, and in 1985 the European Community directive on EIAs was introduced. The purpose of the EIA procedure is to help in decision-making (Glasson *et al.* 1994, Glasson *et al.* 2012).

The environmental impact assessment (EIA) procedure of the Vuosaari harbour construction project was initiated in 1994, when the new environmental act came into force. Helsinki City Council accepted the construction protocol for the harbour in 1996 (Heikkonen 2008). Most problems during the permit process focused on two main issues: 1) What kind of impacts harbour construction may cause to birds at the nearby Natura area and how severe those impacts are? 2) Should the harbour construction be refused because of the so called precautionary principle? *"The precautionary principle enables a rapid response in the face of a possible danger to human, animal or plant health, or to protect the environment. In particular, where scientific data do not permit a complete evaluation of the risk, recourse to this principle may, for example, be used to stop distribution or order withdrawal from the market of products likely to be hazardous"* (European Union 2015). This roughly means that because there was not enough scientific data about the possible impacts of the harbour construction, the permit should not have been allowed.

The whole permission process lasted eight years; in 2002 the harbour was given a final construction licence by the Supreme Administrative Court. The effects of harbour construction on Natura values were investigated, using monitoring programmes. One part of the environmental assessment was monitoring of the birds, which began in the archipelago in 2001 and in the land areas in 2002. Impacts on bird populations were monitored between 2001 and 2011, according to a monitoring programme made for the project (Koskimies 2001).

The advantage of the programme was the fact that it covered different environments and the methods of bird counts are all well standardised. Major shortcoming of the programme was that not enough effort was out to planning the statistical handling of data and what variables should be used. Perhaps a little bit more attention should have been paid to more analytical and detailed analyses of monitoring data. Could models of population changes be used together with environmental variables? These shortcomings can now be seen, of course.

Allthough this was a small-scaled, question-driven monitoring project and its results cannot be easily generalized to other areas, deeper analyses of the main impacts and problems could have been useful for similar projects in future. Using nationwide monitoring data for comparison is also essential for distinguishing local level and nationwide changes (Tiainen 1985, Lindenmayer & Likens 2010). Population changes may be synchronous between different subpopulations or between different species, as the data of Finnish grouse species has shown (Ranta *et al.* 2006). Synchrony between species or subpopulations indicates that there may be a common factor behind population changes. It can be climate, or cyclic food like voles as in the case of Finnish owl species (Lehikoinen *et al.* 2011).

Table 1. A simplified summary of the monitoring programme (Koskimies 2001).There were some exceptions, for example the birds around road connections could not be count during construction. These exceptions are explained in the articles.

	Years before construction			Construction years					Years after construction		
	-3	-2	-1	1	2	3	4	5	+1	+2	+3
Waterfowl point counts		x	x	x	x	x	x	x	x	x	x
Territory mapping of wetland bird species		x	x	x	x	x	x	x	x	x	x
Territory mapping of land bird species		x	x	x	x	x	x	x	x	x	x
Counts of breeding seabirds	x	x	x	x	x	x	x	x	x	x	x
Additional counts of directive speciesat surrounding areas		x	x	x	x	x	x	x	x	x	x
Counts of migratory birds		x									

1.6 BIRD POPULATION CHANGES IN FINLAND DURING RECENT DECADES

Here I will shortly review the most notable changes in Finnish bird populations during the recent decades. I will do this in order to give the reader some reference points where to compare the results of the Vuosaari monitoring program.

Local population dynamics are not independent of large-scale population dynamics in the surrounding areas. In addition, several factors, such as climate and changes in large-scale human land use are also important drivers of the population dynamics of birds.

During the recent decade barnacle goose, Canada goose *Branta canadensis* and great cormorant *Phalacrocorax carbo* numbers have increased rapidly, especially in the western part of the Gulf of Finland (Hario & Rintala 2011). Human actions have created new foraging and resting areas, and larger fish stocks due to eutrophication. The increase in the barnacle goose population near Vuosaari follows the increasing population trend reported around several cities along the southern cost of Finland, including Helsinki metropolitan area (Väänänen *et al.* 2010). Key issues behind this rapid increase are suitable breeding and foraging habitats (Väänänen *et al.* 2011).

In addition, rising temperature has shifted population densities of Finnish birds towards north likely due to climate warming, affecting the populations of the south Finnish birds (Virkkala & Lehikoinen 2014). Mild winters favour such small wintering species as Eurasian treecreeper *Certhia familiaris* and goldcrest *Regulus regulus*. During very cold winters 80-90% of the individuals may die (Väisänen *et al.* 1998). Southern species derive advantage from rising temperatures, whereas northern species suffer. For example, in comparison of bird populations at 96 boreal protected areas between the years 1981-1999 and 2000-2009 norther bird species declined 21% but southern species increased 29%. At the same time, mean temperature rose 0.7-0.8 °C (Virkkala & Rajasärkkä 2011).

1.6.1 FARMLAND SPECIES

Many farmland bird species, like European starling *Sturnus vulgaris* and Eurasian curlew *Numenius arquata*, have declined in Finland during the last 20-30 years (Järvinen & Väisänen 1978, Solonen *et al.* 1991, Tiainen *et al.* 2012, Laaksonen & Lehikoinen 2013, Väisänen & Lehikoinen 2013), but some species, such as northern lapwing *Vanellus vanellus*, have increased (Tiainen *et al.* 2012, Väisänen & Lehikoinen 2013).

The change of breeding and foraging habitats has been suggested to be the main reason behind the drastic decline of farmland birds . Change of farmland habitats and farming processes are key issues for many species (Solonen 1985, Solonen *et al.* 1991, Tucker & Heath 1994, Väisänen *et al.* 1998, Tiainen *et al.* 2012). In England, highest skylark *Alauda arvensis* densities are found at farms with highest crop diversity (Chamberlain *et al.* 2000). The cultivation of fields has intensified and the ditches and fallow areas have disappeared from the fields. Near Vuosaari harbour the barred warbler *Sylvia nisoria*, the curlew and the ortolan bunting *Emberiza hortulana* have all almost disappeared, but they have also disappeared from larger areas in the province of Uusimaa (Solonen *et* *al.* 2010). Suitable habitats may be found in only small patches, which are often remnants of earlier larger habitat areas. In such conditions, populations may be unstable and if the populations are too small they can disappear just by accident. Habitat loss can also generate population fluctuations (Hanski 1999, Ranta *et al.* 2006). However, it is also possible to make new habitat for some of the farmland species, as a study near the Vuosaari harbour has shown (Solonen 2007). In our study area, the number of farmland species near the road increased, probably due to the new habitat created (Paper I).

1.6.2 FOREST SPECIES

Many forest bird species have declined in Finland during the last 20-30 years (Laaksonen & Lehikoinen 2013, Väisänen & Lehikoinen 2013, Tiainen *et al.* 2012), and habitat change of woodland species is an important issue for example in Britain (Fuller *et al.* 2007). In forests, ground nesting bird species decrease because of predation (Mörtberg 2009). The clearance of the undergrowth vegetation in urban woodlands decreases the abundance and diversity of birds. A reduction in the undergrowth vegetation density increases the visibility of the prey and birds in the cleared plots are more vulnerable to predation. Vegetation clearance also decreases the number of insects, which are the main food for many species during breeding season (Heyman 2010).

Populations of many long distant migrants have declined compared with short distance or partial migrants or resident species (Virkkala & Rajasärkkä 2011, Laaksonen & Lehikoinen 2013, Väisänen *et al.* 1998). It has been proven earlier that the populations of the willow warbler, which is the second most abundant species in southern Finland, have fluctuated and there have been several declines in the last 40 years. Population has recovered, and the main reasons for these fluctuations have been suggested to be sudden changes in wintering conditions in Africa (Väisänen *et al.* 1998, Laaksonen & Lehikoinen 2013).

Some forest species, such as the wood pigeon *Columba palumbus*, the European robin *Erithacus rubecula*, the blackcap *Sylvia atricapilla*, the Eurasian blackbird, great tit and blue tit have increased in Finland. Populations of wider areas may change in synchrony: the population trends of 23 boreal forest bird species inhabiting the nearby Natura 2000 area in Vuosaari and in southern Finland were significantly positively correlated (Table II, Paper II).

1.6.3 WETLAND SPECIES

Wetlands are influenced by the structure and habitat changes of nearby areas. It has been shown that adjacent land use 250–300 metres from the wetland affects plant diversity (Houlahan *et al.* 2006). This may lead to changes in animal populations. Near Vuosaari, the Torpviken bay is the best area for waders (Paper III), and there the numbers of the common redshank *Tringa totanus* and the northern lapwing have decreased. The common redshank has decreased slightly along the Finnish coast (Hario & Rintala 2014), but the northern lapwing has clearly increased in agricultural areas in Finland (Ekroos *et al.* 2013, Tiainen *et al.* 2012).This may be the result of many different factors, including survival of breeding individuals in the coastal wintering of Western Europe. The same wader species decreased in Sweden in the Stockholm archipelago (Eklund 2009), so the changes may reflect population changes in a wider area.

Among the species which have increased in wetlands near Vuosaari are species which prefer more eutrophicated water, such as the common coot *Fulica atra*, the great crested grebe *Podiceps cristatus* and the tufted duck *Aythya fuligula* (Paper III). On the other hand, all these species decreased in Finnish lakes during 1986-2012 (Lehikoinen *et al.* 2013b), and the coastal population of the tufted duck has decreased during the same period (Hario & Rintala 2014). However, a study of marsh bird communities in Canada clearly showed that there is a human impact and it depends on how generalistic species are. Especially isolated wetlands near urban areas had a lower species richness of specialized marsh breeding birds than less isolated areas (Smith & Chow-Fraser 2010). Smith et al. recommend a 1000-metre buffer zone around marshes, where urban use of land is not dominant.

1.6.4 SEA BIRD SPECIES

In the Gulf of Finland there are about 30-40 species of seabirds (ducks, geese, waders, gulls and divers, see Paper IV), which are common breeders or migrants along the shores. The most abundant breeding seabird species in the sea area are the common eider *Somateria mollissima*, the black-headed gull, the mew gull, the arctic tern *Sterna paradisaea* and the European herring gull (Hario & Rintala 2011).

The common eider is a well-studied key seabird which breeds along the coast of the Gulf of Finland. During recent decades, the population of common eiders has decreased. Poor fledging success and the consequent low recruitment explain the decreasing trend (Hario & Rintala 2006, Hario *et al.* 2009a). Predators, food availability, female condition and the breeding habitat all have an effect on nestling survival. Large gulls and white tailed eagles *Haliaeetus albicilla* commonly prey on eiders and this has led to changes in female behavior and nest site selection (Öst *et al.* 2008, Öst *et al.* 2011, Jaatinen *et al.* 2011, Ekroos *et al.* 2012).

Another key species in the archipelago is the herring gull. In the early 20th century, there were only a few pairs of herring gull breeding in the archipelago southwest of Helsinki. At the beginning of the 1980s, the population had increased to about 6500 pairs. One explanation for the population expansion was the easy availability of manmade food at rubbish dumps. At the same time, also the great black-backed gull population increased (Bergman 1982), and single breeding pairs still breed in the area. The increase in the European herring gull population has caused various problems. The number of individuals has increased in rubbish dumps and around the city. Some individuals have specialized in hunting common eider ducklings or the chicks of smaller gull species. Such behavior is typical for the great black-backed gull (Bergman 1982). Together with other problems, predation by the European herring gulls partly caused the decline of the lesser black-backed gull *Larus fuscus* (Hario 1990).

During 2004-2007, a special project was targeted at reducing the number of European herring gulls around Helsinki. In total, about 15 000 European herring gulls and 600 greater black-backed gulls were culled at four large open-plan refuse dumps in the Uusimaa province. The aim of the project was to minimize the nuisance effects on humans caused by dense flocks of gull individuals in cities and to reduce the predation pressure on the lesser black-backed gull chicks (Hario *et al.* 2009b).

The culling project succeeded fairly well and the European herring gull population decreased rapidly after the beginning of the project. This is most probably also the reason for the European herring gull population decrease in the study area, not the Vuosaari harbour project (Paper IV).

The populations of the mew gull, the lesser black-backed gull and the black-headed gull have increased in Vuosaari study area (Paper IV). One reason for this may be that after the culling project there were less predatory European herring gull and great black-backed gull individuals left. Larger gulls also predate on terns and small waders. Tern populations have been stable. In other areas the mew gull and the common tern *Sterna hirundo* have increased, the lesser black-backed gull has decreased (Hario & Rintala 2011, Hario & Rintala 2008, Hario & Rintala 2014).

1.7 OBJECTIVES OF THE THESIS: THE POSSIBLE ROLE OF HARBOUR CONSTRUCTION ON CHANGES IN BIRD POPULATIONS

The objective of this thesis is to study local bird population changes and to link the observed changes to the construction of Vuosaari harbour or urbanization in general, to bird population changes in southern Fnland or to other factors, such as predators.

Although it is evident, that bird populations at the construction site of the Vuosaari harbour were destroyed, the estimation of the possible impact on nearby Natura 2000 area is not clear. Several transportation connections lead to Vuosaari harbour: railway, roads and a ship channel. Their construction may have affected bird populations of the area too.

There is evidence that disturbance due to noise and increased mortality caused by traffic may reduce the breeding success of birds (Foppen & Reijnen 1994, Parris & Schneider 2008, Halfwerk *et al.* 2011b). In general the impact of human disturbance on populations of the nearby areas has been poorly studied in northern Europe. In one Finnish study, the nesting success of the pied flycatcher *Ficedula hypoleuca* was lower near roads, probably due to collisions with vehicles (Kuitunen *et al.* 2003). However, in a forest bird study in Sweden, no general difference with distance to the road could be seen (Helldin & Seiler 2003).

The ship channel which comes to the harbour can have similar effects on the seabird populations like the road which leads to the harbour. The seabird populations of the northern Baltic Sea are threatened by many different factors. Boating and other disturbances such as fishing , eutrophication, feral mink *Neovison vison*, birds of prey, weather, toxic substances and many other factors have been mentioned as probable reasons for poor fledgling production and seabird population declines (Hario *et al.* 1987, Hario & Uuksulainen 1993, Nordström *et al.* 2003, Hario 2004, Hario *et al.* 2009a, Hario & Rintala 2011, Skov *et al.* 2011, Hario & Rintala 2014). Negative effects on seabirds may extend in the areas as far as several kilometres away from the source of the disturbance (Watts & Bradshaw 1994, Kala- ja Vesitutkimus Oy *et al.* 1996, Rodgers & Smith 1997, Mensing *et al.* 1998).Thus, it is probable that dredging, dumping and harbour construction may have brought about negative impacts on wetland birds and seabirds breeding on sites close to construction area.

In this thesis I have used the results of the long time monitoring of local bird populations and studied if they possibly express the harmful effects caused by the human activity in the neighbouring area. I have utilised the material that has been collected in the different environments in the study. The changes in the bird populations have been studied as linear trends but also with the help of generalized modelling. Among others, distance to the harbour, to the ship channel or to the road, and the general bird population changes in the areas of southern Finland and Gulf of Finland have been used as explanatory variables.

Hyphotheses

1. The construction of the Vuosaari harbour caused significant changes in the nearby bird populations and the changes deviate from the changes in the bird populations in a wider area.
2. The building of the services of the harbour split habitats, and railway and road connections caused changes in the bird populations.
3. The development of seabird populations was affected by the construction of the Vuosaari harbour and ship channel.
4. In addition, the seabird population changes depended on the character of the studied islands.
5. In addition to human activity, the small predators may have had an effect on the development of waterfowl populations.

2 MATERIALS AND METHODS

2.1 STUDY AREA

The study area is located in Helsinki, northeast of the Vuosaari district and Vuosaari harbour (N60°14.52' E25°9.07'). The study area consists of several monitoring areas of bird populations near the harbour and it also includes breeding islets of seabirds in both sides of the new ship channel (Fig. 8).

2.1.1 ÖSTERÄNGEN FARMLAND AREA

In 2002, the fields of the Österängen study area were used mainly for cultivation; 85% of the area was open fields (spring wheat), while 15% consisted of forests, bushes and gardens. The area was split only by a few drainage ditches. The study area is surrounded mainly by forests and gardens and covers an area of 56.7 ha.

The road through the field was built in 2004 and 2005, and the road was opened for traffic in November 2008. The road is a four-lane highway in the middle of the Österängen field area, and there is also a single-track railway. At the southeastern corner of the field, the road descends into tunnels and comes up near the harbour. The railway continues over the Natura 2000 area on a bridge. New landfills, rocky outcrops and road margins changed the open habitat in 2004. The overall size of the area that changed comprises 6.5 ha, or approximately 5% of the total area.

2.1.2 MUSTAVUORI, KASAVUORI AND LABBACKA FOREST AREAS

The Mustavuori forest area borders with the Mellunkylä valley and the Itäväylä highway in the west, Österängen field in the north and northeast and Porvarinlahti bay in the east. The southern border of the area runs along an electricity line through the forest area of northern Vuosaari. Mustavuori is rocky and wooded in its central parts. The forests are mainly mixed with wider grove areas on the fringes, where e.g. hazel bushes grow. Wooded swamp impressions occur in the southern part of the area and the area includes a small meadow strip in the Mellunmäki valley.

Kasaberget and Labbackka subareas are rocky and more rugged than the Mustavuori area. The high areas of Kasaberget in particular are covered with open rock (more than 40% of area) and the fairly open tree stand is pine-dominated. In these areas there are more differences in altitude compared to

Mustavuori. Furthermore, there are small sparsely wooded swamps in the rock depressions. There are small patches of mixed forest and wide areas of wind-fellings.

Labbacka forest area has rocky ridges and fairly large altitudinal differences. The undergrowth of the rocky areas is fairly scant and pine is the dominating tree species. Some luxuriant forest patches also occur in the dells. After 2004, two road tunnels and one railway tunnel were constructed under Labbacka subarea, and opened for traffic in November 2008. Nearly 10 000 vehicles use the road on weekdays and 6000 on weekends, with an additional 10 trains passing daily.

The total study area of forests was 159.9 hectares.

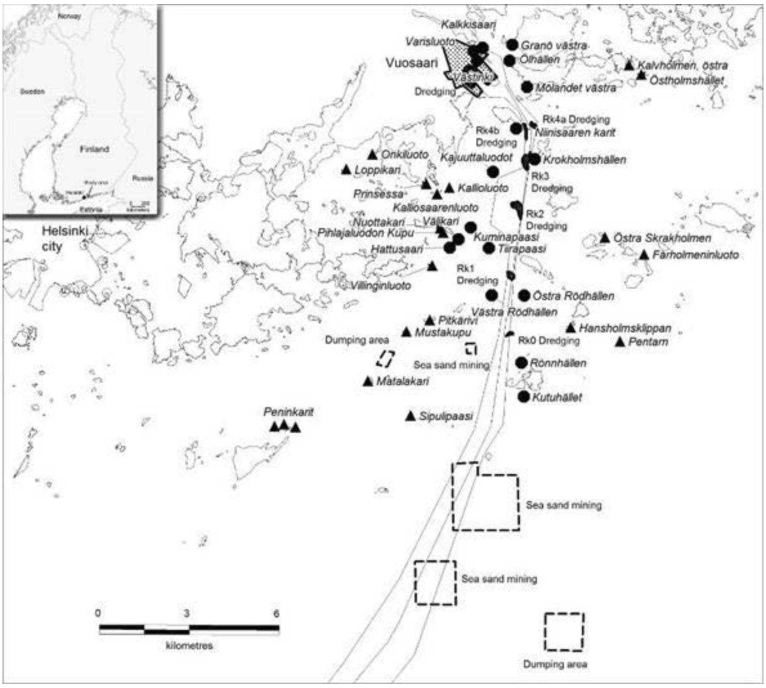

Fig. 8. The study area. The monitored seabird breeding islets are marked with black circles and reference islets with triangles. Dredging, dumping and mining areas are also shown.

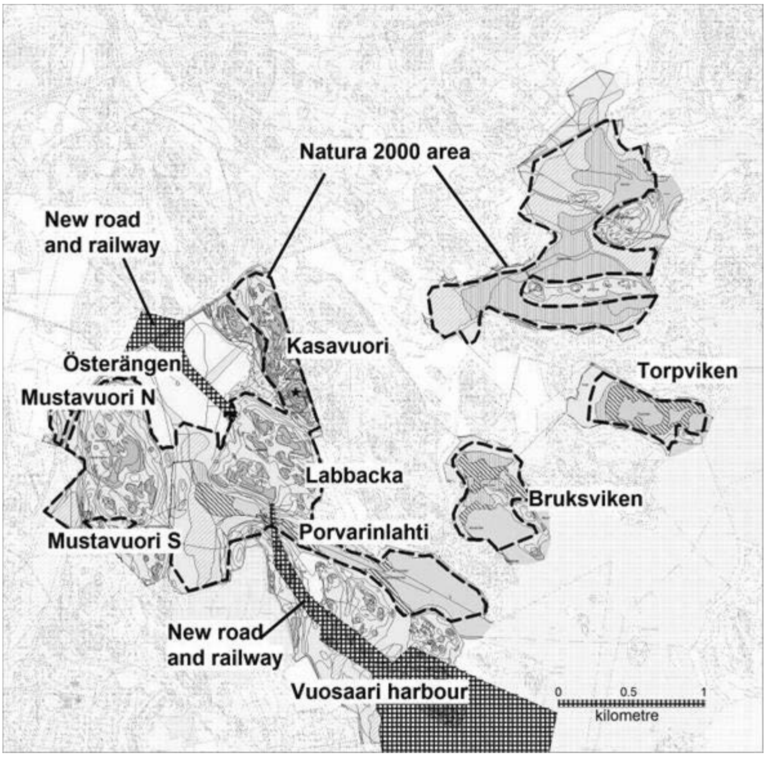

Fig. 9. The monitored forest areas and bays.

2.1.3 PORVARINLAHTI, BRUKSVIKEN AND TORPVIKEN WETLANDS

The total study area of wetlands was 152.5 ha. A new railroad to the harbour crosses the nearest bay, Porvarinlahti (distance to harbour 300 m). The other two bays, Bruksviken and Torpviken, are 800 m and 1900 m further east from the harbour. During most winters, the area freezes and is covered with ice. In winter, the water levels are often high, which combined with heavy winds cause movement of the ice fields that may cut the beds of common reed (*Phragmites australis*). This affects possibilities of breeding in the following season by controlling the area of standing reed beds suitable for many breeding birds, such as reed-warblers (*Acrocephalus* sp.).

Porvarinlahti is a narrow bay on the northern side of Vuosaari. Wide reed beds and a meadow area are located in the western part. The uniform reed bed covers half of the area. There are less than 2 ha of open water, and the turnover of water is limited. In the western and northern parts of the area grows a uniform tree stand in which deciduous trees predominate. Moist meadows are surrounded by stands of common alder (*Alnus glutinosa*). During the study years, birches (*Betula*) spread out as far as the reed bed. The eastern part of Porvarinlahti Bay is less than 5 m deep. Reed beds line its narrow watercourse. The bay enlarges towards its mouth, and the turnover of the water increases. There are also other habitats in the area, such as mixed forest, cultivated fields and shore meadows. Several inhabited cottages and a single small boat dock are located in the area.

Bruksviken is divided into three subareas of nearly equal size, consisting of open-water, reed beds and forest. A forested island is located in the middle of the area. Common alder, silver birch (*Betula pendula*) and downy birch (*B. pubescens*) are typically found in the shoreline forests. The northern part of the bay comprises a low-lying and moist flood meadow that is drier close to the road passing along the northeastern edge. The southern and western parts of Bruksviken are rockier. Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) stands grow in the drier areas.

Torpviken is a low bay with large reed beds. A small island Sillholmen lies in the mouth of the bay. Torpviken is gradually disappearing under the overgrowth; in summer it resembles a lake. The reed bed produces biomass that decomposes slowly and makes the bay shallower. The shore forests vary in their species composition. A narrow fringe of common alder and a dense Norway spruce forest are located at the western edge. In the northern part, near the manor house of Husö, there is a pasture for horses which graze in the area, beginning in early summer. The pasture is occasionally very moist. A luxuriant broad-leaved forest that gradually changes into spruce and pine forests is located on the eastern shore.

The only change in wetland habitats due to harbour construction was the construction of a bridge over the Porvarinlahti bay. All other changes were natural, like reduction of water bodies because of eutrophication and the reed bed overgrouth.

2.1.4 BREEDING ISLETS OF SEABIRDS

The monitored area comprised 17 islets (Fig. 8). These islets were located 2 km from the new harbour area or ship channel. All except one monitored islet were open-access or in recreational use. In the archipelago between the communes of Sipoo and Espoo, the nesting success of seabirds has usually been poorer on open islets subject to recreational use than on islets in the conservation or military areas (Matti Luostarinen, personal observations). In 2004, with permission of the authorities, two islets, Varisluoto and Västinki, were covered by harbour landfills and the construction area,. Västinki, an islet with a colony of black-headed gulls (200 pairs), was covered with landfills after the breeding season, preventing breeding in subsequent years.

The reference area included 21 islets (Fig 8) that were selected on the basis of their seabird fauna, which was similar to that of the study islets. The reference islet were located so far from the new harbour and ship channel construction that we expected that the populations would be unaffected by the construction. Open-access and recreational use were allowed for 12 islets. Nine islets had restricted access: three were military areas and the remaining six were nature reserves.

The islets in the archipelago differ: the inner archipelago islets are more luxuriant, and their shores are usually less susceptible to eroding surge. In the outer archipelago, the islets are more rugged. Hence, the seabird communities also differed along the inner/outer archipelago aspect.

Fig. 10. Österängen farmland.

Fig. 11. Road and railway crossess Österängen and tunnels go through Labbacka forest.

Fig. 12. Hazel stands at Mustavuori.

Fig. 13. Luxuriant vegetation at Mustavuori.

Fig. 14. Goshawk Accipiter gentilis nesting forest at Mustavuori.

Fig. 15. Central parts of Mustavuori forest are rocky and dry.

Fig. 16. A view to sea from the rocky top of Kasavuori forest.

Fig. 17. Railway tunnel at Labbacka.

Fig 18. Porvarinlahti bay before the construction of railway bridge.

Fig. 19. Same area after bridge construction.

Fig. 20. Water lilies and reed beds at Porvarinlahti.

Fig. 21. Shore meadow at Porvarinlahti.

Fig. 22. Bruksviken.

Fig. 23. Common alder forest at Bruksviken.

Fig. 24. Torpviken.

Fig. 25. Horses grazing in Torpviken shore meadow.

Fig. 26. Breeeding islet of gulls and terns.

Fig. 27. The islets of outer archipelago are rocky.

2.2 BIRD DATA

We used standard methods in bird population monitoring and repeated the territory mapping each year following methods used by the Finnish Museum of Natural History for bird census studies in Finland (Koskimies & Väisänen 1988). In the Österängen field area and wetlands we estimated the number of territories using five separate mappings performed between late April and late June. In the forest areas, we estimated the number of territories using ten separate mappings performed between late April and late June.

After fieldwork, we analysed the observations and estimated the number of territories. In the Österängen field area and wetlands we designated an area as a territory if a single bird or a pair was observed in approximately the same position in two or more mappings and at least one of these observations showed territorial behaviour (song, an alarm call, territory fight or a parent bird carrying food to a nest). In the forest areas, we designated an area as a territory if a single bird or a pair was observed in approximately the same position during three or more mappings.

Bird populations in our study area are not independent of the surrounding world. Several bird populations may vary simultaneously over wide areas. We therefore compared the species-specific population trends in the study site that correlated with the corresponding population trends of the same species elsewhere in southern Finland (south from 61°14' N). We used the common bird monitoring data of Finland coordinated by the Finnish Museum of Natural History from the same study years 2002–2011 as collected from Vuosaari. The monitoring data include both point counts (an average of 14 point count routes annually, min – max: 12–17) and line transects (45, 17–73). Although the methodology used in Vuosaari (territory mapping) is different from that used in national counts, the trends of both methods should be comparable.

We only compared the trends of common bird species primarily breeding in forests (Laaksonen & Lehikoinen 2013) that had at least 3 pair observations annually both in Vuosaari and in the common bird monitoring. This produced a total of 23 study species.

Österängen field area was mapped by Jarkko Santaharju, Kasavuori forest area was mapped by Antti Tanskanen, Labbacka forest area by Thomas Oesh (†) and Jorma Vickholm, northern Mustavuori forest area was mapped by Hannu Sarvanne and southern Mustavuori forest area by Antti Tanskanen. Porvarinlahti bay was mapped by Hannu Sarvanne and Jorma Vickholm, Bruksviken and Torpviken bays by Antti Tanskanen. Rauno Yrjölä and Matti Koivula mapped forest areas which remained under harbour construction.

We estimated waterfowl reproductive success in the Porvarinlahti, Bruksviken and Torpviken areas. We counted the nestlings during the breeding season. The counts were done six to eight times between May and August from certain observation posts along shoreline areas, or sometimes a boat was used (typically in late season, when the vegetation was more luxuriant). Reproductive success was counted as the number of 4-week-old nestlings per breeding pair. The nestlings were aged, employing the criteria commonly used in Finland (Pirkola & Högmander 1974). Waterfowl counts were mainly done by Rauno Yrjölä, additional counts were done by Jarkko Santharju, Antti Tanskanen and Jorma Vickholm.

The hunting bag data was collected from local hunters. Generally, the hunting season of small mammal predators is in autumn and early winter. So we assume that the number of predators killed indicate the number of predators present during the previous summer season.

Matti Luostarinen performed all seabird counts during 2001–-2011. In May, the early breeders were counted. In June, the numbers of late breeders were registered, and the adult birds of these species and the young of the early-nesting species were ringed. In late June to early July, the young of the late nesting species were ringed. During several survey years, bad weather occasionally prevented fieldwork, and some islets were visited less than three times during a season. Counts were taken during a 15–-30-min stay per islet; a longer census time would have resulted in damage to the nesting sites. In some locations, the terrain was so difficult that the time-consuming nest censuses were not done so as to minimize disturbance; in these cases, we quickly performed a rough population estimate, based on the number of adult birds in the vicinity of the breeding colonies. On the breeding islets of the endangered Caspian tern *Hydroprogne caspia*, the counts were performed with special care and rapidity.

2.3 STATISTICAL ANALYSES

2.3.1 FARMLAND STUDY (PAPER I)

In the Österängen farmland area, the null hypothesis of the study was that construction of the road would cause no significant changes in breeding bird populations of the study area. We tested the significance of population changes with the Mann-Kendall test, using Systat 12 statistical software (Systat Software Inc., San Jose, CA, USA). The independent variable was the year and the dependent variable the number of territories (or pairs). We calculated the trends for three separate time periods: the entire study period (2002-2011), years around the road construction period (2002-2008) and the post-construction period (2006-2011) when the road was in use. The test for the entire study period is in response to the original task of the Vuosaari EIA, i.e. to determine whether or not bird populations changed. The test for only the first six years show changes during construction, and the test for the last years indicates the impact of road use or habitat succession.

The change in the distribution of the midpoints of territories with regard to the roadway was studied by measuring the distance between the territories to the midpoint of the roadway. The midpoint of a territory was estimated from all species observations on field maps recorded by an observer. The distances were calculated from Geographic Information System (GIS) data, using MapInfo software (MapInfo (now Pitney Bowes Software), Stamford, CT, USA). The difference in the distance distributions of the territory midpoints before and after road construction was tested with the Mann-Whitney *U*-test. This was done only for northern lapwing, Eurasian skylark and meadow pipit *Anthus pratensis*, which were the only species breeding in the open spring wheat field at the beginning of the study. Other species lived in the gardens or forests and bushes at the edge of the study area.

Species diversity was estimated with the rarefaction method, using the EcoSim 700 program (Acquired Intelligence Inc., Victoria, British Columbia, Canada) (Gotelli & Entsminger 2005). Year 2002 was set as the base year, and the change was interpreted as significant if the rarefaction average of a year moved beyond the 95% confidence limits for the year 2002. Rarefaction enables comparison of samples of different total sizes.

2.3.2 FOREST BIRD STUDY (PAPER II)

We calculated the population trends for each species using the TRIM programme (Pannekoek & van Strien 2001). It accounts for overdispersion and serial correlation, and interpolates missing observations using a Poisson general log-linear model. TRIM produces annual growth rates as well as annual abundance indices. In this study we only used general trends (annual additive growth rates). Although no observation gaps were found in the Vuosaari data, we also calculated the trends for this area using the same programme, which makes it easier to compare the growth rates between Vuosaari harbour area and southern Finland.

We first tested whether the species-specific growth rates in Vuosaari were explained by the corresponding growth rates based on data from southern Finland using linear regression. Using t-tests we next tested whether the species-specific growth rates differed between these two areas.

We also compared local population trends inside the Natura 2000 site by comparing the population trends of the subarea situated closest to the construction area (Labbacka) with the combined trends of the other three subareas (Kasavuori, Mustavuori N and S). We compared the trends of all forest bird species observed in both areas using a linear mixed effect model where annual species-specific log-transformed (log(N+1)) population size is the dependent variable, the year, site and their interaction are the explanatory variables and the species is a random factor. The analyses included a total of 36 species.

2.3.3 WETLAND STUDY (PAPER III)

We assumed that the impacts would be highest on birds breeding nearest the harbour, in Porvarinlahti Bay. The null hypothesis of the study was that construction of the harbour and its road connections would cause no changes in the breeding bird populations of the study area and that no differences would be seen between bird populations in Porvarinlahti and the other areas.

We calculated population trends for each species using TRIM. We used bay identity as a covariate to determine whether the population trends were different between groups (Porvarinlahti group 1, other areas group 2). TRIM's Wald-test was used to analyse whether the groups had different population trends.

The hunting bag and waterfowl correlations were tested using Systat 12 statistical software (Systat Software Inc., San Jose, CA, USA).

2.3.4 SEABIRD STUDY (PAPER IV)

To estimate the differences in species-specific population trends by monitoring/reference and open-access/restricted areas, each species having a total number of more than 30 pairs was analysed with generalized additive mixed models (GAMMs), primarily for denoting the smooth term (Wood 2004, Zuur *et al.* 2009) of the trends by the spatial treatment (i.e. the trends between the monitored and reference islets) and generalized linear mixed models (GLMMs) for revealing the interactions of the year-effect and the spatial treatment and island type (i.e. open-access vs. restricted-access). The islet or island identification code was set as a random effect, and the first-order residual temporal autocorrelation structure was controlled in all models. The GAMMs were performed, using the function gamm of library mgcv (mixed GAM (generalized additive model) computation vehicle) and the GLMMs with the function glmmPQL (glmm Program Query Language) of library MASS (Modern Applied Statistics with S) (Venables & Ripley 2002) in R vers. 3.1.2 (R Core Team 2014). Passerine species were not tested, because on many islets the population data of these species were only of the present/absent type. The black guillemot bred only on the reference islets.

3 RESULTS

3.1 RESULTS OF PAPER I

This paper presents the results of the road construction study. During 2002-2011, 43 species were observed in the study area. The annual number of territories varied from 48 to 97 and the number of species from 21 to 25. No clear trend emerged in the yearly number of species. The annual number of near-threatened or threatened species was 1 or 2 before construction, and 4-9 after construction, but again no clear trend emerged.

The number of territories almost doubled after construction of the harbour road (Fig. 2 in Paper I). Only the great tit and Eurasian blue tit, which breeds in gardens and forests around fields, diminished statistically significantly throughout the study period. Species that increased included the tree pipit *Anthus trivialis*, northern lapwing and meadow pipit. At the beginning of the study, the Eurasian skylark increased significantly. At the end of the study period, the numbers of barn swallow *Hirundo rustica* and great tit, and the total number of all territories decreased. The level of species diversity throughout the study period was quite equal to that at the beginning of the study in 2002. Several years lie under the 95% confidence limit for the year 2002, but the trend is uncertain and interannual variation is present (Fig 4 in Paper I).

The average distance of territories of all bird species from the roadway changed during the study period, showing a general decrease ($p = 0.001$). The average distance of Eurasian skylark territories from the road remained the same while the average distance of northern lapwing territories increased only slightly. Both species breed in open fields, and it was expected that they would shift territories further away from the road. Territories of species like meadow pipit, northern wheatear *Oenanthe oenanthe*, white wagtail *Motacilla alba* and common linnet *Carduelis cannabina* were clearly concentrated along the roadside after road construction. See the map of meadow pipit territories as an example (Fig. 6 in Paper I).

3.2 RESULTS OF PAPER II

This paper investigates the possible correlation of forest bird population changes to forest bird populations in southern Finland, and the possible impact of tunnel cosntruction on forest birds in Vuosaari. During 2002-2011, 64 species were observed in forest areas as possibly breeding species. The annual number of territories varied from 473 to 573 and the number of species from 41 to 49.

The population trends of 23 forest bird species in Vuosaari were significantly connected with the species' population growth rates in southern Finland during 2002–2011, but it is important to note that the regression slope did not differ from 1 ($F_{1,21} = 11.9$, $b = 1.09 \pm 0.31$, $P = 0.024$). Although the population trends in southern Finland (mean growth rate +0.4%/year) were on average more positive than in Vuosaari (-0.3%/year), this difference was not significant. Furthermore, no general trend was observed in the populations of 36 forest species present in Vuosaari (table 2 in paper II).

A simple cross tabulation of forest bird species population trendsshows that most of the trends correlate between areas (Table 2). There are six species with opposite trends, but all the others species, except great tit, where not significant. The great tit significantly decreased in Vuosaari, but increased in Southern Finland. This can be a random result.

Table 2. A simple cross tabulation of forest bird species population trends.

Vuosaari	Southern Finland	
	decreaced species	increased species
decreaced species	7	4
increased species	2	10

The average population sizes were smaller in the subareas closest to disturbance caused by tunnel construction (Labbacka) than in the rest of the subareas inside the Natura 2000 area during the whole period (effect of site: $t = -9.76$, $df = 681$, $P < 0.001$). That was due to the larger spatial area of the latter, but no difference was observed in the population trends between these two areas (interaction between year and subarea: $t = -0.30$, $df = 681$, $b = -0.0016 \pm 0.0054$, $P = 0.77$).

3.3 RESULTS OF PAPER III

This paper presents the population changes of wetland bird species and the reproductive success of some waterfowl species near the Vuosaari harbour and discusses the possible reasons behind the observed changes. During the study, we observed 20 wetland species with sufficient data for analyses. Wetland species are a difficult target group for censuses due to their variable territorial behaviour and habitat or site changes during parental care.

In general, the number of species territories differed between the subareas. There were also significant differences between the population trends of species in the various subareas (Fig. 2 paper III).

Some species increased in number during the study. The common or Eurasian teal *Anas crecca*, great crested grebe and tufted duck increased in Porvarinlahti. There were more common coots in Bruksviken and Torpviken than in Porvarinlahti, but the number in Porvarinlahti and Torpviken increased (Fig. 2 in paper III).

Several species decreased during the study years. The common redshank decreased in Torpviken, Eurasian reed-warbler *Acrocephalus scirpaceus* in Bruksviken and reed bunting *Emberiza schoeniclus* in Porvarinlahti. There were more great crested grebes in Bruksviken than in the other areas, but the number of pairs decreased. The mute swan *Cygnus olor* decreased during the monitoring years in Porvarinlahti, but the number of pairs was very low (Fig. 2 in paper III).

The reproductive success of waterfowl species was low. Only a few species (mallard *Anas platyrhynchos*, great crested grebe and common goldeneye *Bucephala clangula*) managed to raise appreciable numbers of 4-week-old nestlings. One possible reason for low reproduction is predation. Raccoon dogs *Nyctereutes procyonoides* were the most numerous small predators in the area, but American mink and red fox *Vulpes vulpes* may also be important predators of nesting waterfowl species. There was a negative relationship between the number of annually hunted medium-sized predators and the production of ducklings (Fig. 4c in paper III). This result is explained by the fact that the hunting season begins after the ducks have bred.

3.4 RESULTS OF PAPER IV

This paper investigates the possible impact of the construction of the new ship channel on seabird populations. The possible effects on the seabird populations were investigated in two areas. One area included islets within two kilometers from the harbor and ship channel. Another area included islets at a larger distance than two kilometers. The birds in the former area were considered to be at risk of disturbance and we call this area the risk area. We assumed that two kilometers was sufficient to exclude disturbance and this area is our reference area.

During 2001–-2011, 28 seabird species were observed breeding on the risk islets, and the annual total number of pairs varied from 980 to 1196. For the reference islets, the corresponding numbers were 32 species and pair numbers varying from 1090 to 1615.

Species-specific models revealed several significant parameter effects on the overall trends and deviations in the trends between the risk and reference areas, as well as inter-area variation in islet-specific pair densities (Table 1, Fig 2 in paper IV). The trend of the ruddy turnstone was somewhat more negative in the risk area than in the reference area, as was the trend of the great black-backed gull.

The number of mute swan pairs decreased over the years, showing lower densities on the reference islets. The Canada goose numbers increased significantly on the reference islets, but not on the risk islets. The numbers of barnacle goose increased slightly faster on the reference than on the risk islets.

The mallard declined significantly on both the risk and reference islets, showing significantly higher pair densities on the reference islets. The tufted duck declined significantly, particularly on the reference islets. The numbers of the common eider showed exponential increases on both the reference and risk islets during recent years.

The Eurasian oystercatcher *Haematopus ostralegus* showed general increases on both the risk and reference islets. The numbers of common redshank decreased slightly, particularly on the risk islets at the beginning of the study period. The common ringed plover *Charadrius hiaticula* densities were generally higher on the reference than on the risk islets. In the risk area, the densities were generally highest on the restricted islets. However, in the reference area, the densities were lowest but temporally increased most quickly on the restricted islets.

Our monitoring data revealed the most substantial changes in numbers for highly colonial species such as the gulls. The European herring gull population showed a general decline, with the highest densities on the restricted-access islets. The lesser black-backed gull increased significantly on the risk islets, while the common gull increased, particularly on the reference islets, but also in the risk area. At the beginning of the study period, the black-headed gull was more numerous on the risk islets than on the reference islets. However, during and after the harbour construction, the numbers of pairs increased significantly in the reference area.

The numbers of the common tern and arctic tern fluctuated substantially during the study period, but the modelling indicated no clear associations with the environmental change. The nonlinear model suggested a population decrease in the reference islets.

4 DISCUSSION

4.1 THE IMPACTS OF URBAN LAND USE

Presently more than 50% of the human population lives in urban areas. Urbanization has already caused and will cause further changes in e.g. bird populations (Jokimäki & Suhonen 1993, McKinney 2008, Rottenborn 1999, Garaffa *et al.* 2009). Rapid urbanization and other human activities usually affect species negatively, but moderate disturbance can also increase biotic diversity (Jokimäki & Suhonen 1993, McKinney 2008). However, the effects of moderate levels of urbanization (i.e., suburban areas) vary significantly among groups, for example most of the plant studies (about 65%) indicate increasing species richness with moderate urbanization, but most invertebrate and vertebrate animal studies indicate decreasing species richness (McKinney 2008). In some cases population densities may be over 30% higher in urban environments compared with rural environments, and densities may reflect the timing of urbanization: the earlier urbanization has happened, the higher densities are now (Møller *et al.* 2012).

4.2 THE IMPACTS OF ROADS

In agricultural grasslands in the Netherlands, 7 out of 12 species that could be analysed showed reduced densities adjacent to a road (Reijnen *et al.* 1996). The results of many studies have suggested that traffic noise is the main negative effect causing population decrease near roads (Reijnen & Foppen 1994, Parris & Schneider 2008), but in fact traffic mortality may be the prevailing factor (Summers *et al.* 2011).

Paper I of this thesis presents a synthesis on the impacts of road construction on local farmland birds. The construction of the road did not significantly reduce bird populations of the Österängen field area. In fact, the observations suggest that the new environment along the roadside provided an advantage to some bird species, and the population of several species increased significantly near the new road.

In comparison with other areas, it is important to remember that road density and the volume of traffic in central Europe are considerably higher than in Finland (Nicodéme *et al.* 2013). In studies in the Netherlands, tens of thousands of vehicles per day were running on the motorways (Reijnen & Foppen 1994), compared with less than 10 000 vehicles (and 10 trains) on weekdays and 6000 vehicles on weekend days on the new Vuosaari harbour road and railway.

According to the results, the construction of the harbour road did not significantly reduce the bird populations of the area, and no general negative trend was found. In contrast, the number of territories of some species increased immediately after the construction of the road. The average distance from the road of the territories of all species did not increase as expected, but instead decreased. Closer examination of the Eurasian skylark and northern lapwing revealed that the number of pairs increased and no clear change occurred in the distribution of territories.

The observations suggest that the new environment along the roadside provided an advantage to some birds, in contrast to the possible negative impacts caused by the road and traffic. A closer look at the territory maps of some species revealed that the most significant change was that territories concentrated along the roadway area, resulting in changes in bird populations. The new environment increased bird populations near the road, at least momentarily. Generally, roadside vegetation has a strong influence on animal species composition and on the width of the road-effect zone (Reijnen *et al.* 1996, Forman & Alexander 1998). This does not suggest that there are no negative impacts, but the advantage is clear when the numbers of territories are examined. Previously, the field area was intensively cultivated and did not offer a suitable nesting habitat for species utilizing the broad margins of the new road area.

4.3 SOME SPECIES BENEFIT FROM MAN MADE HABITATS

Some species, such as the northern wheatear, white wagtail, meadow pipit and common linnet, may have benefited from the construction, which formed new margins and roadside habitats (Paper I). For example, all territories of the vulnerable northern wheatear were located at the margins of the new road area. The northern wheatear clearly benefited from the quantities of stones brought to the area and landfills. A new habitat may attract individuals, but their mortality near a road may be higher or their breeding success lower than in more natural habitats, as in the pied flycatcher study in Finland (Kuitunen *et al.* 2003). In a study in the Netherlands, willow warbler males that did not succeed in breeding near a highway moved more frequently and farther away than successful males (Foppen & Reijnen 1994). If there are surplus individuals nearby, they can occupy abandoned territories.

Although the results suggest that construction of the road did not affect the bird populations negatively, whether there were negative impacts at the individual level remains unclear. It is not known how many individuals died in collisions with vehicles or whether they moved elsewhere and new individuals took over their territories. When populations increase, poor-quality territories may also be occupied.

4.4 SYNCHRONY OF POPULATION CHANGES OVER A WIDER AREA

Paper II of this thesis compared the forest bird population changes with bird population changes in southern Finland and assessed the possible impact of the new tunnel through forest area. Forest bird species populations in the Vuosaari study area seem to fluctuate in synchrony with populations of southern Finland (Table 2, Paper II), which may indicate that in this case population changes in a wider area are more important than impacts of a nearby harbour construction.

Previous nation-wide studies have shown that long-distance tropical migrants, northern species and species living in agricultural environments have declined in Finland. These changes are likely linked with changing conditions in the non-breeding sites (long-distance migrants), rising temperature (northern species) and changes in farmland land use (Virkkala & Rajasärkkä 2011, Tiainen *et al.* 2012, Laaksonen & Lehikoinen 2013, Väisänen & Lehikoinen 2013).

The distribution of many Finnish bird species has moved towards the north, likely due to rising temperature, (Virkkala & Lehikoinen 2014). Present findings support the idea that local population dynamics are not independent of large-scale population dynamics in the surrounding areas, and factors such as climate and large-scale human land use changes are also important population drivers.

Furthermore, the results were unable to show that the building of Vuosaari harbour and traffic lanes caused significant population decreases in the Natura 2000 site. On the other hand, the harbour construction may have had a negative impact on local forest bird populations. Outside the Natura 2000 site 50 hectares of forest was clear-cut for constructing the harbour.Based on the average densities of forest birds in southern Finland, this meant the habitat loss of at least a few hundred bird territories. Compared with the yearly clear-cut area of the whole Uusimaa province (more than 18000 hectares), the proportion of impact area is 0.27%.

There are several explanations why there were no significant changes in the trends between the Natura 2000 site and southern Finland in general. It is possible that the common forest birds in the boreal zone are rather tolerant of medium-level disturbance such as road traffic noise. The fact that the study site is currently already situated rather close to the urban areas of Helsinki could have modified the bird community composition in the Natura 2000 site towards more disturbance-tolerant species. It should also be kept in mind that all the study species are common forest birds, and scarce and perhaps more disturbance-sensitive species were not considered due to data limitations. In this case, the control data is collected from a much larger area (southern Finland) and species composition may be different, leading to increasing variance which may weaken the possibilities to find differences. The cencus methods were different too.

The present results indicate that the impact of the construction work on the harbour had only a limited impact on the population trends of common birds in the Natura 2000 site and other, more general factors such as the climate and changes in the non-breeding grounds were likely a more important driver of local bird dynamics. It is possible to argue that since a negative impact was not detected the preparation process and design of the construction work of the harbour had been conducted well enough to maintain the biodiversity values of the nearby Natura 2000 site.

4.5 POPULATION CHANGES AND REPRODUCTION OF WETLAND BIRDS

Paper III of this thesis compared the population trends of wetland bird species at three different bays, and waterfowl reproductive success in the same area. We observed only a few clear changes in wetland bird populations. Despite the harbour and other construction works nearby, most of the breeding bird species populations have remained at similar levels during recent decades as they were before. Among the species that have increased are those that prefer more eutrophicated wetlands, such as the common coot, great crested grebe and tufted duck.

The reasons behind these changes may be local, but many wetland birds are declining in Finland. The common redshank, Eurasian reed-warbler and reed bunting are all species that have declined in the Vuosaari study area, as well as over wider areas of Finland. The common coot, great crested grebe and tufted duck have increased in Vuosaari, but decreased elsewhere in Finland (Lehikoinen *et al.* 2013b). In Vuosaari, reed beds are still increasing in size and meadows and open bodies of water are disappearing. This type of eutrophic wetland habitat is crucial for these three species.

Some of the declining species are waders that breed in open seashore meadows. The negative population trends of such species may have been due to the change in vegetation. The native meadow plant species are disappearing, and species that tolerate eutrophication are increasing (von Numers & Korvenpää 2007). Bushes and reed beds are converting shore meadows into terrain less suitable for waders, which may be why the common redshank has decreased along the coasts of Finland (Hario & Rintala 2014).

Other factors behind the population changes may include varying migration strategies of species, weather conditions and pure coincidence. Some waterfowl species tend to overwinter in more northern areas than they used to do. The numbers of tufted ducks, common goldeneyes and goosander *Mergus merganser* overwintering in Finland are much higher now than in previous decades (Lehikoinen *et al.* 2013a). The northern overwintering areas are close to the breeding areas, but this implies the risk that during some winters there may be higher overwintering mortality.

The reproductive success of all waterfowl species was very poor. When local hunters hunt small mammalian predators mainly in autumn and early winter, the number of predators killed indicates the number of predators which were present during waterfowl breeding season.

The total number of waterfowl nestlings and the hunting bag of small mammal predators negatively were correlated. Waterfowl nesting success decreased with an increase in the hunting bag. However, the removal of predators slightly increased the population size in the following year. If the reproductive success of these waterfowl species is often as poor as our results suggest, the populations can remain stable only if new recruits come from outside the study area. The study area near Vuosaari Harbour may be a sink area, with new individuals arriving there from other areas.

This phenomenon needs further study, but it is clear that small mammal predators must be removed from the Natura 2000 area to maintain favourable population levels of waterfowl species.

4.6 THE WINNERS AND LOSERS OF ARCHIPELAGO BIRDS

Paper IV of this thesis compared the population trends of seabirds breeding near harbour or ship channel (monitored islands) to the population trend of seabird breeding further away (reference islets). The Vuosaari Harbour and ship channel construction represent one aspect of the urbanization process in the City of Helsinki, which has been intensifying and expanding during recent decades.

Despite human activities, the populations of some seabird species have quite uniform trends over wide coastal areas of Finland. In the Vuosaari study area mallard and tufted duck declined during the study years. During the same period (1986—2013) the tufted duck decreased moderately in Finland (Hario & Rintala 2014). The mallard has increased slightly in inland lake areas (Lehikoinen *et al.* 2013b, Pöysä *et al.* 2013), but in the archipelago the species has apparently shown no general population trends. The Canada goose and particularly the barnacle goose have increased along the coastal Gulf of Finland (Hario & Rintala 2014).

The barnacle goose population increased strongly in the study area, and the species has adapted very well breeding in the City of Helsinki. Barnacle geese breed in the archipelago, but use fields, golf courses or even city parks as feeding areas during summer and autumn. The first pair bred in Helsinki in 1989, and in 2009 the population was estimated at 900 breeding pairs and more than 8000 staging individuals in the autumn (Väänänen *et al.* 2010).

The populations of the great black-backed gull and the European herring gull have decreased in our study area, at the same time the mew gull, lesser black-backed gull and black-headed gull have increased. This may have resulted from the presence of fewer predatory European herring gull and great black-backed gull individuals. Construction of the Vuosaari Harbour and landfills on the Varisluoto and Västinki islets during 2003–2004 reduced the number of common black-headed gulls. However, when all the islets were examined, the total pair numbers of common black-headed gulls returned to the levels observed in the early 2000s, i.e. more than 250 pairs. Nationwide, the common black-headed gull declined in the early 2000s, but later its population began to increase again (Hario and Rintala 2014).

During the study years common redshank population decreased, both on the monitored and reference islets. Only the common ringed plover population increased slightly, especially on the restricted-reference islets. The Archipelago Bird Census revealed that the common ringed plover has moderately increased and the ruddy turnstone and common redshank have moderately decreased in the coastal areas of Finland during 1986-2013 (Hario & Rintala 2014).

Many seabirds live long and they are faithful to their breeding sites. Especially long-living gulls and terns may be observed breeding at the same island year after year, but their reproduction may be low. This low reproduction may go unobserved in the data, and decreasing populations may be seen after a delay of several years.

In addition to natural reasons (predators, species competition etc.), the changes of seabird populations can also be caused by human impact (Paper IV). Boating and other disturbances such as fishing, toxic substances and eutrophication have been mentioned as the probable causes of poor fledgling production and seabird population declines (Hario *et al.* 1987, Hildén & Hario 1993, Hario & Uuksulainen 1993, Nordström *et al.* 2003, Hario 2004, Skov *et al.* 2011, Hario & Rintala 2011, Hario & Rintala 2014).

4.7 ISLAND TYPE MATTERS

The type of island has some importance for the bird population changes. Nesting archipelago birds are more often disturbed on open-access islets than in restricted-access conservation or military areas (Matti Luostarinen, personal observations). The population of the common ringed plover was increasing on restricted access islets in the reference area, where disturbance is lowest. Also the density of the European herring gull population was highest there. The trends of ruddy turnstone and great black-backed gull populations were somewhat more negative in the monitored than in the reference areas. This may have been a random result, or these species may be more sensitive to human disturbance than others. Most species showed no difference between trends in the monitored and reference islets. Other studies have shown that in Finland more common eiders breed in protected areas than would otherwise be expected considering the total extent of these areas (Kilpi 1997).

4.8 HYPHOTHESES REVISITED

Hypothesis 1 - that the construction of the Vuosaari harbour would cause significant changes in the nearby bird populations and the changes would deviate from the changes in the bird populations in a wider area – was not supported by this study. There were some negative changes in bird populations, but in many cases population changes were connected with population changes over a wider area.

Hyphothesis 2 – that the building of the services of the harbour would split habitats, and railway and road connections would cause changes in the bird populations – was supported by this study. But as the example from Österängen field area showed, some of the changes were positive, because the construction of the road provided a new habitat, which was suitable for many species. Populations of those species clearly increased near the road.

Hyphothesis 3 – that the development of seabird populations would be affected by the construction of the Vuosaari harbour and ship channel – was partly supported by this study. Harbour construction destroyed two breeding islands, and that affected especially the common black-headed gull population. Covering the islet with land masses was a planned action which had a permission of the environmental authorities.

Hyphothesis 4 – that the seabird population changes would depend on the characters of the island – was supported by this study. It seems that the island type had more effect on population changes than the distance to the harbour. Populations of many species were stable or increased on restricted access islands, whereas the populations on open access island were more vulnerable.

Hyphothesis 5 – that in addition to the human activity, small predators would have a negative effect on the development of waterfowl populations – was weakly supported by this study. There was a negative correlation between production of waterfowl nestlings and the number of predators, but there was no evidence for another factor behind both variables.

4.9 CONCLUSIONS

Population changes can be caused by a wide variety of impacts of urbanization and many other factors (rising temperature, species competition etc.) . Some of the impacts are negative, some positive. Sometimes positive impacts may prevent us seeing the negative ones, as the example of roadside vegetation for birds showed. How can we measure cumulative impacts on a changing environment?

The Vuosaari harbour construction project and the estimation of its impacts on nature clearly showed the difficulty of assessing the severity of impacts, and how many different factors there may be operating. Even though clear negative effects caused by the construction of the harbour could not be perceived, it does not mean that there would not have been any.

Why the clear negative impacts near the harbour difficult to demonstrate? There are several possibilities:

- There were no negative impacts.
- There were not any, because the mitigation measures were so effective.
- There were not any, because species were already used to human impact. Data of other species was too sparse.
- There were negative effects, but because of the monitoring method used it was not possible to discern them.
- There were negative effects, but immigration of new birds to the area prevented seeing the negative impacts.

Examining only the number of pairs does not necessarily enable estimation of direct individual impacts. When populations increase, poor-quality areas may also be occupied, often by young and unexperienced individuals. This can prevent the determination of the real effects of construction.

The poor breeding success may have been masked by individuals that originated from other areas. It could be more precise to follow nesting success of individuals with different distances from the source of disturbance. That could give more accurate results than the monitoring of variation of populations. In the future, we need to develop better monitoring methods to monitor population changes, but also individual reproduction and survival rates of nearby breeding birds during large construction projects.

Summing up, large scale construction projects are so rare in Finland, that probably we do not yet have enough experience to use right assessment and monitoring methods for studying possible negative impacts. In the future, the only way to do better EIA assessments and studies is to learn from literature and from different projects how to make such study designs, which reliably show the factors behind negative impacts and the scale of impacts. Instead of monitoring populations, a more detailed study of individuals and the use of experimental design could be better. This sets challenges to authorities and the environmental impact assessment to develop new and more exact methods. "In order to prevent the unfavorable effects of urbanization on nature, and to ensure sustainable development of urban areas, ecological information and knowledge have to be taken more seriously into consideration in urban planning" (Niemelä 1999, Yli-Pelkonen & Niemelä 2005).

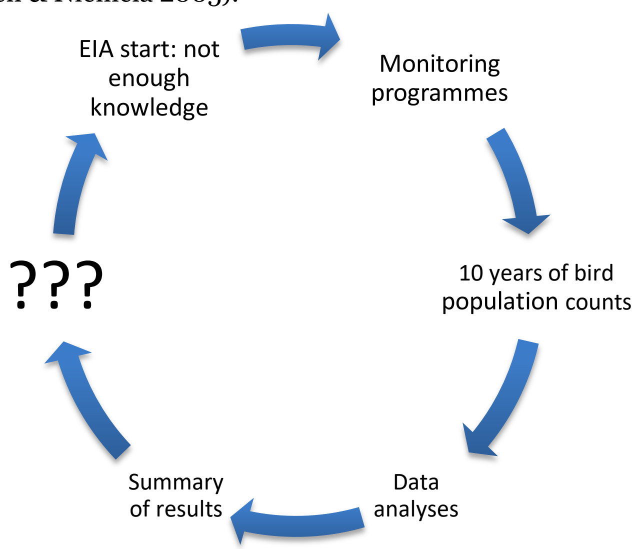

Figure 28. Possible support for future environmental impact assessments was unclear.

This monitoring project has shown how difficult it is to estimate possible negative impacts caused by a single construction project. Before the project started, biologists said that severe negative impacts are possible, and according to the so called precautionary principle the construction of Vuosaari harbour should not be allowed. Monitoring lasted ten years, and there were no clear significant negative impacts to be seen caused by construction. However, reviewers of the manuscripts which form this thesis have pointed out that we only have studied one harbour and the number of territories of most species was comparatively small, especially the number of Birds Directive species. One of the main targets of the original monitoring idea was to answer what happens to those protected species with small populations. Question remains, are these kinds of long lasting monitoring programs really useful, or are they just waste of time and money?

ACKNOWLEDGEMENTS

First I want to thank my family, my wife Tiina, my son Sampo and my daughter Noora. Without their support I would not have been able to make a study lasting a decade and this thesis.

Second I want to thank the supervisors of my work, Dr. Hannu Pietiäinen and Prof. Antero Järvinen. And the other members of the steering group, Prof. Jari Niemelä and Dr. Aleksi Lehikoinen. Their support, advice and comments have been important in the progress of this thesis. Furthermore, I want to thank Prof. Veijo Kaitala, who encouraged me to accomplish my doctoral studies in the Department of Biosciences.

The bases of the whole work were the repeated bird countsd during a decade. Behind the reliable results and their analysis are the following top ornithologists, who earn big thanks: Lic.Sc. Antti Tanskanen, MSc. Hannu Sarvanne, Mr. Jorma Vickholm, Mr. Jarkko Santaharju, Mr. Matti Luostarinen, Dr. Matti Koivula, MSc. Thomas Oesch (†) and Mr. Jari Kontiokorpi.

Furthermore, the thanks also belong to the persons who have participated in the analysis of the material and given data and advice: Prof. Risto A. Väisänen, Lic.Sc Pertti Koskimies, Dr. Tapio Solonen, MSc Lasse J. Laine, MSc. Antti Below, Mr. Martti Hario, Dr Jukka Rintala, MSc. Visa Eronen, Mr. Jukka Tanner, MSc. Ari Piispanen and MSc. Pekka Kontiala.

I have talked with many people about the difficulties of impact assessment of construction work at Vuosaari, among them are Mr. Juhani Niinimäki (†), MSc. Sauli Vatanen, MSc. Panu Oulasvirta, MSc. Jouni Leinikki, MSc. Veijo Kinnunen and MSc. Aimo Lamberg.

The whole monitoring study was led by the steering group of the Vuosaari Harbour Project:

Pekka Kansanen, Director general of the Environment centre, City of Helsinki
Matti Osara, Senior advisor, Ministry of Environment
Markku Mikkola-Roos, Senior researcher, Finnish Environmental Institute
Ilpo Huolman, Senior advisor, Centre for Economic Development, Transport and the Environment, Uusimaa
Matti Nieminen, Senior environmental advisor, City of Helsinki
Raimo Pakarinen, Environmental inspector, City of Helsinki
Ronald Westermark (†), Project manager, VUOLI-project
Antti Mäkinen, Head of project management, VUOSA-project
Ari Parviainen, Head of development, Port of Helsinki
Susanna Koivujärvi, Environmental advisor, Finnish Transport Agency

Arto Kärkkäinen, Environmental advisor, Centre for Economic Development, Transport and the Environment, Uusimaa
Pirkko Pulkkinen, Senior environmental inspector, City of Helsinki

And finally I want to thank all those bird-watchers who gave the observations of uncommon and rare species found in our study area. And I want to thank those numerous persons, who during the years prepared the year reports for the authorities and for the general public.

LITERATURE CITED

Avery, M. L. 1979: Review of avian mortality due to collision with manmade structures. - *Bird Control Seminars Proceedings. Paper 2.*

Benítez-López, A., Alkemade, R. & Verweij, P. A. 2010: The impacts of roads and other infrastructure on mammal and bird populations: A meta-analysis. - *Biological Conservation* 143:13071316.

Bergman, G. 1982: Population dynamics, colony formation and competition in *Larus argentatus, fuscus* and *marinus* in the archipelago of Finland. - *Annales Zoologici Fennici* 19:143164.

Bissonette, J. A. & Rosa, S. A. 2009: Road Zone Effects in Small-Mammal Communities. - *Ecology and Society* 14.

Bouchard, J., Ford, A. T., Eigenbrod, F. E. & Fahrig, L. 2009: Behavioral Responses of Northern Leopard Frogs (*Rana pipiens*) to Roads and Traffic: Implications for Population Persistence. - *Ecology and Society* 14.

Chamberlain, D. E., Vickery, J. A. & Gough, S. 2000: Spatial and temporal distribution of breeding skylarks *Alauda arvensis* in relation to crop type in periods of population increase and decrease. - *Ardea* 88:6173.

Coffin, A. W. 2007: From roadkill to road ecology: A review of the ecological effects of roads. - *Journal of Transport Geography* 15:396406.

Dauvin, J.-C., Alizier, S., Vallet, C. & Ruellet, T. 2010: Does the Port 2000 harbour construction have an effect on the Seine estuary suprabenthic community? - *Estuarine, Coastal and Shelf Science* 86:4250.

Eigenbrod, F., Hecnar. Stephen J. & Fahrig, L. 2009: Quantifying the Road-Effect Zone: Threshold Effects of a Motorway on Anuran Populations in Ontario, Canada. - *Ecology and Society* 14.

Eklund, N., editor 2009: Kustfågelbeståndets utveckling i Stockholms läns skärgård. Sveriges Ornitologiska Förening.

Ekroos, J., Kuussaari, M., Tiainen, J., Heliölä, J., Seimola, T. & Helenius, J. 2013: Correlations in species richness between taxa depend on habitat, scale and landscape context. - *Ecological Indicators* 34:528535.

Ekroos, J., Öst, M., Karell, P., Jaatinen, K. & Kilpi, M. 2012: Philopatric predisposition to predation-induced ecological traps: habitat-dependent mortality of breeding eiders. - *Oecologia* 170:979986.

European Union 2015: The precautionary principle. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al32042 (2016).

Fahrig, L. & Rytwinski, T. 2009: Effects of Roads on Animal Abundance: an Empirical Review and Synthesis. - *Ecology and Society* 14:120.

Foppen, R. & Reijnen, R. 1994: The Effects of Car Traffic on Breeding Bird Populations in Woodland. II. Breeding Dispersal of Male Willow Warblers (*Phylloscopus trochilus*) in Relation to the Proximity of a Highway. - *Journal of Applied Ecology* 31:95101.

Forman, R. & Deblinger, R. D. 2000: The Ecological Road-Effect Zone of a Massachusetts (U.S.A.) Suburban Highway. - *Conservation Biology* 14:3646.

Forman, R. T. & Alexander, L. E. 1998: Roads and Their Major Ecological Effects. - *Annual Review of Ecology and Systematics* 29:207231.

Forman, R.T.T. & Alexander, L.E. 1998: Roads and Their Major Ecological Effects. - *Annual Review of Ecology and Systematics* 29:207231.

Fuller, R. J., Smith, K. W., Grice, P. V., Currie, F. A. & Quine, C. P. 2007: Habitat change and woodland birds in Britain: implications for management and future research. - *Ibis* 149:261268.

Garaffa, P. I., Filloy, J. & Bellocq, M. I. 2009: Bird community responses along urban–rural gradients: Does the size of the urbanized area matter? - *Landscape and Urban Planning* 90:3341.

Glasson, J., Therivel, R. & Chadwick, A. 1994: Introduction to environmental impact assessment. Principles and procedures, process, practice and prospects. UCL, London.

Glasson, J., Therivel, R. & Chadvik, A. 2012: Introduction to environmental impact assessment. Routledge, London & New York.

Goodwin, S. E. & Shriver, W. G. 2010: Effects of Traffic Noise on Occupancy Patterns of Forest Birds. - *Conservation Biology:*406411.

Gotelli N. J.& Entsminger, E. J. 2005: EcoSim: Null models software for ecology. Version 7.0. http://www.garyentsminger.com/ecosim/index.htm (March 04, 2011).

Grecian, J. W., Inger, R., Attril, M. J., Bearshop, S., Godley, B. J., Witt, M. J. & Votier, S. C. 2010: Potential impacts of wavepowered marine renewable energy installations on marine birds. - *Ibis* 152:683697.

Halfwerk, W., Bot, S., Buikx, J., van der Velde, M., Komdeur, J., Cate, C. ten & Slabbekoorn, H. 2011a: Low-frequency songs lose their potency in noisy urban conditions. - *Proceedings of the National Academy of Sciences* 108:1454914554.

Halfwerk, W., Holleman, L. M., Lessells, C. M. & Slabbekoorn, H. 2011b: Negative impact of traffic noise on avian reproductive success. - *Journal of Applied Ecology* 48:210219.

Hanski, I. 1999: Metapopulation Ecology. Oxford University Press, Oxford.

Hario, M. 1990: Breeding failure and feeding conditions of Lesser Black-backed Gulls Larus f. fuscus in the Gulf of Finland. - *Ornis Fennica* 67:113--129.

Hario, M. 2004: Organochlorine concentrations in diseased vs. healthy gull chicks from the northern Baltic. - *Environmental Pollution* 127:411423.

Hario, M., Kastepõld, T., Kilpi, M., Staav, R. & Stjernberg, T. 1987: Status of Caspian Terns *Sterna caspia* in the Baltic. - *Ornis Fennica* 64:154157.

Hario, M., Mazerolle, M. J. & Saurola, P. 2009a: Survival of female common eiders *Somateria m. mollissima* in a declining population of the northern Baltic Sea. - *Oecologia* 159:747756.

Hario, M. & Rintala, J. 2006: Fledgling production and population trends in Finnish common eiders (*Somateria mollissima mollissima*) - evidence for density dependence. - *Canadian Journal of Zoology* 84:10381046.

Hario, M. & Rintala, J. 2008: Haahkan ja lokkien kannankehitys rannikoilla 1986-2007. - *Linnut-vuosikirja 2007:*5259.

Hario, M. & Rintala, J. 2011: Saaristolintukantojen kehitys Suomessa 1986-2010. - *Linnut vuosikirja 2010:*4051.

Hario, M. & Rintala, J. 2014: Saaristolinnuston kehitys Suomen rannikolla 1986-2013. - *Linnut Vuosikirja 2013:*4653.

Hario, M., Rintala, J. & Tanner, J. 2009b: Keskisen Suomenlahden harmaalokkiprojekti. Kannanrajoitustoimet 2004-2007. - *Riista- ja kalatalous - tutkimuksia*.

Hario, M. & Uuksulainen, J. 1993: Mercury load according to moulting area in primaries of the nominate race of the Lesser Black-backed Gull *Larus f. fuscus*. - *Ornis Fennica* 70:3239.

Heikkonen, M. 2008: Vuosaaren satama ja ympäristö. Suunnittelusta rakentamiseen. Vuosaaren satamahanke.

Helldin, J. O. & Seiler, A. 2003: Effects of roads on the abundance of birds in Swedish forest and farmland Habitat Fragmentation due to Transportation Infrastructure - IENE 2003.

Heyman, E. 2010: Clearance of understory in urban woodlands: Assessing impact on bird abundance and diversity. - *Forest Ecology and Management* 260:125131.

Hildén, O. & Hario, M. 1993: Muuttuva saaristolinnusto. Forssan kirjapaino Oy, Forssa.

Hoskin, C. J. & Goosem, M. W. 2010: Road Impacts on Abundance, Call Traits, and Body Size of Rainforest Frogs in Northeast Australia. - *Ecology and Society* 15.

Houlahan, J. E., Keddy, P. A., Makkay, K. & Findlay, C. S. 2006: The effects of adjacent land use on wetland species richness and community composition. - *Wetlands* 26:7996.

Jaatinen, K., Öst, M. & Lehikoinen, A. 2011: Adult predation risk drives shifts in parental care strategies: a long-term study. - *Journal of Animal Ecology* 80:49-56.

Jokimäki, J. & Suhonen, J. 1993: Effects of urbanization on the breeding bird species richness in Finland: a biogeographical comparison. - *Ornis Fennica* 70:7177.

Järvinen, O. & Väisänen, R. A. 1978: Population trends of Finnish Starlings in the 1970s. - *Ornis Fennica* 55:8082.

Kala- ja Vesitutkimus Oy, Mikkola-Roos, M. & Hirvonen, H. 1996: Toukolanranta, rakentamisen ympäristövaikutukset. Ekologinen näkökulma II. - *Helsingin kaupunkisuunnitteluviraston julkaisuja 1996:20*.

Kilpi, M. 1997: Saaristolinnuston suojelun nykytaso Suomen rannikolla. In: Kilpi, M. & Asanti, T. (eds.) Saaristolinnuston suojelun nykytila Suomen rannikolla. - *Suomen ympäristö* 103:137.

Koskimies, P. 2001: Vuosaaren satamahankkeen luontovaikutusten seurantaohjelma. Osa 1. Linnustovaikutusten seurantaohjelma. - *Helsingin kaupungin ympäristökeskuksen julkaisuja*.

Koskimies, P. & Väisänen, R. A. 1988: Linnustonseurannan havainnointiohjeet. Helsingin yliopiston eläinmuseo., Helsinki.

Krijgsveld, K. L., Akerhoek, K., Schenk, F., Dijk, F. & Dirksen, S. 2009: Collision risk of birds with modern large wind turbines. - *Ardea* 97:357366.

Kuitunen, M., Rossi, E. & Stenroos, A. 1998: Do Highways Influence Density of Land Birds? - *Environmental Management* 22:297302.

Kuitunen, M. T., Viljanen, J., Rossi, E. & Stenroos, A. 2003: Impact of Busy Roads on Breeding Success in Pied Flycatchers *Ficedula hypoleuca*. - *Environmental Management* 31:7985.

Laaksonen, T. & Lehikoinen, A. 2013: Population trends in boreal birds: Continuing declines in agricultural, northern, and long-distance migrant species. - *Biological Conservation* 168:99107.

Langen, T. A., Gunson, K. E., Scheiner, C. A. & Boulerice, J. T. 2012: Road mortality in freshwater turtles: identifying causes of spatial patterns to optimize road planning and mitigation. - *Biodiversity and Conservation* 21:30173034.

Lehikoinen, A., Jaatinen, K., Vähätalo, A. V., Clausen, P., Crowe, O., Deceuninck, B., Hearn, R., Holt, C. A., Hornman, M., Keller, V., Nilsson, L., Langendoen, T., Tománková, I., Wahl, J. & Fox, A. D. 2013a: Rapid climate driven shifts in wintering distributions of three common waterbird species. - *Global Change Biology* 19:20712081.

Lehikoinen, A., Pöysä, H., Rintala, J. & Väisänen, R. A. 2013b: Suomen sisävesien vesilintujen kannanvaihtelut 1986-2012. - *Linnut vuosikirja 2012:*95101.

Lehikoinen, A., Ranta, E., Pietiäinen, H., Byholm, P., Saurola, P., Valkama, J., Huitu, O., Henttonen, H. & Korpimäki, E. 2011: The impact of climate and cyclic food abundance on the timing of breeding and brood size in four boreal owl species. - *Oecologia* 165:349355.

Lindenmayer, D. B. & Likens, G. E. 2010: The science and application of ecological monitoring. - *Biological Conservation* 143:13171328.

Liu, J., Hull, V., Morzillo, A. T. & Wiens, J. A. 2011: Sources, Sinks and Sustainability. Cambridge University Press, Cambridge.

McCall, S. C., McCarthy, M. A., van der Ree, R., Harper, M. J., Cesarini, S. & Soanes, K. 2010: Evidence that a Highway Reduces Apparent Survival Rates of Squirrel Gliders. - *Ecology and Society* 15.

McDonnell, M. J., A. K. Hahs, and J. Breuste, editors 2009: Ecology of cities and towns. A comparative approach. Cambridge University Press, Cambridge, UK, New York.

McKinney, M. L. 2008: Effects of urbanization on species richness: A review of plants and animals. - *Urban Ecosystems* 11:161176.

Mensing, D. M., Galatowitsch, S. M. & Tester, J. R. 1998: Anthropogenic effects on the biodiversity of riparian wetlands of a northern temperate landscape. - *Journal of Environmental Management* 53:349377.

Møller, A. P., Diaz, M., Flensted-Jensen, E., Grim, T., Ibáñez-Álamo, J. D., Jokimäki, J., Mänd, R., Markó, G. & Tryjanowski, P. 2012: High urban population density of birds reflects their timing of urbanization. - *Oecologia* 170:867875.

Mörtberg, U. 2009: Landscape ecological analyses. Pages 439455 *in* M. J. McDonnell, A. K. Hahs and J. Breuste, editors. Ecology of cities and towns. A comparative approach. Cambridge University Press, Cambridge, UK, New York.

Nicodéme, C., Diamandouros, K., Díez, J., Durso, C., Brecx, C. & Metushi, S. 2013: European Road Statistics 2012. European Union Road Federation.

Niemelä, J. 1999: Ecology and urban planning. - *Biodiversity and Conservation* 8:119131.

Niemelä, J. 2011: Urban ecology. Patterns, processes, and applications. Oxford University Press, Oxford [England], New York.

Nordström, M., Högmander, J., Laine, J., Nummelin, J., Laanetu, N. & Korpimäki, E. 2003: Effects of feral mink removal on seabirds, waders and passerines on small islands in the Baltic Sea. - *Biological Conservation* 109:359368.

Orłowski, G. 2008: Roadside hedgerows and trees as factors increasing road mortality of birds: Implications for management of roadside vegetation in rural landscapes. - *Landscape and Urban Planning* 86:153161.

Pannekoek, J. & van Strien, A. J. 2001: TRIM 3 Manual. Trends and Indices for Monitoring Data . - *Research paper no. 0102. CBS Voorburg, The Netherlands: Statistics Netherlands (available at www.ebcc.info).*

Parris, K. M. & Schneider, A. 2008: Impacts of Traffic Noise and Traffic Volume on Birds of Roadside Habitats. - *Ecology and Society* 14:123.

Parris, K. M., Velik-Lord, M. & North, J. M. A. 2009: Frogs Call at a Higher Pitch in Traffic Noise. - *Ecology and Society* 14.

Pirkola, M. K., and J. Högmander, editors 1974: Sorsapoikueiden iän määritys.

Pulliam, H. R. 1988: Sources, sinks, and population regulation. - *American Naturalist* 132:652661.

Pulliam, H. R. & Danielson, B. J. 1991: Sources, sinks, and habitat selection: a landscape perspective on population dynamics. - *The American Naturalist* 137, supplement:5066.

Pöysä, H., Rintala, J., Lehikoinen, A. & Väisänen, R. A. 2013: The importance of hunting pressure, habitat preference and life history for population trends of breeding waterbirds in Finland. - *European Journal of Wildlife Research* 59:245256.

R Core Team 2014: R: A language and environment for statistical computing.

Ranta, E., Lundberg, P. & Kaitala, V. 2006: Ecology of Populations. Cambridge University Press, Cambridge, UK.

Reijnen, R. & Foppen, R. 1994: The Effects of Car Traffic on Breeding Bird Populations in Woodland. I. Evidence of Reduced Habitat Quality for Willow Warblers (*Phylloscopus trochilus*) Breeding Close to a Highway. - *Journal of Applied Ecology* 31.

Reijnen, R. & Foppen, R. 1995a: The Effects of Car Traffic on Breeding Bird Populations in Woodland. III. Reduction of Density in Relation to the Proximity of Main Roads. - *Journal of Applied Ecology* 32:187202.

Reijnen, R. & Foppen, R. 1995b: The Effects of Car Traffic on Breeding Bird Populations in Woodland. IV. Influence of Population Size on the Reduction of Density Close to a Highway. - *Journal of Applied Ecology* 32:481491.

Reijnen, R., Foppen, R. & Meeuwsen, H. 1996: The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. - *Biological Conservation 75:*255260.

Rodgers, J. A. & Smith, H. T. 1997: Buffer zone distances to protect foraging and loafing water birds from human disturbance in Florida. Wildlife Society Bulletin, [S.l.].

Rottenborn, S. C. 1999: Predicting the impacts of urbanization on riparian bird communities. - *Biological Conservation* 88:289299.

Rytwinski, T. & Fahrig, L. 2012: Do species life history traits explain population responses to roads? A meta-analysis. - *Biological Conservation* 147:8798.

Rytwinski, T. & Fahrig, L. 2013: Why are some animal populations unaffected or positively affected by roads? - *Oecologia* 173:11431156.

Skov, H., Heinänen, S., Žydelis, R., Bellebaum, J., Bzoma, S., Dagys, M., Durinck, J., Garthe, S., Grishanov, G., Hario, M., Kieckbusch, J. J., Kube, J., Kuresoo, A., Larsson, K., Luigujoe, L., Meissner, W., Nehls, H. W., Nilsson, L., Petersen, I. K., Mikkola-Roos, M., Pihl, S., Sonntag, N., Stock, A., Stipniece, A. & Wahl, J. 2011: Waterbird Populations and Pressures in the Baltic Sea. Norden.

Slabbekoorn, H. & Peet, M. 2003: Birds sing at a higher pitch in urban noise. - *Nature* 424:267.

Slabbekoorn, H., Yang, X.-J. & Halfwerk, W. 2012: Birds and anthropogenic noise: singing higher may matter. - *The American Naturalist* 180:142-5; author reply 14652.

Smith, A. M., Wood, A. C., Liddy, M. F., Shears, A. E. & Fraser, C. I. 2010: Human impacts in an urban port: The carbonate budget, Otago Harbour, New Zealand. - *Estuarine, Coastal and Shelf Science* 90:7379.

Smith, L. A. & Chow-Fraser, P. 2010: Impacts of Adjacent Land Use and Isolation on Marsh Bird Communities. - *Environmental Management* 45:10401051.

Solonen, T. 1985: Agriculture and birdlife in Finland. A review. - *Ornis Fennica* 62:4755.

Solonen, T. 2007: Recovering bird diversity by landscaping a landfill: early stages of succession.17:15-28. - *Ornis Svecica* 17:1528.

Solonen, T., Lehikoinen, A. & Lammi, E. 2010: Uudenmaan linnusto. Helsingin Seudun Lintutieteellinen Yhdistys Tringa, Helsinki.

Solonen, T., Tiainen, J., Korpimäki, E. & Saurola, P. 1991: Dynamics of Finnish Starling *Sturnus vulgaris* populations in recent decades. - *Ornis Fennica* 68:158169.

Summers, P. D., Cunnington, G. M. & Fahrig, L. 2011: Are the negative effects of roads on breeding birds caused by traffic noise? - *Journal of Applied Ecology* 48:15271534.

Tiainen, J. 1985: Monitoring bird populations in Finland. - *Ornis Fennica* 62:8089.

Tiainen, J., Seimola, T., Rintala, J. & Holmstöm, H. 2012: Maatalousympäristön linnuston muutos Suomessa 20012011.

Townsend, C. R., Begon, M. & Harper, J. L. 2003: Essentials of ecology. Blackwell publishing, Malden.

Trombulak, S. C. & Frissell, C. A. 2000: Review of Ecological Effects of roads on Terrestrial and Aquatic Communities. - *Conservation Biology* 14:1830.

Tucker, G. M. & Heath, M. F. 1994: Birds in Europe: their conservation status. - *BirdLife conservation series*.

Watts, B. & Bradshaw, D. S. 1994: The influence of human disturbance on the location of Great Blue Heron colonies in the Lower Chesapeake Bay. - *Colonial Waterbirds* 17:184186.

Venables, W. N. & Ripley, B. D. 2002: Modern applied statistics with S. Springer-Verlag.

Virkkala, R. & Lehikoinen, A. 2014: Patterns of climate-induced density shifts of species: poleward shifts faster in northern boreal birds than in southern birds. - *Global change biology* 20:29953003.

Virkkala, R. & Rajasärkkä, A. 2011: Climate change affects populations of northern birds in boreal protected areas. - *Biology Letters* 7:395398.

von Numers, M. & Korvenpää, T. 2007: 20th century vegetation changes in an island archipelago, SW Finland. - *Ecography* 30:789800.

Wood, S. N. 2004: Stable and efficient multiple smoothing parameter estimation for generalized additive models. - *J. Am. Stat. Assoc.* 99:673686.

Väisänen, R. A., Lammi, E. & Koskimies, P. 1998: Distribution, numbers and population changes of Finnish breeding birds. Otava, Helsinki.

Väisänen, R. A. & Lehikoinen, A. 2013: Suomen maalinnuston pesimäkannan vaihtelut vuosina 1975-2012:6281.

Väänänen, V.-M., Laine, J., Lammi, E., Lehtiniemi, T., Luostarinen, V.-M. & Mikkola-Roos, M. 2010: Suomen valkoposkihanhikanta jatkaa kasvuaan. - *Linnut-vuosikirja 2009:*7277.

Väänänen, V.-M., Nummi, P., Lehtiniemi, T., Luostarinen, V.-M. & Mikkola-Roos, M. 2011: Habitat complementation in urban barnacle geese: from safe nesting islands to productive foraging lawns. - *Boreal environmental research* 16 (suppl.B):2634.

Yli-Pelkonen, V. & Niemelä, J. 2005: Linking ecological and social systems in cities: urban planning in Finland as a case. - *Biodiversity and Conservation* 14:19471967.

Yrjölä, R. A. & Santaharju, J. L. M. 2015: The Impact of Road Construction on a Community of Farmland Birds. - *Annales Zoologici Fennici* 52:3344.

Zuur, A. F., Ieno, E. N., Walker, N. J., Saveliev, A. A. & Smith, G. M. 2009: Mixed Effects Modelsand Extensions in Ecologywith R. Springer.

Öst, M., Lehikoinen, A., Jaatinen, K. & Kilpi, M. 2011: Causes and consequences of fine-scale breeding dispersal in a female-philopatric species. - *Oecologia* 166:327336.

Öst, M., Wickman, M., Matulionis, E. & Steele, B. 2008: Habitat-specific clutch size and cost of incubation in eiders reconsidered. - *Oecologia* 158:205216.