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The impact of road construction on a community of farmland birds

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Birds are commonly used as tools in environmental monitoring. Bird population changes were studied during construction of the new Vuosaari harbour in 2001–2011. The aim of the monitoring programme was to determine the impacts of road construction on bird populations in the Österängen agricultural area (Helsinki, Finland). Our results indicate that 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 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 as a result of habitat succession.

Introduction

The effects of human activity on the environment have been studied, especially in Europe and North America. The sphere of influence of urbanization varies. Impacts may differ greatly, depending on habitat type and the scale of human activities. Some species are also more sensitive than others. Human activity may result in negative impacts that can affect bird species, often several kilometres away (Watts & Bradshaw 1994, Kala- ja Vesitutkimus Oy *et al.* 1996, Rodgers & Smith 1997, Mensing *et al.* 1998).

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 EIA procedure is to help in decision-making (Glasson *et al.* 2012). A new harbour was planned for Helsinki already in the mid-1960s, but the Vuosaari harbour project was implemented in 1992, when the city authorities began planning of the area. The EIA procedure of the project was initiated in 1994, when the new environmental act came into force. The Helsinki City Council accepted the construction protocol for the harbour in 1996 (Heikkonen 2008).

Planning of the harbour encountered much opposition. After extended deliberation, Finland's Supreme Administrative Court determined that the project would degrade nature values of the nearby Natura area (F10100065, "Mustavuoren lehto ja Östersundomin lintuvedet"). In the court's decision, however, they stated that degradation could not be considered significant for those local nature values, on the basis that this area had been included in the Natura network (Nordberg 2007). As a result of the decision, nature conservation and economic interests became mutually antagonistic, leading to a long and complex authorization process. Strong arguments were made against the harbour, and some environmental scientists invoked the precautionary principle to support their view. Complaints were finally processed in the courts at the national and EU levels.

During the harbour project, many environmental studies were conducted because the harbour was located next to a Natura area. Also, when Finland joined the European Union (EU) in 1995, 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 that of birds (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. The monitoring programmes were carried out as a cooperative project between the Helsinki Environment Centre and the Port of Helsinki. The monitoring of birds began in the archipelago in 2001 and in land areas in 2002. Impacts on bird populations were monitored between 2001 and 2011. The number of breeding pairs and population changes were the main outcomes monitored.

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). Trombulak and Frissell (2000) summarized the most important ecological effects of road construction as follows: mortality from road construction, mortality from collision with vehicles, modification of animal behaviour, alteration of the physical and chemical environment, the spread of exotics, and an increased use of areas by humans.

The main objective of this study was to compare densities of farmland bird species in the vicinity of the Vuosaari harbour road before and after its construction. Observed population changes were tested against the null hypothesis of no change. The focus was on whether road construction caused negative changes that could be avoided or mitigated during the construction process.

Material and methods

The possible effects of road construction on bird populations were investigated along a road in the Österängen field area, which was one of the several monitoring areas near the Vuosaari harbour (60°14.52´N, 25°9.07´E). The study area is bordered by a Natura area. Bird populations were monitored using yearly breeding bird counts.

The road through the field was built in 2004 and 2005, and bird counts in the area were performed in 2002–2003 and 2006–2011. The road was opened to traffic in November 2008. The monitoring of bird populations continued for three years after the opening of the Vuosaari harbour.

Study area

The study area of Österängen is located in Helsinki, northeast of the district of Vuosaari (Fig. 1). The new harbour is located south of the study area, but the new traffic lanes to the harbour split Österängen. At the northern boundary of the area is the Itäväylä motorway. The study area is surrounded mainly by forests and gardens, and covers 56.7 ha. Forests are part of the Natura area, as is the adjacent Porvarinlahti Bay.

In 2002, the fields of the 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 roadway that divides the field created a new biotope and marginal zone in the area. The road is a four-lane highway in the middle of the Österängen field area, and there is also a single railway. At the southeastern corner of the

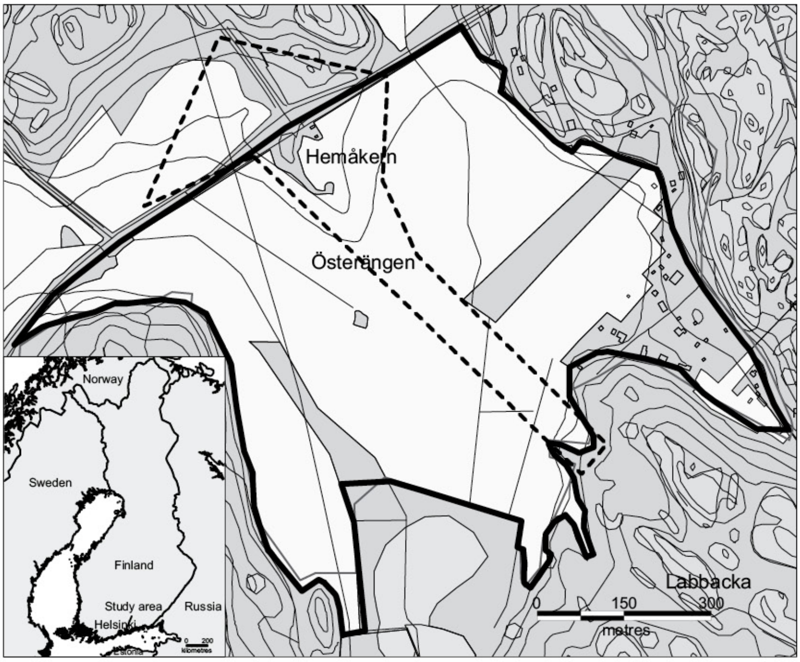

Fig. 1. The area delimited with a solid, black line is the study area. The area delimited with a dashed line is the new road and railway area. The insert in the lower-left corner Finland shows the location of the study area in Finland.

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 size of the area that changed comprised overall 6.5 ha, or approximately 5% of the total area.

Territory mapping

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 (Koskimies & Väisänen 1988) for bird census studies in Finland. We estimated the number of territories using five separate mappings performed between late April and late June. After fieldwork, we analysed the observations and estimated the number of territories. 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, alarm call, territory fight or parent bird carrying food to a nest).

If possible, the same person mapped the various subareas each time, thereby increasing the comparability of our results. Jarkko Santaharju performed most of the territory mappings at Österängen.

Statistical analyses

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 a Mann-Kendall test, using Systat 12 (Systat Software Inc., San Jose, CA, USA). The Mann-Kendall test was used to determine whether a repeating trend can be perceived in the time series examined. No periodic or cyclic changes should be present in the time series. Interannual changes in bird populations also weaken the test if the changes are not consistent. The more the population changes interannually, the greater the number of years needed to estimate the trends.

In statistical testing, the independent variable was the year and the dependent variable the number of territories (or pairs). Only significant

($p < 0.05$) or near-significant ($p < 0.1$) changes are presented. We calculated the trends for three separate 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.

If a species was not observed in a certain year, the number of territories was assumed to be null, i.e. not missing data. This could have led to results showing continuous trends for some infrequently observed species, if they were only observed for a few years at the beginning or the end of the study period, and not during other years. Trends of all species were tested, and five years was set as the minimum period to reliably use the trend test.

The change in 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/the observer. The distances were calculated from the Geographic Information System (GIS) data, using the 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 a Mann-Whitney *U*-test. This was done only for lapwing (*Vanellus vanellus*), Eurasian skylark (*Alauda arvensis*) 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 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). The 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.

Results

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 (Appendix 1). 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). The statistically significant or indicative changes of the various species are shown in Table 1. Only the great tit (*Parus major*) and Eurasian blue tit (*Cyanistes caeruleus*), which breed 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. Population changes of the northern lapwing, Eurasian skylark and meadow pipit are shown in more detail in Fig. 3. These three species bred in the open field area where the road was constructed.

The level of species diversity throughout the study period was quite similar to that at the beginning of the study in 2002 (Fig. 4). Several years lie below the 95% confidence limit of year 2002, but the trend is uncertain and interannual variation is present.

The average distance of territories of all bird species from the roadway changed during the study period (Fig. 5), showing a general decrease ($p = 0.001$) (Table 2). The average distance of Eurasian skylark territories from the road remained the same, while that of northern lapwing territories increased only slightly. Both species breed in open fields, and it was expected that they would shift territories further away

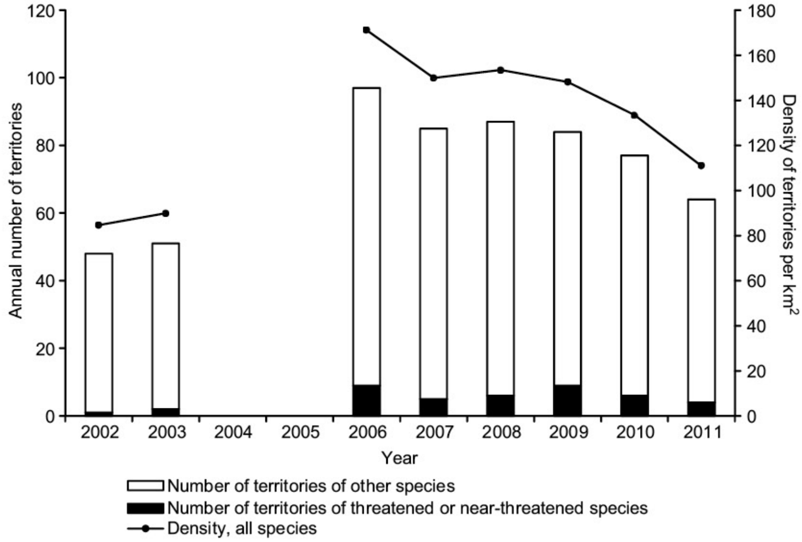

Fig. 2. Annual number of territories and density of territories per km².

from the road. The northern lapwings showed a small change, but the result was not statistically significant. 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 (Fig. 6).

Discussion

Road construction did not significantly reduce bird populations of the Österängen field area. In fact, our observations suggest that the new environment along the roadside provided a momentary advantage to some bird species, whose populations increased significantly near the new road.

Table 1. Statistically significant or indicative trends of some bird species. Changes were calculated for three separate time periods: the entire study period (2002–2011), the first part of the study (2002–2008) and the latter part of the study after road construction (2006–2011). The Mann-Kendall test (Statistic) shows the direction (positive or negative) of the trend. A higher value means a more monotonic trend. ASE = Asymptotic standard error.

Years	Species	*n*	Statistic	ASE	*p*
2002–2011	Tree pipit	8	24	7.958	0.001
	Northern lapwing	8	17	7.895	0.022
	Meadow pipit	8	15	8.021	0.040
	Northern wheatear	8	13	7.724	0.068
	Mallard	8	12	6.000	0.080
	Yellowhammer	8	–13	8.021	0.068
	Great tit	8	–15	7.895	0.040
	Eurasian blue tit	8	–15	6.904	0.040
2002–2008	Eurasian skylark	5	8	4.082	0.042
	Fieldfare	5	7	3.958	0.075
	Yellowhammer	5	7	3.958	0.075
2006–2011	Northern lapwing	6	14	5.228	0.004
	Tree pipit	6	9	4.865	0.060
	European greenfinch	6	–8	5.228	0.096
	Common chaffinch	6	–9	5.132	0.060
	Common linnet	6	–9	4.865	0.060
	Eurasian blue tit	6	–9	4.865	0.060
	Barn swallow	6	–12	5.033	0.017
	Great tit	6	–12	5.228	0.017
	Total number of territories 2006–2011	6	–13	5.323	0.008

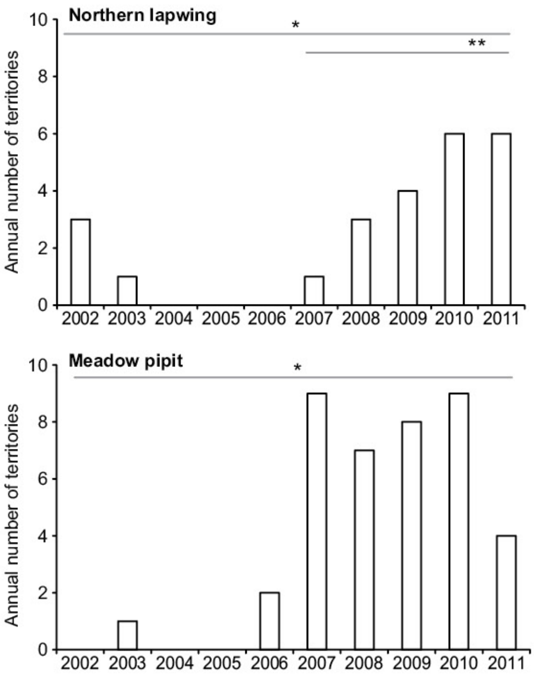

Fig. 3. Number of territories of bird species living in open field areas. Statistically significant changes: * $p < 0.05$, ** $p < 0.01$.

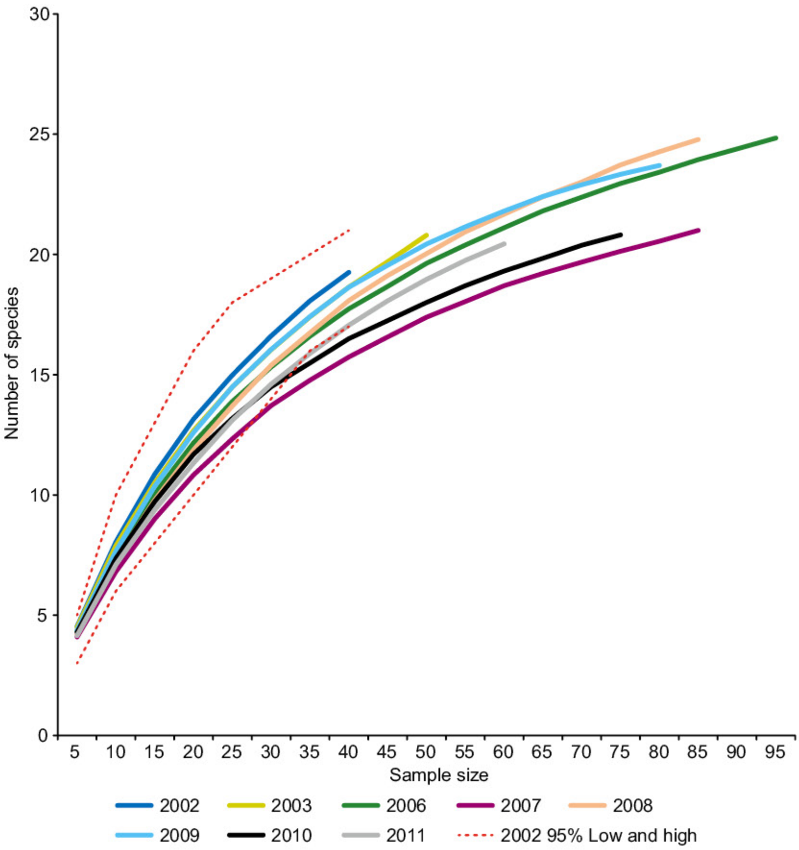

Fig. 4. Rarefied species richness during the study period. The average diversity for each year was compared with the 95% confidence limits of 2002. The higher the curve at a given sample size, the more species are expected to be in the sample, e.g. year 2002 has the highest number of species and year 2007 the lowest at the sample size = 40.

Rapid urbanization and other human activities usually affect species negatively, but moderate disturbance can also increase biotic diversity (Jokimäki & Suhonen 1993, McKinney 2008). In Finland, the highest bird species richness is found in rural areas and the lowest in large city centres (Jokimäki & Suhonen 1993).

Recent decades have seen widespread changes in the population numbers of some boreal bird species. Many farmland bird species declined in Finland during the last 20–30 years (Tiainen *et al*. 2012, Laaksonen & Lehikoinen 2013, Väisänen & Lehikoinen 2013), but some species, such as northern lapwing and Eurasian skylark, increased slightly (Tiainen *et al*. 2012).

The Vuosaari harbour and road construction are part of the urbanization process. A new harbour was needed as a substitute for an old harbour area near the Helsinki city centre that had been converted into a residential area. Although a few neutral or positive impacts of urbanization and road construction on bird species have been reported (Fahrig & Rytwinski 2009), the impacts are usually negative. 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).

In comparing our results with those obtained by others, 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 driving on the motorways (Reijnen & Foppen

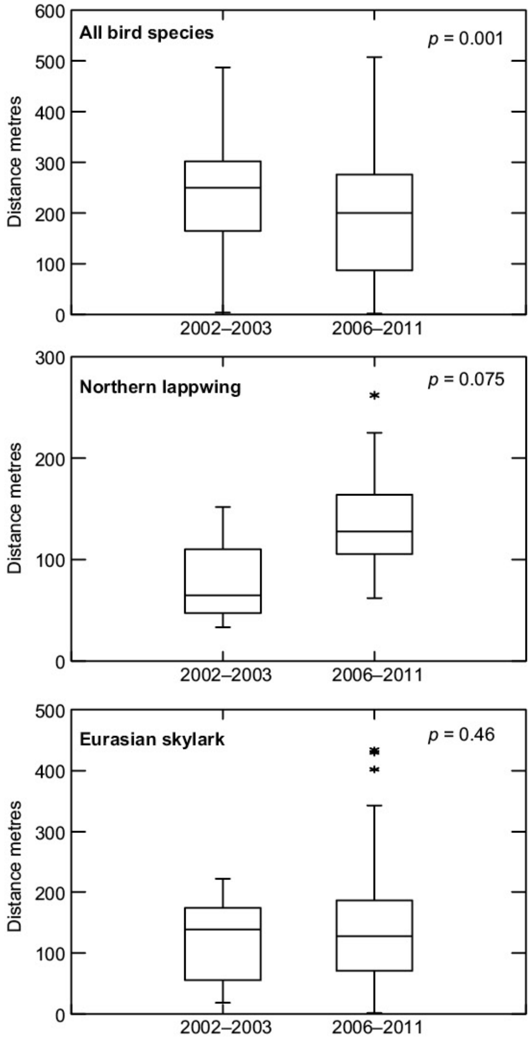

Fig. 5. Boxplots of the distances of the territories from the roadway during the study period. The whiskers reflect the brim values of the observations, the box the proportion (25%–75%) of the observations and the crossed line the median. Asterisks represent outlying brim values. Probabilities given by the Mann-Whitney *U*-test are shown.

Table 2. Comparison of the mean distance from the road before (2002 and 2003) and after (2006–2011) construction of the road. Results of the Mann-Whitney *U*-test.

Species	Mann-Whitney statistics	df	χ^2 approximation	*p*
All species	30299.00	1	10.421	0.001
Northern lapwing	17.00	1	3.175	0.075
Eurasian skylark	595.00	1	0.545	0.460
Meadow pipit	34.00	1	1.400	0.237

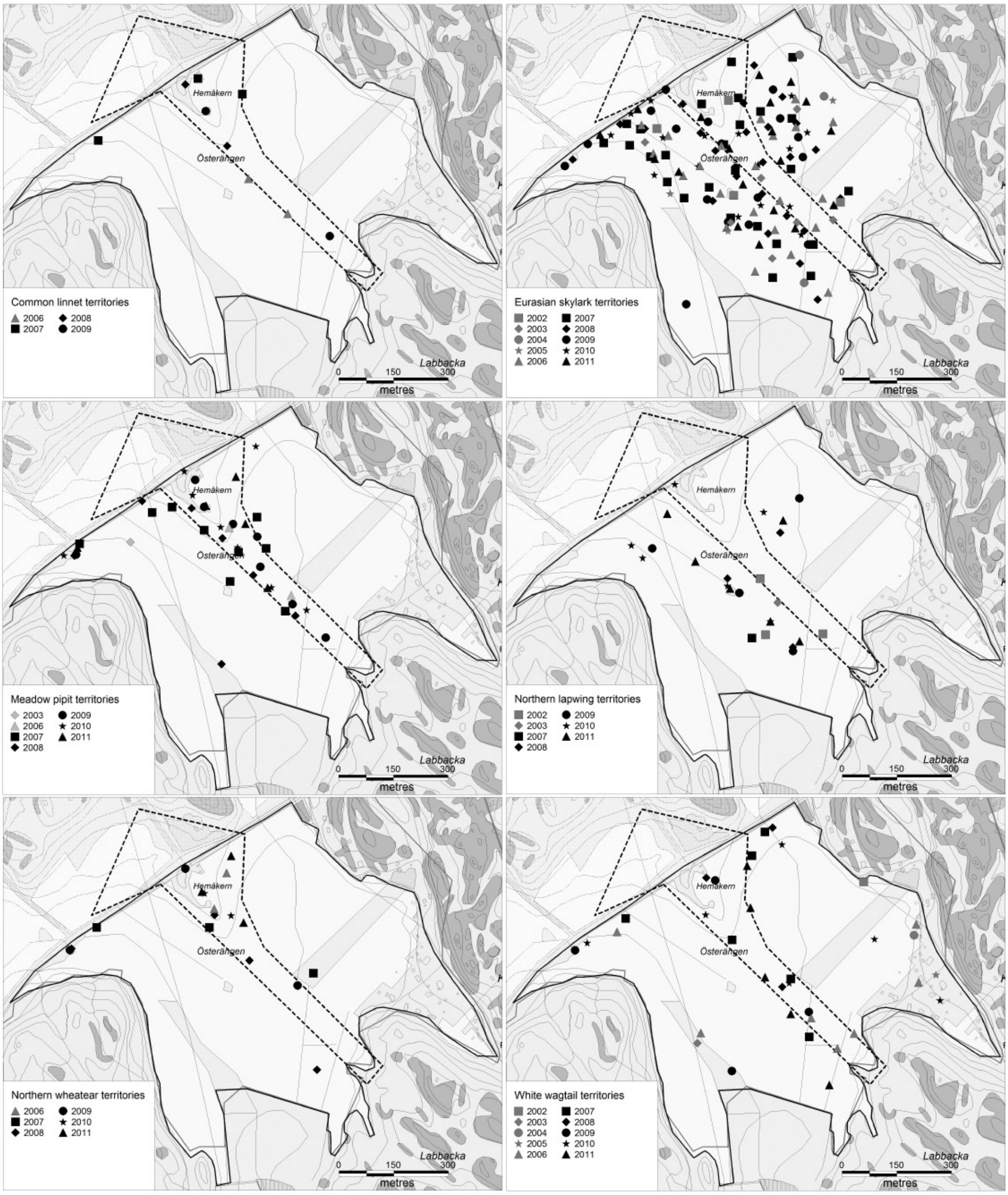

Fig. 6. Territories of some species inhabiting the open field area and its margins. Grey symbols represent the five first years, black symbols the five last years. Symbols show the estimated midpoints of territories. Dashed lines delimit the construction area of roads and the railway.

1994), compared with fewer than 10 000 vehicles (and 10 trains) on weekdays and 6000 vehicles on weekend days on the new Vuosaari harbour road and railway. When there is little traffic, the impact of roads is probably negligible.

Based on our results, we conclude that the construction of the harbour road did not significantly reduce bird populations in the area, and no general negative trend was found. In contrast, the number of territories of some species did increase immediately after the construction of the road. The average distance from the road of the territories of all the 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.

Our 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 in Fig. 6 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 also 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.

Some species, such as the northern wheatear (*Oenanthe oenanthe*), white wagtail (*Motacilla alba*), meadow pipit and common linnet (*Carduelis cannabina*), may have benefited from the construction, which formed new margins and roadside habitats. For example, all territories of the vulnerable northern wheatear (Rassi *et al.* 2010) 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. This species' breeding habitat is highly diversified, but generally it inhabits rocky areas or areas with low, sparse vegetation (Anonymous 2008). 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 (*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.

Although our results suggest that construction of the road did not affect the bird stocks negatively, whether there were negative impacts at the individual level remains unclear. It is not known how many individuals died in collisions with road vehicles or whether they moved elsewhere and new individuals took over their territories. Examining only the number of territories does not necessarily enable estimation of direct individual impacts. When populations increase, poor-quality territories may also be occupied, often by young and inexperienced individuals, which can prevent determination of the real effects of road construction. Therefore, in future EIAs in Finland, detailed studies are warranted to determine breeding success, survival of individuals and how individuals react to noise, disturbance or other factors encountered in their breeding environments.

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Appendix 1. Number of territories per species. Missing years 2004 and 2005 were the construction years, when birds were not counted.

Species	Scientific name	2002	2003	2006	2007	2008	2009	2010	2011
Mallard	*Anas platyrhynchos*	–	–	–	–	–	–	1	1
Northern lapwing	*Vanellus vanellus*	3	1	–	1	3	4	6	6
Little ringed plover	*Charadrius dubius*	–	–	1	2	1	1	–	–
Common sandpiper	*Actitis hypoleucos*	–	–	3	1	1	1	1	1
Stock dove	*Columba oenas*	1	–	–	1	1	–	–	–
Common wood pigeon	*Columba palumbus*	–	1	–	–	–	–	–	–
Eurasian wryneck	*Jynx torquilla*	–	–	–	–	1	–	–	–
Eurasian skylark	*Alauda arvensis*	4	7	22	26	24	18	16	19
Barn swallow	*Hirundo rustica*	1	2	3	3	2	2	–	–
Common house martin	*Delichon urbicum*	–	–	1	–	–	–	–	–
Tree pipit	*Anthus trivialis*	1	1	–	–	–	2	3	2
Meadow pipit	*Anthus pratensis*	–	1	2	9	7	8	9	4
White wagtail	*Motacilla alba*	1	1	7	6	3	4	6	5
European robin	*Erithacus rubecula*	–	1	2	–	2	–	–	–
Thrush nightingale	*Luscinia luscinia*	–	–	–	–	–	–	–	1
Whinchat	*Saxicola rubetra*	–	–	–	–	–	3	–	–
Northern wheatear	*Oenanthe oenanthe*	–	–	2	3	4	3	2	3
Common blackbird	*Turdus merula*	1	2	3	2	1	–	1	2
Fieldfare	*Turdus pilaris*	3	4	5	4	6	4	5	2
Song thrush	*Turdus philomelos*	–	–	–	–	–	–	–	1
Redwing	*Turdus iliacus*	1	–	–	–	–	–	–	–
Blyth's reed warbler	*Acrocephalus dumetorum*	–	–	–	–	–	–	–	1
Lesser whitethroat	*Sylvia curruca*	–	–	–	–	1	–	1	–
Common whitethroat	*Sylvia communis*	2	2	–	4	1	–	1	1
Garden warbler	*Sylvia borin*	1	–	1	–	–	1	–	–
Willow warbler	*Phylloscopus trochilus*	2	1	4	1	3	–	3	3
Spotted flycatcher	*Muscicapa striata*	2	–	–	–	–	–	–	–
European pied flycatcher	*Ficedula hypoleuca*	4	3	5	–	5	3	3	2
Eurasian blue tit	*Cyanistes caeruleus*	3	3	3	3	2	3	2	1
Great tit	*Parus major*	4	6	6	5	4	5	3	2
Red–backed shrike	*Lanius collurio*	1	1	1	–	–	2	–	–
Common magpie	*Pica pica*	1	–	1	1	1	1	–	–
Common starling	*Sturnus vulgaris*	–	–	1	–	–	–	–	–
Eurasian tree sparrow	*Passer montanus*	–	–	–	–	–	1	–	–
Common chaffinch	*Fringilla coelebs*	4	5	6	5	4	5	3	4
European greenfinch	*Carduelis chloris*	1	2	6	1	3	4	1	–

continued

Appendix 1. Continued.

Species	Scientific name	2002	2003	2006	2007	2008	2009	2010	2011
Eurasian siskin	*Carduelis spinus*	–	1	–	–	–	3	1	–
European goldfinch	*Carduelis carduelis*	–	–	–	–	1	1	–	1
Common linnet	*Carduelis cannabina*	–	–	2	3	2	2	–	–
Common rosefinch	*Carpodacus erythrinus*	–	–	1	1	–	–	3	–
Hawfinch	*Coccothraustes coccothraustes*	–	–	1	–	–	–	–	–
Ortolan bunting	*Emberiza hortulana*	–	1	–	–	–	–	–	–
Yellowhammer	*Emberiza citrinella*	7	5	8	3	4	3	6	2
Total		48	51	97	85	87	84	77	64
Number of species		21	21	25	21	25	24	21	21
Density pairs per km^2		84.7	89.9	171.1	149.9	153.4	148.1	133.4	110.9
Pairs of threatened, nearly threatened or directive species		1	2	9	5	6	9	6	4