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The effect of changes in land use on waterfowl species turnover in Finnish boreal lakes

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Effects of different land-use types on nutrient and chemical run-off have been widely researched, but the total effect of changes in land use on communities of aquatic species is poorly known. We evaluated the effect of land-use change on waterfowl communities of boreal lakes. We conducted the study with topographic maps and GIS-techniques in central Finland. We compared changes in the structure of waterfowl communities with changes in land use around 15 lakes over a period of 50 years. Over the period, agricultural land and bogs were reduced in area, while ditched areas increased significantly. The numbers of waterfowl breeding pairs and species increased slightly on the majority of lakes. The largest increases in breeding pairs were for Goldeneye *Bucephala clangula* and Teal *Anas crecca*. Interestingly, Mallard *Anas platyrhynchos* decreased in terms of both breeding pairs and the number of occupied lakes, although it has increased nationally. We found evidence of decreasing pair numbers of Mallards on lakes where adjacent dwellings increased in number. Changes in land use correlated with those in waterfowl communities but lake size appears to affect these results. After controlling for the effect of lake size, only the number of adjacent dwellings correlated significantly with changes in the number of breeding pairs of Mallards. According to our results, changes in the area of agricultural, bog or ditched land around lakes could not be clearly linked with changes in waterfowl communities.

1. Introduction

Rural landscapes have undergone radical changes in Northern Europe during the past few decades. From the late 1950s, in particular, boreal landscapes have changed towards intensively managed forests, agricultural and urban areas. These modifications in the use of rural areas have had an unknown number of effects on boreal freshwater flora and fauna (e.g., Rich & Woodruff 1996, Higgins *et al*. 2002, Barkman 2003). Sala *et al.* (2000) predicted that the land-use change would be one of the major threats to freshwater biodiversity in the future, because humans live in and modify riparian zones and land use is expected to have far-reaching effects on freshwater ecosystems even in terrestrial biomes that are otherwise sparsely populated. Moreover, the effect of wetland loss on regional diversity might be larger than the expected effect of habitat loss alone (Richter *et al.* 1997, Lemly et al. 2000, Amezaga *et al.* 2002).

We studied the connection between land-use change and waterfowl species turnover on 15 boreal lakes. The most substantial environmental changes affecting waterfowl are pollution, eutrophication, habitat loss, fragmentation, hunting, collecting, disturbance (e.g., dwellings and industry), and the introduction of new species (von Haartman 1975, Owen & Black 1990, Andersson & Nilsson 1999). Land use is a factor that affects the majority of these elements directly or indirectly through its impact on water quality (Mander *et al.* 2000, Tong & Chen 2002). Although the impact of land use on water quality, sediments and water flow is well understood, the total effect of land-use change on aquatic biota has been studied only rarely.

Among all forms of land use, the impact of agriculture on aquatic species inhabiting adjacent waters has probably been the best identified phenomenon. Mensing *et al.* (1998) reported that shrub vegetation, fish and birds were influenced by the extent of adjacent cultivated land, while amphibians and fish responded to the extent of open water and rangeland. That study also noted that wet meadow vegetation was affected by local disturbances and environmental factors such as grazing, nutrient loading and pH level. Hebert and Wassernaar (2001) analysed the concentration of nutrients in waterfowl and demonstrated that the mean stable nitrogen level in Mallard *Anas platyrhynchos* feathers was correlated with the percentage of land under agricultural development. Also disturbances may affect waterfowl. For instance, Chen *et al.* (2000) noticed that disturbance affected waterfowl species distribution, density and diversity. Pedestrians in England did not greatly affect the behaviour of wintering waterfowl but heavy disturbance caused *Anas* ducks to relocate (Marsden 2000). Some waterfowl species, including Teal *Anas crecca*, suffer from construction work and footpaths adjacent to these birds' wintering or breeding areas (Burton *et al.* 2002a, 2002b).

Alteration of the environment of freshwater lakes is not the only factor affecting waterfowl community structure. Many waterfowl species of eutrophic lakes have expanded from southern Europe to northern Europe during the 20th century (Kalela 1946, von Haartman 1973, Väisänen *et al.* 1998). This trend may arise from general eutrophication and climatic warming. Another possible reason for species turnover is interspecific competition. Elmberg *et al.* (1994) showed that the richness of waterfowl species may be well explained by the number of prey taxa in a given lake. Moreover, interspecific competition between Mallard and Teal does not limit the number of these species (Elmberg *et al.* 1997). Another possible reason for the change in waterfowl species turnover is human-made nests. Goldeneye *Bucephala clangula*, for example, prefers nest boxes over natural cavities (Pöysä & Pöysä 2002). Human-caused environmental changes have been recognised as the principal factor for the most of the rapid expansions in waterfowl populations (von Haartman 1973).

In this study, we studied the overall effect of land-use change on waterfowl species turnover

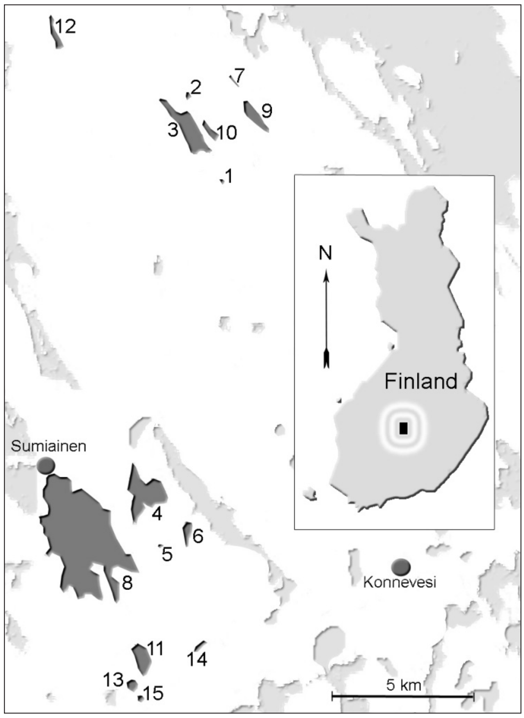

Fig. 1 Map of the study area and its location in Finland. Lakes are shown in grey. The study lakes (dark grey) are numbered 1 to 15 and their names are listed in Table 2.

and breeding pair numbers in central Finland. We examined the relationship between changes in land use and changes in waterfowl communities on 15 lakes over a period of 50 years. We relied on reference data for waterbird species and breeding pair abundance in 1955–56 (Pöyhönen 1962) and collected additional data for comparison in 2002–2003.

2. Material and methods

2.1. Study area

In 1962, Pöyhönen published data about breeding waterfowl numbers in central Finland (62° N, 26° E), which belongs to the southern boreal zone (Järvinen & Väisänen 1980). The study was undertaken on 12 small ponds and lakes (0.2–18 ha) and on three larger lakes (121–700 ha) within an area approximately 25 km by 15 km (Fig. 1). We repeated that study and counted waterfowl on the same lakes and using the same methods as Pöyhönen (1962).

2.2. Waterfowl counts

In the reference research (Pöyhönen 1962), birds were counted twice, first between 22nd May and 17th June 1955 and second between 16th May and 16th June 1956. This period is suitable for waterfowl counts because the ice cover has already melted in April or May and vegetation has not yet grown too tall to hide birds. Species and numbers of breeding pairs were recorded by walking around each lake at the shoreline, except at Lake Sumiainen where a rowing boat was used. Observed individuals were interpreted as pairs from observations concerning female-male pairs or single adult birds, or females with chicks, except that a single male was not counted as a breeding pair for Mallard, Common Pochard *Athya ferina*, Tufted Tuck *A. fuligula* and Goldeneye. This exception was because the populations of these species commonly include more males than females. We repeated these counts using the same protocol in May and June, that is, first between 21st May and1st June 2002 and second between 25th May and 15th June 2003. This method is not commonly used but we applied the same protocol in order to obtain data relevant for comparison between the two periods (1955–56 versus 2002–03).

2.3. Changes in land use

Land use was examined and habitat types coarsely classified, and dwellings were counted, from the shoreline up to 500 meters away from each lake. Land use in 1955–56 was estimated from topographic maps (1:20,000) made between late 1950s and early 1960s and printed between 1960 and 1972 by the Finnish National Land Survey Office. Former land use was also checked visually using aerial photographs taken in the summer of 1954. We analysed present land use from digital topographic maps (Perus-CD 1999) and aerial photographs (from the years 1995–1999) made by the Finnish National Land Survey Office. Total land area analysed for the study was 3388 hectares.

For the study purposes, land use was studied using three categories: agricultural land, bogs and ditched areas. Agricultural areas included fields and meadows. Bogs included all unditched bogs, open bogs, open bogs on the shoreline and swamps, which were marked in the maps. Ditched areas included all ditched bogs and ditched forests. These three land-use classes were chosen because they were reliable to digitize from the maps. We also assumed that changes in agriculture and ditching would be critical for waterfowl breeding success and turnover. These three land-use classes covered approximately 2/3 of the area surrounding the lakes. The rest of the landscape mostly consisted of un-ditched forests, roads and suburban yards. The number of human dwellings was counted and lake sizes in the 1950s and in 2000 were estimated using the same maps. Land use patches were digitized and patch sizes determined using ArcView 3.2 software.

2.4. Data analyses

Mean numbers of waterfowl pairs at each lake were calculated using the count data for 1955–56 and 2002–03. These means were treated as independent observations in statistical tests. Changes in weather conditions in breeding areas is the most

Table 1. Changes in the numbers of breeding pairs and number of occupied lakes by different waterfowl species. Mean values for two years are shown.

Species	1955–56		2002–03			
	Pairs	Occupied lakes	Pairs	Occupied lakes	Pairs, change	Occupancy change
Whooper Swan *Cygnus cygnus*	0	0	4	4	4	4
Black-throated Diver *Gavia arctica*	2	1	4.5	2	2.5	1
Teal *Anas crecca*	14.5	5.5	36	7	21.5	1.5
Northern Pintail *A. acuta*	0	0	7.5	2	7.5	2
Wigeon *A. penelope*	13.5	3.5	12.5	3	–1	–0.5
Northern Shoveler *A. clypeata*	0	0	4	1	4	1
Mallard *A. platyrhynchos*	16	7	3	1.5	–13	–5.5
Garganey *A. querquedula*	0	0	2	1	2	1
Common Pochard *Athya ferina*	11.5	3.5	3	2	–8.5	–1.5
Tufted Duck *A. fuligula*	8.5	3.5	10	2.5	1.5	–1
Goldeneye *Bucephala clangula*	8	5.5	32.5	6.5	24.5	1
Great Crested Grebe *Podiceps cristatus*	1.5	1.5	10.5	3	9	1.5
Red-necked Grebe *P. grisegena*	3	1	2.5	2	–0.5	1
Horned Grebe *P. auritus*	4	3.5	2	1	–2	–2.5
Goosander *Mergus merganser*	0	0	2.5	1	2.5	1
Red-breasted Merganser *M. serrator*	1	1	9.5	1	8.5	0

common environmental factor affecting short-term fluctuations in waterfowl population size (Kauppinen & Väänänen 1999). Some species are more sensitive to harsh spring weather while others are more sensitive to winter severity. We used the means to reduce the effect of annual change in waterfowl populations. We calculated changes in the number of waterfowl breeding pairs and numbers of species for each study lake. We also counted the numbers of new and disappeared species by comparing data from 1955–56 and 2002–03. We estimated species turnover rate (STO) using the function

$$STO = 0.5\,(I + E) \qquad (1)$$

where I is the number of new species and E is number of extinct species (Schoener 1988). Community turnover was calculated as the percentage of dissimilarity. Dissimilarity of communities between periods was measured using the percentage dissimilarity index:

$$PDS = 1 - PS \qquad (2)$$

where $PS = \Sigma \min (p_{i1}, p_{i2})$, p is the proportion of individuals of species i in 1955–56 and in 2002–03 (Suhonen *et al.* 2010).

Changes in the mean number of breeding pairs and in the mean number of occupied lakes were analysed with Wilcoxon rank tests because these sets of means were related samples. Using a one-sample *t* test (against change = 0), we tested whether the changes in breeding pair numbers and changes in land use were significant. Changes in land-use classes and in lake size were used as relative proportions (%) of the analysed area to reduce the effect of variation in lake sizes in statistical evaluations. For correlations of lake size, we used size data obtained from current maps ("Lake area 2000s" in the tables). We $\log_{10}$ transformed lake size for Kendall partial correlations. Prior to the analysis, the number of dwellings was transformed to $|\log_{10}(x+1)|$, where x was the change in the number of dwellings.

We used Spearman rank correlations to examine the relationship between habitat factors or lake size and breeding-pair or species numbers, and I, E, TR (see above) and dissimilarity. We also calculated Kendall partial correlations for factors that correlated with species changes to find out if there was an association with lake size. Correlations between the change in a given species, habitat factors and lake size were tested in the same way using Spearman rank and Kendall partial correlations. Because the breeding-pair numbers of Whooper

Table 2. Relative change in the waterfowl communities between 1950s and 2000s for each of the 15 studied lakes. Change in breeding-pair numbers ("Change, pairs") represents the total change in the number of breeding pairs in all species together. The number of new species ("New") represents species that were not detected in 1955–56 but were found in 2002–03. "Absent" represents species that occurred in 1955–56 but were not found in 2002–03. Species turnover ("STO"), percentage dissimilarity of waterbird communities between periods ("PDS"), and changes in lake area ("Area, change"; in%) and in the number of dwellings ("Dwellings, change"; in *n*) are also shown.

Lake	Change, pairs	New	Absent	STO	PDS	Area 2000	Area, change	Dwellings, change
Pyhälampi (1)	–1.5	1	2	1.5	0.67	0.3	–50.0	0
Kotanen (2)	–3.0	0	3	1.5	0.88	1.8	–40.0	0
Pyhäjärvi (3)	27.5	5	0	2.5	0.51	96	–29.9	2
Kalajärvi (4)	11.0	2	0	1.0	0.40	110	–9.1	7
Paskolampi (5)	–1.0	0	1	0.5	1	0.2	–50.0	0
Majalampi (6)	1.5	4	3	3.5	1	12.5	25.0	2
Pieni Kangasjärvi (7)	–0.5	1	2	1.5	1	0.3	–95.0	2
Sumiainen (8)	13.5	4	2	3.0	0.61	731	4.4	154
Iso Kangasjärvi (9)	8.0	3	2	2.5	1	17.5	–2.8	4
Pirttijärvi (10)	3.5	2	0	1.0	0.89	14.6	–2.7	0
Lahnanen (11)	1.0	2	1	1.5	1	31.3	4.3	4
Sorvajärvi (12)	1.5	2	0	1.0	1	12.7	–15.3	–1
Ala-Papulampi (13)	0.5	1	0	0.5	1	2.4	–4.0	1
Loipanlampi (14)	0.5	1	0	0.5	1	2	0.0	3
Ylä-Papulampi (15)	0.0	0	0	0.0	1	0.6	50.0	0

Swan *Cygnus cygnus* and Mallard changed on the same lakes, we studied changes of the mean breeding-pair numbers of these species according to colonization or not by Whooper Swans and by using Mann-Whitney *U* tests. We applied non-parametric tests because the majority of variables did not pass the assumptions of data normality. All statistical analyses were done in SPSS 11.0.

3. Results

3.1. Changes in waterfowl abundance

We found altogether 16 waterfowl species. Most species were commoner in 2002–03 than in 1955–56 (Table 1). Five of these species did not occur on these lakes in 1955–56, these being Whooper Swan, Northern Pintail *Anas acuta,* Northern Shoveler *Anas clypeata*, Garganey *Anas querquedula* and Goosander *Mergus merganser.* No species became absent from the study lakes. Breeding pairs increased for all eleven species originally present and ten species had colonized new lakes. The mean breeding-pair number per lake increased almost significantly from 5.6 (± 8.9 SD) to 9.7 (± 16.5 SD) (Wilcoxon signed rank test: $T = 22.5$, $N = 15$, $P = 0.059$). The mean number of species per lake did not change from 1955–56 to 2002–03 (mean 2.4 ± 2.7 SD and 2.7 ± 3.4, respectively; $T = 36.5$, $N = 15$, $P = 0.525$).

The number of breeding pairs of Goldeneye increased (one-sample *t* test: $t = 2.39$, df = 14, $P = 0.032$) as did that of Teal, albeit statistically non-significantly ($t = 1.91$, df = 14, $P = 0.077$). For Mallard, the change in breeding pairs was negative ($t = –2.27$, df = 14, $P = 0.040$), as it was for Common Pochard, although the change for this species was statistically non-significantly ($t = –2.03$, df = 14, $P = 0.062$). The Whooper Swan colonized four new lakes.

The total number of breeding waterfowl species diminished only at lakes that had shrunk or almost dried up, however, this change was not significant ($r_s = –0.45$, $N = 15$, $P = 0.089$). The number of new species at a given lake was frequently larger than the number of species no longer present. Turnover rate was moderately higher at one large lake (>100 ha) and at two medium-sized lakes (10–100 ha) but this was not a consistent trend as the turnover rate on other medium-sized lakes was lower than the average turnover (Table

2). The community turnover, measured by "dissimilarity", varied from 0.4 to 1.00. In this respect, larger lakes appeared slightly more stable than smaller ones (Tables 2 and 4).

3.2. Changes in land use

One of the lakes, Pieni Kangasjärvi, had almost dried up since 1955–56, and Pyhäjärvi had also reduced in size. The area of seven lakes had stayed approximately the same, and the area of four lakes had slightly increased (Table 2). Changes in the number of human dwellings varied between –1 and 154. The number of dwellings had increased at nine lakes and decreased at one lake. The majority of new dwellings were at Sumiaisjärvi.

Some common changes had taken place at all studied lakes. For instance, the amount of ditched area had increased and that of bogs had decreased. The majority of forests adjacent to the study lakes had been ditched and agricultural areas had decreased. Changes in land use were statistically significant in all studied land-use classes (Table 3).

3.3. The relationship between waterfowl abundance and land-use changes

Changes in breeding-pair numbers correlated with certain changes in land use. In areas where the area of bogs had considerably decreased, the number of breeding pairs had slightly decreased, but in areas where the area of bogs had not changed the number of breeding pairs had increased, apparently due to the influx of new species (Table 4). An increase in the ditched area around a given lake was associated with a decrease in the number of breeding pairs, while an increase in the number of dwellings was associated with an increase in the number of breeding pairs. The number of new species was significantly and positively correlated with increases in the area of bogs and in the number of dwellings. Percentage dissimilarity did not significantly correlate with land-use changes (Table 4). However, increasing lake size positively correlated with increases in the number of breeding pairs and in the number of new species. After controlling for the effect of lake size, none of the changes in land use correlated significantly with changes in breeding pairs (Kendall partial correlation: $-0.299 < r_p < 0.090$, df = 12, $P > 0.299$) or in new species numbers ($0.254 < r_p < -0.479$, df = 12, $P > 0.377$).

Table 3 Relative changes in land use from the 1950s to 2000s. Mean values (± SD) describe variation among the 15 lakes. The *t*-test compares the two study periods (1955–56 versus 2002–03) as described fully in the text. *** denotes that $p < 0.001$.

Land-use class	Change ± SD	t
Agricultural land	–3.0 ± 2.7	–4.267***
Bogs	–6.0 ± 3.7	–6.294***
Ditched areas	13.4 ± 4.7	8.280***

Table 4. Spearman rank correlation coefficients between changes in waterfowl communities (i.e., number of new species, "New"; number of absent species, "Absent"; rate of species turnover, "Turnover"; change in the number of breeding pairs, "Pairs, change; change in the number of species, "Species, change"; and proportion of a given species over all species, "Dissimilarity") and changes in environmental variables (i.e., the proportion of agricultural land, "% agricultural"; the proportion of bogs, "% bogs"; the proportion of ditched areas,"% ditched"; the number of dwellings, "n dwellings"; lake size, "% size"; and lake size in the early 2000s, "Size 2000"). *N* = 15. Probabilities are denoted as * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$.

	New	Disappeared	Turnover	Pairs, change	Species, change	Dissimilarity
% agricultural	–0.470	–0.166	–0.418	–0.429	–0.355	0.004
% bogs	0.559*	–0.309	0.098	0.678**	0.467	–0.012
% ditched	–0.323	0.440	0.022	–0.560*	–0.426	0.309
n dwellings	0.534*	0.134	0.439	0.560*	0.489	–0.218
% size	0.317	–0.132	0.035	0.397	0.391	0.200
Size 2000	0.818***	–0.200	0.447	0.912***	0.842***	–0.447

Table 5. Spearman rank correlation coefficients between the number of Mallard, Teal and Goldeneye individuals and environmental variables. $N = 15$. Probabilities are denoted as * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$.

Variable	Mallard	Teal	Goldeneye
Change in agricultural area (%)	0.560*	–0.218	–0.456
Change in bog area (%)	–0.484	0.386	0.750**
Change in ditched area (%)	0.576*	–0.292	–0.632*
Change in no. dwellings	–0.630*	0.289	0.488
Change in lake size (%)	–0.095	–0.014	0.284
Lake size, early 2000s	–0.654**	0.388	0.757**

We also tested correlations between changes in the number of breeding pairs of the three most abundant species and changes in land-use classes (Table 5). These analyses suggest that the change in the number of breeding pairs of Mallard was connected with a change in the amount of agricultural land and ditched areas present, and in the number of dwellings present. Changes in the breeding-pair numbers of Goldeneye were associated with changes in the areas covered by bogs and ditched habitat. Changes in the breeding-pair numbers of Mallard and Goldeneye were also significantly correlated with lake size. However, after again removing the effect of lake size only the change in the number of dwellings correlated significantly with the change in Mallard breeding pairs (Kendall partial correlation: $r_p = -0.718$, df = 12, $P = 0.004$).

The mean number of breeding pairs of Mallard decreased more at lakes colonized by Whooper Swans than at lakes without Whooper Swans (–2.4 ± 2.3 SD; $N = 4$ and –0.3 ± 0.5SD; $N = 11$, respectively; Mann-Whitney U test: $U = 7.5$, $P = 0.039$). Colonization of a lake by Whooper Swans did not affect the breeding-pair numbers of Teal (2.5, ±5.1 SD, $N = 4$ and 1.0 ± 1.8 SD, $N = 11$, respectively; $U = 21.5$, $P = 0.950$).

4. Discussion

4.1. Effects of land-use change on waterfowl communities

In general, over the past 50 years, waterfowl communities seem to have become more numerous and diverse: both species and breeding-pair numbers had apparently grown on most of the studied lakes. Waterfowl occupied new lakes in most cases. This general trend, however, may rather be an effect of eutrophication and climatic warming than land-use change. We found five new species which were not present in 1955–56.

Pöyhönen (1962) did his censuses too late in relation to the normal breeding period of ducks, but we followed his time schedule for consistency, even though the timing for waterfowl counts was sub-optimal with respect to their breeding phenology. Variation in the phenology of the two consecutive years may also bias our results (Oja & Pöysä 2007).

In agricultural landscapes the input rate of fertilizers is the most important factor contributing to nitrogen, phosphorus and organic matter runoff, while at a larger scale, actual land use plays the main role (Mander *et al.* 2000). When arable land around lakes is abandoned, the flow of nutrients and organic matter into lakes decreases significantly. A decline in agriculture may also affect waterfowl directly as the landscape "closes in" due to a reduction in meadows and fields. According to our results, however, changes in the area of fields and meadows had no effect on the waterbird community.

Major changes occurred in bogs in the study area where open bogs, spruce-dominated bogs with a thin peat layer and shoreline bogs all diminished over the period. We found fewer new waterfowl species at lakes where the surrounding bogs had diminished than at lakes where these bogs had not diminished. However, this correlation was reliant on lake size. Bogs are extremely valuable for many species. Existing bogs are presently mostly ditched. Also forests have commonly been ditched to increase wood production. Ditching affects water biota through water quality and it may also affect waterfowl by reducing the open area around lakes (Ruuhijärvi *et al.* 2000). We noticed that breeding-pair numbers increased less at lakes where ditching was prevalent, but this effect was also dependent on lake size.

Some farms that used to be inhabited in 1955–56 had been abandoned in the 1970s–1980s, though some new buildings and farms had been built since the 1950s. In addition to this, new summer cottages had appeared on many shorelines. According to our results, new dwellings around a given lake were associated with increases in the number of new species and breeding pairs. Nevertheless, this effect was dependent on lake size, and after controlling for this effect there was no longer a statistical relationship between dwellings and waterfowl breeding activities. This connection may be distorted by the fact that the largest number of new houses was around at a single lake, Sumiainen.

In accordance with our results, the area of lake has previously been found to be a better predictor of waterfowl species number than the length of the shoreline (Elmberg *et al.* 1994); the bigger the lake, the more species. In our data, this connection was evident: lake size was the only factor that was undoubtedly connected to the species turnover: the larger the lake, the more new species and more breeding pairs. However, there was no statistically significant correlation between the change in lake size and the change in its waterfowl community.

4.2. Effects of land-use change at the species level

According to our results, among all species the breeding-pair numbers of the Goldeneye had increased the most. This species has also expanded its range during the scope of this study, and expanded its range slightly northwards. According to the breeding bird atlas of Finland (Väisänen *et al.* 1998), our national Goldeneye numbers are approximately equivalent to those of the Mallard and Teal.

Many nest boxes designed for Goldeneye can be found around the studied lakes, which may also have affected its breeding success. Dow and Fredga (1983) noticed that the majority of Goldeneye females breed in nest boxes and they have a strong tendency to return to breed in the boxes occupied in earlier years.

Mallard and Teal are the two most numerous *Anas* species in Finland and Northern Europe (Väisänen *et al.* 1998), and the Mallard population has increased in most areas in Finland. We noticed, however, that Mallard had decreased at the same time as there was a tendency for all other *Anas* species to increase. Moreover, Mallard decreased from every lake occupied by the Whooper Swan. This could be due to competition for resources, as the foraging behaviour and ecomorphological characteristics are relatively similar for these species (Pöysä & Sorjonen 2000). However, Pöysä and Sorjonen (2000) did not find evidence of an adverse impact of Whooper Swan colonization on population densities of other waterfowl species. Several studies of interspecific co-existence of dabbling ducks in Northern Europe (Elmberg *et al.* 1993, Nummi & Pöysä 1993) and North America (Du Bowy 1988) have concluded that interspecific resource competition is not a crucial factor for these ducks, especially presently when the majority of lakes are more eutrophic than previously (Nummi & Väänänen 2001). Thus, it is unlikely that the contemporaneous decrease of Mallard and increase of Teal would be due to food or space competition. The increased number of dwellings appears to be connected to the decrease in Mallard numbers: the more new dwellings, the fewer Mallard breeding pairs. The observed decrease of Mallard may also be partly due to hunting, as it is the most hunted waterfowl species in central Finland (Kauppinen & Väänänen 1999). However, in the temporal and spatial hunting-control research made by Bergnballe *et al.* (2004), Teal suffered more from hunting than Mallard. In our study, Mallard numbers had decreased in the areas where Teal had increased.

The Whooper Swan has greatly increased in numbers across Finland since mid-1900s, from *circa* 15 to 1,500 pairs (Väisänen *et al.* 1998). This trend was evident also in our research area. In 1955–56, when Pöyhönen's (1962) counts were done, the species was nearly extinct in Finland due to hunting, and the species occurred only in the most northern part of the country (Kokko 1950). The reason for the increase of the Whooper Swan is effective protection rather than change in land use (Väisänen *et al.* 1998).

4.3. Conclusions

We found correlations between the numbers of breeding pairs or the number of species and the amount of bogs or ditched areas, but we did not find clear evidence for an effect of land-use change on waterfowl species turnover. Lake size appeared to explain most of the variation in species turnover. Changes in single species were more significant than changes in species turnover and, according to our results, there appears to be a connection between changes in the number of lakeside dwellings and in Mallard breeding-pair numbers. All the factors affecting bird assemblages are hard to control for in one study, which is the reason why these kinds of studies are rare. However, we need more information about this important subject to obtain more assurance about the effects of changing land use on aquatic biota. We suggest similar studies with a larger sample size would offer possibilities for more accurate statistical testing.

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Maankäytön muutosten vaikutukset vesilinnuston vaihteluun suomalaisilla boreaalisilla järvillä

Maankäytön vaikutuksia ravinteiden ja kemikaalien huuhtoutumiseen on tutkittu runsaasti, mutta maankäytön muutosten kokonaisvaikutukset vesieliöiden yhteisöihin tunnetaan puutteellisesti. Selvitimme maankäytön muutoksien vaikutuksia vesilinnustoon keskisuomalaisilla boreaalisilla järvillä soveltamalla peruskartta- ja ilmakuva-aineistoja. Vertailimme 50 vuoden aikana tapahtuneita vesilinnuston muutoksia samanaikaisiin maankäytön muutoksiin 15 järvellä. Jakson aikana viljely- ja suomaat vähenivät, mutta ojitetut alueet runsastuivat merkitsevästi.

Vesilintujen pari- ja lajimäärät kasvoivat valtaosalla järvistä. Suurimmat pesimäparien määrän muutokset todettiin telkällä *Bucephala clangula* ja tavilla *Anas crecca*. Yllättäen sinisorsalla *Anas platyrhynchos* vähenivät sekä parimäärä että asuttujen järvien määrä, vaikka laji on Suomessa runsastunut. Sinisorsan parimäärät näyttivät laskeneen eritoten järvillä, joiden rantoja oli mökitetty. Maankäytön muutos korreloi vesilintuyhteisön muutoksien kanssa, mutta tähän tulokseen vaikuttaa voimakkaasti järven koko. Järven koon huomioimisen jälkeen vain järven ranta-asutuksen määrä korreloi merkitsevästi sinisorsien parimäärän muutoksen kanssa. Näiden tuloksien valossa maatalous-, suo- ja ojitetun maan pinta-ala järven välittömässä tuntumassa ei suoraan näytä liittyvän vesilinnustossa tapahtuviin muutoksiin.

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