Avocetta 33: 191-198 (2009)

The Urban Waterfowl Fauna of Moscow in comparison with some other European cities

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Abstract – The attempt of comparing the waterfowl fauna of the sixteen European cities described in the monograph of Kelcey & Reinwald (2005), with the addition of original data collected for ten seasons (1998-2007) in Moscow was made. The two main questions will be addressed here:
1) Is there a SW-NE gradient in the European urban waterfowl species richness?
2) What kind of factors (natural and anthropogenic) were responsible of the pattern of the species richness distribution?
The comparisons have revealed an increase of native urban waterfowl species richness from the South to the North of Europe, i.e. towards the cities situated in more severe climate zones. The same process occurs in the corresponding regional species richness. The area of the city is of subordinate importance for the native species richness. This effect possibly is determined by local habitat properties. The large area of swamps and other wetlands of the North-Eastern part of Europe are natural refuges for breeding and moulting of the large amount of the native European waterfowl species. Some of these species inhabit the cities. Only the regional human population density affects the amount of urban alien species. Climate warming may produce further increasing of wintering and of potential breeding species richness in the Eastern European cities, e.g. in Moscow.

INTRODUCTION

The impact of urbanization on birds is examined over one hundred years, especially since the middle of XX century in Northern Europe and North America (Marzluff *et al.* 2001b). In spite of it only few papers compare the fauna of large cities. Such comparisons concern only a few cities of Eastern and Northern Europe (Luniak 1990; Konstantinov *et al.*; 1996; Jokimäki *et al.* 2002; Muslow 2005; Witt *et al.*, 2005) or Northern Europe and North America (Clergeau *et al.* 1998). At the same time the obtained data on all species of the European land native bird-fauna shows, according to Tomiałojć (2000), that it tends to be richer in Eastern than in Western Europe. He suggests that the European waterfowl fauna is more uniform than the landbirds' one. The European urban bird fauna distribution and the factors responsible for its pattern are rather obscure. Step towards its clarification has been made in the monograph edited by J.G. Kelcey and G. Reinwald (2005). This book is the first one that describes in detail the birdlife of sixteen European cities from the South-West to the North-East of Europe, including the two biggest cities of Russia: Moscow and St. Petersburg. These authors pay more attention to the similarities of urban conditions and bird distribution patterns, than to their differences. In the present paper an attempt to compare the waterfowl fauna (bird species of the orders Podicipediformes, Anseriformers and some of Gruiformes) of the above-mentioned cities was made.

Two main questions will be addressed here:

1) Is there a SW-NE gradient in the European urban waterfowl species richness?
2) What kind of factors (natural and anthropogenic) were responsible of the pattern in this species richness pattern?

The most important factors affecting waterfowl fauna in European cities are determined by their geographical, climatic and landscape position, which consequently determine the regional natural species richness. The size of the city's area plays a secondary role. The future climate warming may increase the amount of urban breeding and especially wintering species. The regional human population density doesn't influence on the native species richness of European cities. On the contrary, the latter impacts on the amount of alien species.

MATHERIAL AND METHODS

The European cities' fauna. The monograph "Birds of

European cities" includes sixteen cities that are situated from SE (Lisbon, 38°5' N, 9°1'E) to the NE (St. Petersburg, 59°57'N, 30°19'E) of Europe. The biggest is Moscow (1000 km^2), whose population consists of about 10 million people. The climate of Europe is mostly temperate. European regions West of Berlin are situated in the humid oceanic climate; those in the East in the humid continental one. Much of southern Europe is situated in subtropical climate zone. All examined cities are distributed from the 4th to the 10th hardiness zones of Europe (http://printable-maps.blogspot.com/2008/09/map-of-climate-zones-in-europe.html). The average winter temperature in Lisbon is 10-11^{0}C, in Prague, Bratislava and Wien about 0°C, in Moscow and St. Petersburg –7/9°C. These last cities are situated near the big route of migration through the Baltic and White Sea.

Urban habitats are in general quite similar. Everywhere the high density of buildings and constructions in the center determines rather mild climate with nonfreezing water bodies, available food resources, air and water pollutions, permanent noise and illumination, absence of natural predators and direct human persecution, with higher levels of permanent human disturbance in the cities. On the other hand, the between-cities differences in the habitat types are not clear.

All sections of the monograph (Kelcey & Reinwald 2005) are constructed according to the same plan: each chapter lists in appendix with the list of species of the corresponding city, categorized into breeding, wintering, native and alien ones. The authors, as a general rule, use original long-term observations that are already published (Biadun 1994a, b, 2001; Feriancova-Mazarova 1994; Iankov 1983; Khrabryi 2001, 2002; Konstantinov *et al.* 1996; Luniak 1990; Luniak *et al.* 2001; Murgui 2000, 2001; Witt 2000, 2003; Witt *et al.* 2003, 2005). It means that the lists of urban species are almost complete. We regard it as a guarantee of their correct comparison without standartization.

The levels of human population density for the corresponding countries, which we consider as a measure of human impact, differ greatly. That of Belgium is an average 337 person/km^2, and the same of St. Petersburg region is only 17 person/km^2.

Waterfowl fauna of Moscow. The main characters of Moscow are as follows: the city occupies a large area (over 1000 km^2), has a intra-continental position, temperate-continental climate, a relatively large proportion of green and natural areas inside the city (about 25%), including more than 300 ponds. The Moscow-river crosses the city from NW to SE for over 72 km. About one-third of it and many

Figure 1. The main locations of waterfowl breeding sites in Moscow area.

tributaries do not freeze in winter. The snow-less and ice-less period has prolonged in the last decades. The Moscow region now is surrounded by sparsely populated areas, differentiating it from the more densely populated regions of Eastern and especially Western Europe.

Since the 1980's regular surveys of wintering, and since 1998's of breeding, waterfowl have been conducted in Moscow. A city-wide survey of wintering birds was carried out in the middle of January by the volunteers from the Russian Bird Conservation Union (Avilova, Eremkin, 2001). Since 1998 detailed surveys of breeding and molting waterfowl combining ground observations and counts from boat was carried out in the middle of each summer (Avilova *et al.*, 2003). Detailed data on breeding wildfowl populations were studied on inventorying city-important water-bodies in 1998-2007. More than 80% water-bodies was covered each season, the total area was about 1000 hectares.

We have visited practically all urban waterfowl habitats of Moscow (fig.1) for revising bird fauna and assess population levels. Using the whole information available we have defined the general list of the species and categorized each as "breeding" and "wintering" ones (Tab. 1).

We have analyzed the impact of different natural factors: geographical position of the city (latitude and longi-

Table 1. Number of breeding and wintering waterfowl species in Moscow (1998-2007).

Species	Number of broods	Number of wintering birds
Mallard *Anas platyrhynchos*	459 ± 52,31 (269 - 790)	9995 ± 771,00 (7500 - 15373)
Ruddy Shelduck *Tadorna ferruginea*	17 ± 7,69 (10 - 29)	268 ± 37,73 (105 - 456)
Goldeneye *Bucephala clangula*	26 ± 2,82 (18 - 47)	94 ± 21,49 (5 - 182)
Tufted Duck *Aythya fuligula*	22 ± 1,44 (16 - 28)	46 ± 5,27 (25 - 73)
Moorhen *Gallinula chloropus*	19 ± 1,83 (6 - 28)	0,8 ± 0,33 (0 - 3)
Pochard *Aythya ferina*	4 ± 1,23 (1 - 11)	5 ± 2,08 (0 - 23)
Coot *Fulica atra*	3 ± 0,47 (0 - 5)	1 ± 0,31 (0 - 3)
Great Crested Grebe *Podiceps cristatus*	3 ± 0,61 (0 - 6)	1,3 ± 0,42 (0 - 4)
Shoveler *Anas clypeata*	0,6 ± 0,22 (0 - 2)	0
Black-necked Grebe *Podiceps nigricollis*	0,3 ± 0,21 (0 - 2)	0, 2 (0 - 2)
Garganey *Anas querquedula*	0,2 ± 0,13 (0 - 1)	0
Teal *Anas crecca*	0,1 ± 0,10 (0 - 1)	5 ± 0,89 (2 - 11)
Scaup *Aythya marila*	0	2 ± 1,68 (0 - 17)
Pintail *Anas acuta*	0	1,2 ± 0,49 (0 - 4)
Little Grebe *Tachybaptus ruficollis*	0	1,2 ± 0,53 (0 - 5)
Smew *Mergellus albellus*	0	1 ± 0,60 (0 - 6)
Goosander *Mergus merganser*	0	0,8 ± 0,41 (0 - 3)
Long-tailed Duck *Clangula hyemalis*	0	0 - 1
Whooper Swan *Cygnus cygnus*	0	0 - 1
White-fronted Goose *Anser albifrons*	0	0 - 1
Wigeon *Anas penelope*	0	0 - 1
Cormorant *Phalacrocorax carbo*	0	0 - 1

tude), climate severity (minimum temperature of the climatic zone, average winter temperature), as well as the impact of anthropogenic factors (area of the city and regional human population density) on regional native waterfowl species richness on the number of species in the city. For comparing the number of species we have applied methods of descriptive (Kolmogorov-Smirnov test for normality) and nonparametric (Spearman rank correlation coefficient, *Rs*, Mann-Whitney U-test) statistics. To analyze the first-order effects of multiple continuous predictor variables we have used multiple linear regression (*Statistica 6,0*). To determine the prolongation of favorable-for-waterfowl snow- and ice-free period we have compared the no. of days without permanent snow cover from the 20th of October till the end of the winter for each year.

RESULTS

Moscow. Moscow waterfowl fauna for the decade (1998-2007) in total consist of 22 species (Tab.1).

Breeding waterfowl species. The number of breeding species reaches up to 12. The number of native breeding species did not increase during the study decade. At present the size of breeding populations of Mallard *Anas platyrhynchos* and Goldeney *Bucephala clangula* are growing (*Rs = 0.92, p = 0.0001; Rs= 0.85, p = 0.0017*, *n = 10* respectively). The populations of Tufted Duck *Aythya fuligula* and Moorhen *Gallinula chloropus* are stable. The number of Pochards *Aythya ferina* is low. Only a few pairs of breeding Great Crested *Podiceps cristatus* and Black Necked *P. nigricollis* Greebes and Coots *Fulica atra* are observed in Moscow every year. Teal *Anas crecca,* Garganey *A. querquedula* and Shoveler *A. clypeata* have stopped nesting yearly from the late 1990s. Gadwall *Anas strepera* has not been nesting in Moscow since 1996. These four species probably are forced out from Moscow by the expansion of the Mallard. The number of other species, especially grebes and Coot, is perhaps limited due to the same reason.

Alien species. The Ruddy Shelduck *Tadorna ferruginea* is the single alien species of Moscow. The number of nesting Ruddy Shelducks increases rapidly (*Rs = 0.86, p = 0.001, n = 10*), the same happens for wintering ones (*Rs = 0.99, p <0.001, n = 10*).

Wintering species. The number of wintering species reaches up to 20. It grew (*rs = 0.81, p = 0.00003, n = 23*) noticeably from 1984/85. The most increasing species of Moscow are Mallard and Goldeneye (*rs = 0.95, p = 0.00002*, *n = 10* and *rs = 0.90, p = 0.0003, n = 10* respectively). Great Crested Grebes (*rs = 0.90, p = 0.0003, n = 10*) and non-breeding Pintails *Anas acuta*, (*rs = 0.64*, *p = 0.047, n = 10*) are also growing in number. Some species of waterfowl do not winter every year in Moscow (Tab.1).

Waterfowl of European cities. The investigated European cities are inhabited by 55 waterfowl species but only 32 of them breed there (see *Appendix*). Mallard and Moorhen inhabit all investigated cities; Coot, Great Crested and Little Grebes all except one; Tufted Duck, Garganey and Mute Swan more than a half of the cities; Teal, Pochard and Gadwall about a half; Shoveler and Goldeney less than a half. The Black-necked Grebe and Greylag Goose breed in three of investigated cities, Slavonian Grebe in two of them. Goosander breeds only in Berlin, Red-breasted Merganser only in St. Petersburg and Cormorant only in Warsaw. Almost all of the most distributed European breeding species - excluding Little Grebe, Mute Swan and Gadwall - breed in Moscow *(Appendix).*

The amount of native breeding species tend to be more numerous in large cities and correlates with the city's area (*Rs = 0.65, p = 0.006, n = 16*), because large cities contain more suitable habitats, especially at their periphery. The number of species grows also from the South to the North (*rs = 0.87, p =0.00001, n = 16*), where the investigated cities of the Eastern Europe countries (East Germany, Poland, Czech Republic, Slovakia and Russia) are situated. The West-East gradient of the species richness is near significant (*rs = 0.47, p = 0.06, n = 16*). Evidently the more cities will be analyzed in the future the better this trend will be detected. Being taken as a whole, this pattern seems coherent with the main temperature gradient or winter severity of Europe, oriented SW-NE (http://printable-maps.blogspot.com/2008/09/map-of-climate-zones-in-europe.html). The species richness of breeding waterfowl is higher in the cities situated in more severe climate zones with low minimal temperatures *(Rs = -0.76, p = 0.0005, n = 16*). The same happens for the corresponding regional species richness (*Rs = -0.65 p = 0.005, n = 16*).

About a half of the European urban waterfowl fauna list is composed by alien species. The most common are Mandarin Duck *Aix galericulata* and Canada Goose *Branta canadensis.* Black Swan *Cygnus atratus* Wood Duck *Aix sponsa* and Egyptian Goose *Alopochen aegyptiacus* are also widely distributed in Western Europe *(Appendix).* According to Kelcey et Reinwald (2005), there are twelve alien species in the Western European cities, but only seven in the Eastern ones, and only one, the Ruddy Shelduck, inhabits Moscow. There are no alien species in Lublin, Bratislava and St. Petersburg. Recently the introduction rate increased: five of the six species of Brussels appeared after 1990s (Weiserbs, Jacob, 2005). Zoological parks play an important role in this introduction, for example in Moscow and Berlin (Popovkina, 2004; Witt, 2005).

At the same time the alien species richness decreases neither from the West to the East nor from the North to the South of Europe. The richness of these species does not correlate with the city area and the average minimal temperatures of corresponding climate zone. On the contrary,

Table 2. Rank correlation values (Rs) between the natural and anthropogenic factors and the waterfowl species richness (ns: not significant).

Wildfowl Species group	Latitude	Longitude	Regional species richness	minimum temperature of the climatic zone	Average regional winter temperature	City area	Regional human population density
Native species richness of the city	Rs = 0,87 p = 0,00001	Rs = 0,47 p = 0,06	Rs = 0,66 p = 0,006	Rs = -0,77 p = 0,0004	Rs = -0,60 p = 0,013	Rs = 0,65 p = 0,006	ns
Regional native species richness	Rs = 0,81 p = 000,1	ns	-	Rs = -0,66 p = 0,005	Rs = -0,70 p = 0,004	ns	ns
Alien species richness of the city	ns	ns	ns	ns	ns	ns	Rs = 0,51 p = 0,039

the increase of alien species richness positively correlates with the regional human population density (Tab. 2).

Since natural factors which have an influence on native urban species richness correlate with each other and also with the regional species richness, I excluded most of them - with the exception of latitude - from the analysis. Then I applied multiple regression method to the remaining factors: city area and latitude. The results reveal that the waterfowl richness is determined in general by geographic position of the city or latitude (*rs = 0.78, p = 0.024, N = 16*), whereas the area of the city is of subordinate importance. The wintering waterfowl species richness in Moscow correlates with the duration of snow free period (*rs = 0.42; p = 0.05, N = 23*).

DISCUSSION

In spite of the fact that most European waterfowl species have extensive geographic ranges (Hagemeijer, Blair, 1997) the species richness of breeding waterfowl is higher in more severe climate zone. This effect is possibly determined by the habitat properties. The natural factor which is involved in producing this pattern of distribution is the large area of swamps and other wetlands in the North-Eastern part of Europe. They are natural breeding and moulting refuges for a large part of the native European waterfowl populations (AA.VV., 1998; Sviridova, 2000; Krivenko, Vinogradov, 2008), fig. 2.

I analyzed seven factors that can impact on the waterfowl species richness in the cities, but no one does (statistically) impact on the total amount of species. On the contrary, two main factors, geographic position and the area of the city, have an influence on native species, but only one, human population density, affects alien species (tab. 2). It seems that the high level of human mobility and activity leads to dispersing of exotic waterfowl around the Western part of Europe.

Climate warming is probably the second environmental factor which leads to the increase of wintering and breeding species richness in the European cities. It is likely that the modern changes in species abundance and richness of wintering waterfowl are produced by climatic factors, mostly by the overall increase of the winter air temperatures (Svazas, 2001; Ferrer *et al.*, 2008). The increase in early migrants, for example the Goldeneye, in Moscow become possible due to exceptionally mild winters without permanent snow cover, recorded in 2004/2005 and especially in 2006/2007.

These factors acting together drive the urban waterfowl species distribution across Europe. But, at the single-city level, the determinants of species composition may be rather difficult to understand.

The human impact plays a negative role in the commu-

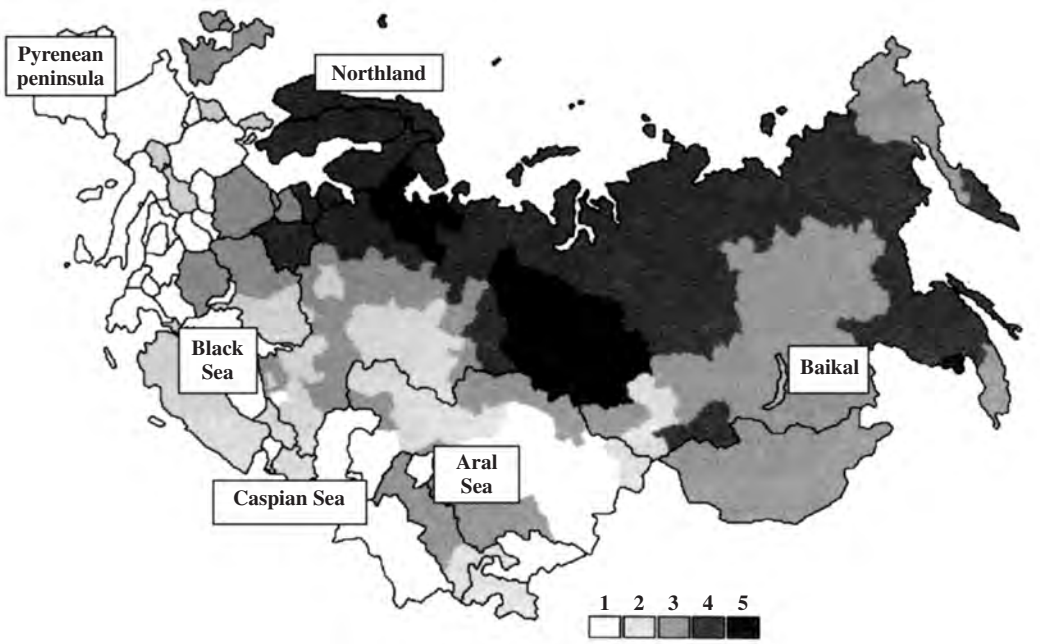

Figure 2. The distribution of swamps and other wetlands at the North-East of Europe in accordance with the data of the Moscow office of Wetland International and Russian national report of land resources.

nities' stability (Jedraszko-Dabrowska D 1990; Tomiałojć, 2000; Cam *et al.*, 2000; Rosa *et al.*, 2003). The strong anthropogenic pressure in dense populated countries stimulates some species to change their habits, leading to partial synanthropy (Tomiałojć, 2003; Luniak, 2004). Mallard (Figley, VanDraff, 1982; Engel *et al.*, 1988;), Swan Goose, Coot (Jedraszko-Dabrowska, Debinska, 1993), Moorhen (Chempulic, 1993; Holzinger, 2000; Schmolz, 2000), Great Crested Grebe (Vogrin, 2002), Goldeneye (Svazas, 2001, Raudonikis, 2002) and other waterfowl species show urban habits in the densely populated environment. Alien species often cross with the native ones (Gosser, Conover, 1999; Blackburn, Duncan, 2001; Whitford, 2002, Randler *et al.*, 2002a,b). Together they form complicated artificial communities in many Western cities, where they partly compensate the impoverished fauna of native communities.

The extensive growing of the Eastern Europe cities started not so long ago, differently from the Western ones. The drastic enlargement of Moscow began after 1960. River banks, other water bodies and swamps were built up correspondingly. Many water bodies stopped freeze in winter, attracting various waterfowl species during migrations. On the other hand artificial water purifiers and cleaning ponds have been created in the course of the city development. They also became very attractive to native species and promoted some of them to transfer their habits from natural to urban. The waterfowl fauna in Moscow now consists of wild and urban populations of the same species. The leading species is the Mallard as everywhere. Rapid and widespread occupation by Mallards of the most suitable water bodies led to decrease of wild Shovelers, Garganeys and Teals. As a consequence, these species do not reach any more sustainable breeding population levels. On the other hand, urban populations of Tufted Duck, Pochard, Coot, Great Crested Grebe did not increase because of Mallards' expansion. This is not the case for a highly territorial species such as the Common Goldeneye.

It seems that the waterfowl fauna of Eastern European cities, including Moscow, is now in the process of transformation and changing of its structure, consisting of native and urban populations. This process is of great importance for most Eastern European countries in the course of the integration. Nevertheless, the conservation of wetlands and, on the other hand, the enlargement of urban wintering sites and stopovers will guarantee the maintenance of waterfowl species in the Eastern European cities for a long time. To continue monitoring of European urban waterfowl ornithologists of different countries have to join their efforts.

Acknowledgements – I am deeply indebted to the editors of the issue "Birds in European cities" John G. Kelcey and Goetz Reinwald for the involving me into the process of comparing bird fauna across Europe. My special thanks to Dr. Javier Quesada for his friendly and interesting consultation that suggested me some fruitful ideas. Also thanks to V.O.Mokievskii for the discussion of the manuscript and to A.B.Kerimov for his valuable advises, to my colleagues A.B.Popovkina and G.S.Eremkin for the intellectual support and to the numerous volunteers for providing me with the field information. The English of the paper was kindly revised by S.V.Ogurtsov and M.Ja. Goretskaya. Financial support came from the project "Universities of Russia: fundamental investigations".

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APPENDIX

List of the breeding waterfowl species recorded in the European cities through the end of the XX - beginning of the XXI century. +* = alien species.

Species	Lisboa	Valencia	Brussels	Bonn	Hamburg	Florence	Roma	Berlin	Prague	Vienna	Bratislava	Warsaw	Lublin	Sofia	Moscow	St Petersburg
Mallard	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Moorhen	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Coot	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+
Little Grebe	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+
Great Crested Grebe	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+
Mute Swan	-	-	+*	+	+	+	+*	+	+	+	+	+	+	-	-	-
Tufted Duck	-	-	+	-	+	-	-	+	+	+	+	+	+	-	+	+
Garganey	-	-	-	-	+	-	-	+	+	+	+	-	+	+	+	+
Pochard	-	-	+	-	+	-	-	+	+	-	-	+	-	-	+	+
Teal	-	-	-	-	+	-	-	+	+	+	+		-+	+	+	+
Gadwall	-	-	-	-	+	-	-	+	+	+	+	-	-	-	-	+
Mandarine Duck	-	+*	-	+*	+*	-	-	+*	-	+*	-	+*	-	-	-	-
Canada Goose	-	-	+*	+*	+*	-	-	+*	+*	+*	-	-	-	-	-	-
Spoonbill	-	-	-	-	+	-	-	+	+	-	-	-	-	-	+	+
Wood Duck	-	-	-	+*	-	-	-	+*	+*	-	-	+*	-	+*	-	-
Black Swan	-	-	+*	+*	-	-	-	-	+*	-	-	-	-	+*	-	-
Goldeneye	-	-	-	-	+	-	-	+	-	-	-	-	-	-	+	+
Egyptian Goose	-	-	+*	+*	+*	-	-	-	-	-	-	-	-	-	-	-
Graylag Goose	-	-	-	+	+	-	-	+	-	+*	-	-	-	-	-	-
Black-necked Grebe	-	-	-	-	-	-	-	-	+	-	+	-	-	-	+	-
Slavonian Grebe	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-
Ruddy Shelduck	-	-	-	-	+*	-	-	-	-	-	-	-	-	-	+*	-
Shelduck	-	-	-	-	+*	-	-	-	-	-	-	-	-	-	-	-
Goosander	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Red-Breasted Merganser	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Barnacle Goose	-	-	+*	-	-	-	-	-	-	-	-	-	-	-	-	-
Magellan Goose	-	-	+*	-	-	-	-	-	-	-	-	-	-	-	-	-
Whooper Swan	-	-	-	-	-	-	-	-	+*	-	-	-	-	-	-	-
Snow Goose	-	-	-	-	-	-	-	-	+*	-	-	-	-	-	-	-
Cormorant	-	-	-	-	-	-	-	+*	-	-	-	-	-	-	-	-
Swan Goose	-	-	-	+*	-	-	-	-	-	-	-	-	-	-	-	-
Flamingo	-	-	-	-	-	-	-	-	+*	-	-	-	-	-	-	-