Abundance of wintering waterbirds on the Hron River (Slovakia) in 2007–2020

Početnosť zimujúcich vodných vtákov na Hrone (Slovensko) v rokoch 2007–2020

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Wintering waterbirds were censused and the effect of ice cover on their abundance was studied on the Hron River (Slovakia) in mid-January 2007–2020. Altogether 24 sites along a 90-km stretch of the middle part of the river was surveyed, of which 23 were sites with running water (81 ha) and one with stagnant water (Kozmálovce reservoir; 63 ha). A total of 25 waterbird species (annual mean 11.2) and 19,645 individuals (annual mean 1,405) were recorded. Mallard (*Anas platyrhynchos*; relative abundance 86.4%), Great Cormorant (*Phalacrocorax carbo*; 8.7%), Common Merganser (*Mergus merganser*; 1.6%) and Grey Heron (*Ardea cinerea*; 0.8%) were the most abundant species. During the 14-year period, the Great Cormorant abundance decreased, while the abundance of Mallard, as well as total abundance of the whole assemblage of 25 species remained stable. In the entire study area (all the 24 sites pooled), only the abundance of Common Goldeneye (*Bucephala clangula*) negatively correlated with the ice cover. Within a subset of sites with running water, the abundance of Mallard and Mute Swan (*Cygnus olor*), as well as the total abundance of 18 species recorded here positively correlated with the ice cover. At the site with stagnant water, the abundance of Mallard, Common Merganser, Common Goldeneye, Great Cormorant and Grey Heron, as well as the total abundance of 21 species recorded here negatively correlated with the ice cover. This supports the importance of running water as a “cold weather refuge” for wintering waterfowl.

*V januári 2007–2020 boli na rieke Hron (Slovensko) sčítané zimujúce vodné vtáky a študovaný efekt miery zaľadnenia na ich početnosť. Pozdĺž 90 km stredného toku Hrona bolo sledovaných celkom 24 lokalít, z toho 23 prúdivých riečnych úsekov (81 ha) a jeden so stojatou vodou (vodná nádrž Kozmálovce; 63 ha). Celkom sme registrovali 25 druhov vodných vtákov (ročný priemer 11,2) a 19 645 jedincov (ročný priemer 1 405). Najpočetnejšími druhmi boli kačica divá (*Anas platyrhynchos; *dominancia 86,4 %), kormorán veľký (*Phalacrocorax carbo*; 8,7 %), potápač veľký (*Mergus merganser*; 1,6 %) a volavka popolavá (*Ardea cinerea*; 0,8 %). Počas 14 rokov poklesla početnosť kormorána veľkého; početnosť kačice divej a celého zoskupenia 25 druhov bola stabilná. V celom študovanom území (všetkých 24 lokalít spolu) iba početnosť hlaholky severskej (*Bucephala clangula*) negatívne korelovala s mierou zaľadnenia.*

*V rámci podmnožiny prúdivých riečnych úsekov sme zistili pozitívnu koreláciu početnosti kačice divej, labute veľkej (*Cygnus olor*) a celkovej početnosti všetkých 18 zistených druhov s mierou zaľadnenia. Naopak, na lokalite so stojatou vodou sme zistili negatívnu koreláciu početnosti kačice divej, potápača veľkého, hlaholky severskej, kormorána veľkého a volavky popolavej a celkovej početnosti všetkých 21 zistených druhov s mierou zaľadnenia. To potvrdzuje význam tečúcich vôd ako refúgií pre zimujúce vodné vtáctvo v chladných zimách.*

Keywords: *Common Merganser, Great Cormorant, ice cover, International Waterbird Census, Mallard*

INTRODUCTION

Waterbirds are not only a key attribute of wetland ecosystems, forming important links in food webs, but also indicators of the ecological condition and productivity of wetland ecosystems (Guareschi et al. 2015). Their abundance is one of the most commonly used designation criteria to protect wetland sites (Wetlands International 2021). Waterbirds have been shown to be very responsive to climate change (Brommer 2008, Bussière et al. 2015, Marchowski et al. 2017).

The abundance of waterbirds is monitored regularly by the International Waterbird Census (IWC) programme (Wetlands International 2021), which is one of the longest running (in Europe since 1967), most extensively harmonised and largest citizen-science biodiversity monitoring programmes in the Western Palearctic. The IWC, managed by individual countries and coordinated by Wetlands International, is carried out each winter in mid-January (i.e., the coldest part of the winter, when waterbird numbers are the most stable) on predetermined dates and sites, with the aim of maximizing the synchrony of the field effort. The goal of the IWC is to monitor the status and distribution of waterbird populations, describe their changes, assess the importance of individual sites for waterbirds during the non-breeding season, and to identify important wintering areas for these species (Delany 2005).

Abundance of many waterbird species, including the species of conservation concern, have changed significantly in recent decades, particularly due to habitat degradation and/or climate change, but there is also a high year-to-year variation in waterbird abundance (e.g., BirdLife International 2004, Wetlands International 2021). These changes have been explained at the European (e.g., Musilová et al. 2014, Fox et al. 2016, Musilová et al. 2018), national (e.g., Fouque et al. 2009, Musil et al. 2011, Nilsson & Haas 2016, Musilová et al. 2018) and regional levels (Mourková et al. 2009, Vránová 2010, Baláž et al. 2018).

Ice cover is one of the most important factors affecting the census results, given that waterbirds need ice--free open water for foraging and safety from predation and disturbance (e.g., Schummer et al. 2010, Baláž 2016). Particularly bottom-feeding waterbirds (e.g., Common Pochard, *Aythya ferina*, Common Goldeneye, *Bucephala clangula*, Eurasian Coot, *Fulica atra*) tend to be more sensitive to ice cover in several regions of Europe than piscivores (e.g., Common Merganser, *Mergus merganser*, Smew, *Mergellus albellus*; Marchowski et al. 2017, Baláž et al. 2018).

The Hron River is an important biocorridor in the mountainous part of Slovakia, especially during the winter and migration seasons. Waterbirds have been regularly censused here since 1998, mostly during the mid-winter period

(Krištín & Sárossy 2001, Lešo 2005, Veľký et al. 2005, Lešo & Kropil 2011). However, all these studies were only descriptive, i.e. they have not placed the census results in the context of environmental factors. In Slovakia, only one study from the northern part of the country analysed the effect of ambient temperature on wintering waterbirds (Baláž et al. 2018).

The aim of this study was to analyse the 1) variation in species composition and abundance of wintering waterbirds on the Hron River in the period 2007–2020 and 2) the effect of ice cover on waterbird abundance.

METHODS

Study area

The Hron River is the second longest (length 297 km) and one of the most important left-bank tributaries of the Danube River in Slovakia (the total elevation range of 831 m and the catchment area of 5,464 km^2; Bitušík et al. 2006). The studied middle part of the river lies in the submontane and colline belts of the Carpathians. Of the 24 study sites (see Fig. 1 and Appendix 1), the upper 22 are located in the Hron River valley within three volcanic mountain ranges (Kremnické vrchy, Štiavnické vrchy and Pohronský Inovec Mts.), and the lower two sites in the Podunajská nížina lowland. All sites cover the continuous 90-km watercourse between Sliač (altitude 300 m a. s. l., discharge 27 m^3. s^{-1}; Anonymous 2011) and Kozmálovce (altitude 175 m a. s. l., discharge 47 m^3. s^{-1}; Anonymous 2011; Fig. 1). The total water surface area was 144 ha, while the total area of 23 river sites with running water (including one reservoir with slowly running water, site no. 10; Fig. 1., Appendix 1) was 81 ha, and the area of one site with stagnant water (Kozmálovce reservoir) was 63 ha (site no. 23; Fig. 1, Appendix 1). The latter is the largest and most important wintering site of waterbirds within the study area (Krištín & Sárossy 2001, Veľký et al. 2005, Maďar 2015).

Data collection and analysis

Waterbirds (for the list of species of conservation concern see Wetlands International 2021) were surveyed once a year between 11 and 22 January. Each year the census was done by 3–4 observers (see Acknowledgements), walking individually along the banks of predefined sites. Binoculars (10 × 50) and a telescope (20–60 × 90) were used. The species composition, abundance and ice cover (% of frozen water surface) was recorded at each particular site at the time of survey.

We describe the number of species, the abundance of particular species (mean ± SD, maximum), as well as their relative abundance within the waterbird assemblage (%) and frequency of occurrence across 14 study years (%). We pooled data from all 24 study sites, and we also separately present the data from the site with stagnant water – the Kozmálovce reservoir (Appendix 1).

Abundance trends of wintering waterbirds in the period 2007–2020 were estimated using the TRIM 3.54. software (Pannekoek & Van Strien 2001), which is frequently used for evaluation of abundance changes within long-term bird monitoring programmes (e.g., Šťastný et al. 2004, Slabeyová et al. 2014, Sanz-Peréz et al. 2020). TRIM (log-linear time effects model) scales the trends as stable, moderate or strong decline/increase. The year 2007 was used as the reference level (i.e., 100% abundance) for evaluation of the relative changes of abundance in the following years. Trends in abundance were analysed separately only for the four most abundant species (Mallard, *Anas platyrhyn-*

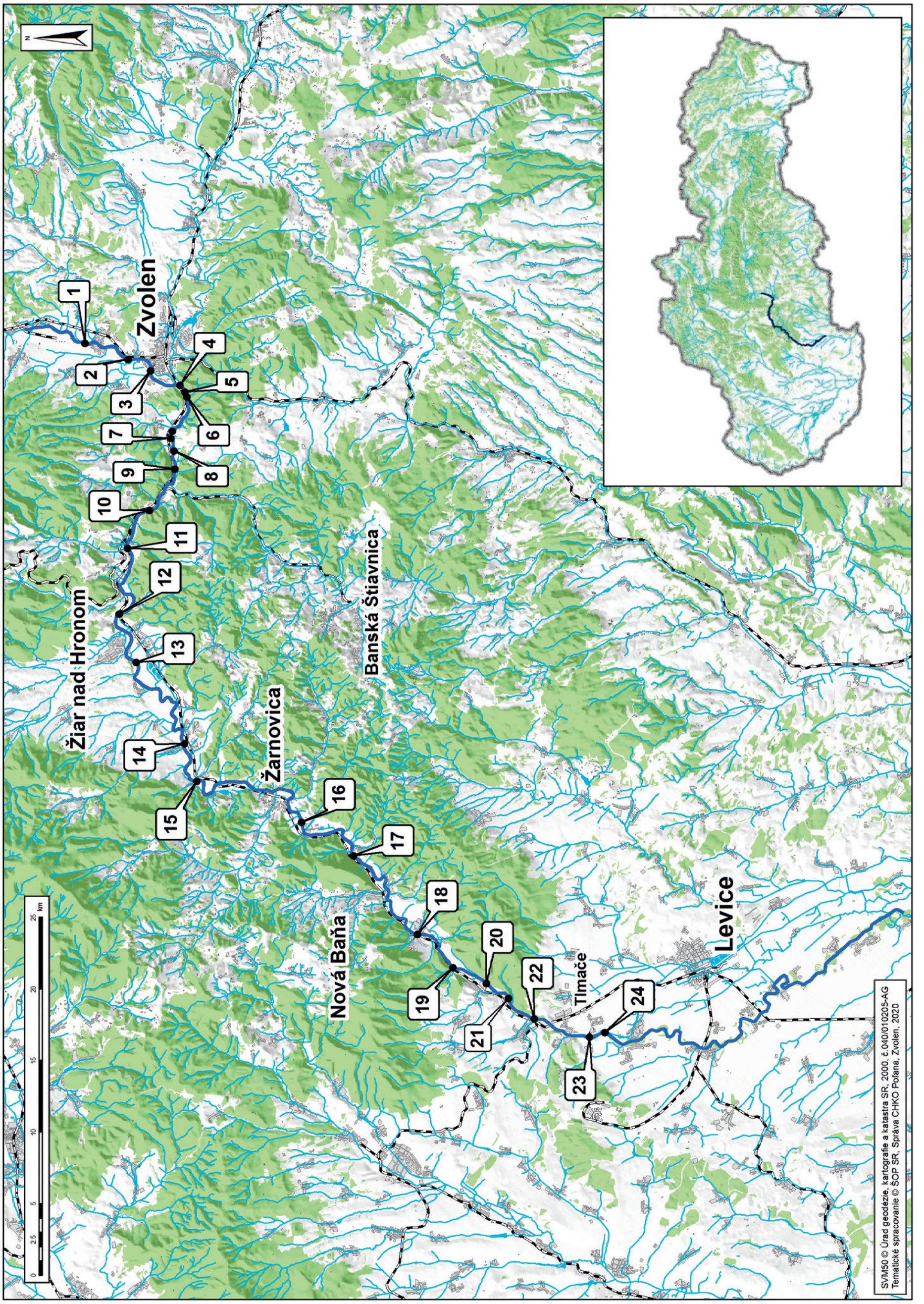


Fig. 1. Map of the study area and 24 census sites on the Hron River (central Slovakia). Site No. 23 is the only site with stagnant water, the Kozmálovce reservoir. For detailed position of the sites see Appendix 1. (source: Geodesy, Cartography and Cadastre Authority of the Slovak Republic, 2000).

Obr. 1. *Lokalizácia študovaného územia a 24 sledovaných lokalít na toku Hrona (stredné Slovensko). Lokalita č. 23 je vodná nádrž Kozmálovce. Detailná pozícia lokalít viď Príloha 1. (zdroj: Úrad geodézie, kartografie a katastra SR, 2000).*

chos, Great Cormorant, *Phalacrocorax carbo*, Common Merganser, and Grey Heron, *Ardea cinerea*), as the software could not determine clear trends (i.e., the outcome of the analysis was "uncertain trend") for species that were recorded irregularly and in small numbers. Yearly abundances of these four species found in all surveyed study sites were analysed. Moreover, the trend in the total abundance of the whole waterbird assemblage (pooled numbers of all species separately from all study sites) was also analysed. Detailed information on the TRIM program and model used is available at Pannekoek & Van Strien (2001) and Van Strien et al. (2001).

Correlation analysis (nonparametric Spearman's rank correlation coefficient) was used to evaluate the relationship between the ice cover and the abundance of a particular species or the total abundance of the whole waterbird assemblage in the period 2007–2020 (Table 2). Weighted yearly means of ice cover across study sites (the weight was the area of a site) and corresponding yearly values of abundance entered the analysis. The correlation analysis was carried out 1) for the whole study area (pooled data from all 24 sites), 2) for a subset of sites with running water (pooled data from 23 sites) and 3) for the site with stagnant water (Kozmálovce reservoir). The analysis was performed in Statistica version 7.0 (StatSoft®).

RESULTS

Species composition, abundance and frequency

Altogether, we recorded 25 waterbird species (Table 1, Appendix 2). Annually, we registered from eight (in 2013, 2014 and 2018) to 15 species (in 2016) with the yearly mean of 11.2 species.

Altogether, we counted 19,645 individuals. Annually, we recorded from 637 (in 2018) to 2,901 individuals (in 2012) with the yearly mean of 1,405 individuals (Appendix 2). The most abundant species were Mallard (86.4% of the total abundance of all species), Great Cormorant (8.7%), Common Merganser (1.6%) and Grey Heron (0.8%; Table 1). The 10 most abundant species covered

Table 1. Frequency of occurrence (%), abundance, and relative abundance (%) of wintering waterbirds at 24 sites on the Hron River in 2007–2020 (values in brackets come from the only site with stagnant water, the Kozmálovce reservoir). The species are ordered by relative abundance. For original data see Appendix 2.

Tab. 1. *Frekvencia výskytu (%), početnosť a dominancia (%) zimujúcich vodných vtákov na 24 lokalitách na rieke Hron (v zátvorkách sú dáta z jedinej lokality so stabilnou vodou, vodnej nádrže Kozmálovce) v rokoch 2007–2020. Poradie druhov je podľa dominancie. Originálne dáta viď Príloha 2.*

species / *druh*	frequency / *frekvencia*	abundance / *početnosť*			relative abundance / *dominancia*
		mean / *priemer*	SD	maximum	
Anas platyrhynchos	100 [78.6]	1212.1 [537.6]	533.3 [526.0]	2676 [1748]	84.6 [92.2]
Phalacrocorax carbo	100 [78.6]	121.6 [22.8]	58.7 [25.0]	267 [89]	8.7 [3.9]
Mergus merganser	93 [57.1]	21.9 [4]	21.2 [4.7]	67 [13]	1.6 [0.6]

species / *druh*	frequency / *frekvencia*	abundance / *početnosť*			relative abundance / *dominancia*
		mean / *priemer*	SD	maximum	
Ardea cinerea	100 [64.3]	12.3 [1.5]	7.3 [1.7]	27 [5]	0.9 [0.3]
Anas crecca	85.7 [14.3]	7.7 [0.2]	8.4 [0.6]	26 [2]	0.6 [<0.1]
Cygnus olor	78.6 [50]	7.4 [4.6]	10.7 [10.8]	41 [41]	0.5 [0.8]
Ardea alba	64.3 [35.7]	3.9 [1.9]	5.3 [4.8]	18 [18]	0.3 [0.3]
Bucephala clangula	50 [50]	3.4 [3.3]	4.4 [4.4]	12 [12]	0.2 [0.6]
Aythya ferina	28.6 [28.6]	1.8 [1.8]	3.8 [3.8]	13 [13]	0.1 [0.3]
Tachybaptus ruficollis	42.8 [14.3]	1.5 [0.4]	2.4 [0.9]	8 [3]	0.1 [<0.1]
Fulica atra	42.8 [21.4]	1.2 [0.6]	2.0 [1.6]	6 [6]	0.1 [0.1]
Larus michahellis	42.8 [35.7]	1.1 [1]	1.7 [1.6]	5 [5]	0.1 [0.2]
Alcedo atthis	71.4 [21.4]	1.1 [0.2]	1.1 [0.4]	4 [1]	0.1 [<0.1]
Motacilla cinerea	35.7 [14.3]	0.9 [0.2]	1.5 [0.6]	5 [2]	0.1 [<0.1]
Cinclus cinclus	78.6 [0]	1.9 [0]	1.4 [0]	5 [0]	0.1 [0]
Anser anser	7.1 [7.1]	1.6 [1.6]	6.1 [6.1]	23 [23]	0.1 [0.3]
Anser erythropus	7.1 [7.1]	0.1 [0.1]	0.5 [0.5]	2 [2]	<0.1 [<0.1]
Anser fabalis	7.1 [0]	0.3 [0]	1.1 [0]	4 [0]	<0.1 [0]
Mareca penelope	7.1 [0]	0.3 [0]	1.1 [0]	4 [0]	<0.1 [0]
Aythya fuligula	7.1 [7.1]	0.3 [0.3]	1.1 [1.1]	4 [4]	<0.1 [<0.1]
Mergellus albellus	7.1 [7.1]	0.1 [0.1]	0.3 [0.3]	1 [1]	<0.1 [<0.1]
Podiceps cristatus	14.3 [14.3]	0.3 [0.3]	0.8 [0.8]	3 [3]	<0.1 [<0.1]
Haliaeetus albicilla	14.3 [0]	0.2 [0]	0.6 [0]	2 [0]	<0.1 [0]
Larus canus	27.2 [21.4]	0.3 [0.3]	0.6 [0.6]	2 [2]	<0.1 [<0.1]
Larus cachinnans	14 [7.1]	0.1 [0.1]	0.4 [0.3]	1 [1]	<0.1 [<0.1]

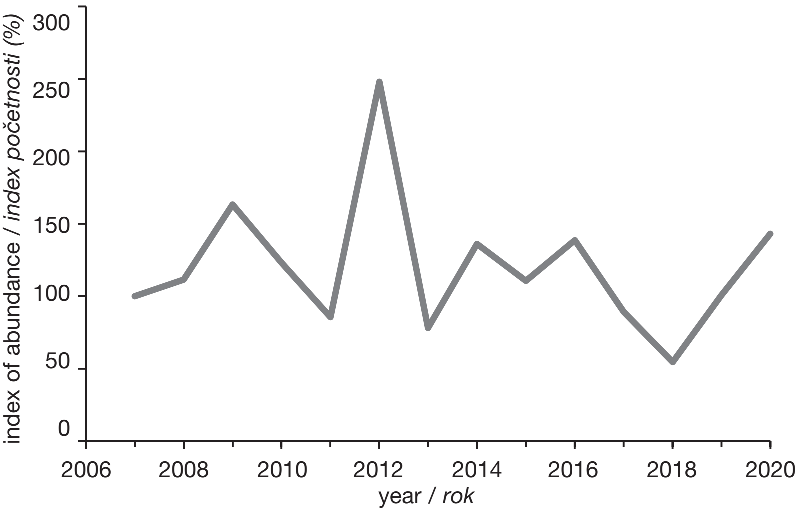


Fig. 2. Trends in numbers of all 25 recorded waterbird species on the middle Hron River in January 2007–2020. Time indices compared with the year 2007 are shown (using TRIM 3.54).
Obr. 2. *Trend početnosti všetkých 25 druhov vodných vtákov na strednom toku Hrona v januári 2007–2020. Zobrazené sú časové indexy v porovnaní s rokom 2007 (analyzované v programe TRIM 3.54).*

99.3% of the total abundance of all 25 registered species (Table 1, Appendix 2).

Total abundance of the whole waterbird assemblage was stable during the entire monitored period (Fig. 2). Of the four most abundant species that were analysed separately, the Mallard abundance was stable (Fig. 3a), the Great Cormorant abundance showed a moderate decline (Fig. 3b), while the trends in Common Merganser and Grey Heron were uncertain (Fig. 3c–d).

The most frequently recorded species were Mallard, Great Cormorant and Grey Heron (100% frequency of occurrence across 14 years) and Common Merganser (93%; Table 1, Appendix 2).

Effect of ice cover on abundance

In the entire study area (all 24 sites pooled), only the abundance of Common Goldeneye negatively correlated with the ice cover (Table 2). Within a subset of sites with running water, the abundance of Mallard and Mute Swan, as well as the total abundance of all 18 recorded waterbird species positively correlated with the ice cover (Table 2). At the site with stagnant water, we found a negative effect of ice cover on the abundance of Mallard, Common Merganser, Common Goldeneye, Great Cormorant and Grey Heron, as well as on the pooled abundance of the whole assemblage of 21 registered species (Table 2).

DISCUSSION

Species composition, abundance and frequency

Altogether, 25 waterbird species were recorded during the 14 mid-January counts on the middle Hron River, central Slovakia. Such a number of species represents one-third of all 75 waterbird species recorded in mid-January and 21% of all 119 waterbird species recorded during the winter seasons 2013/2014–2017/2018

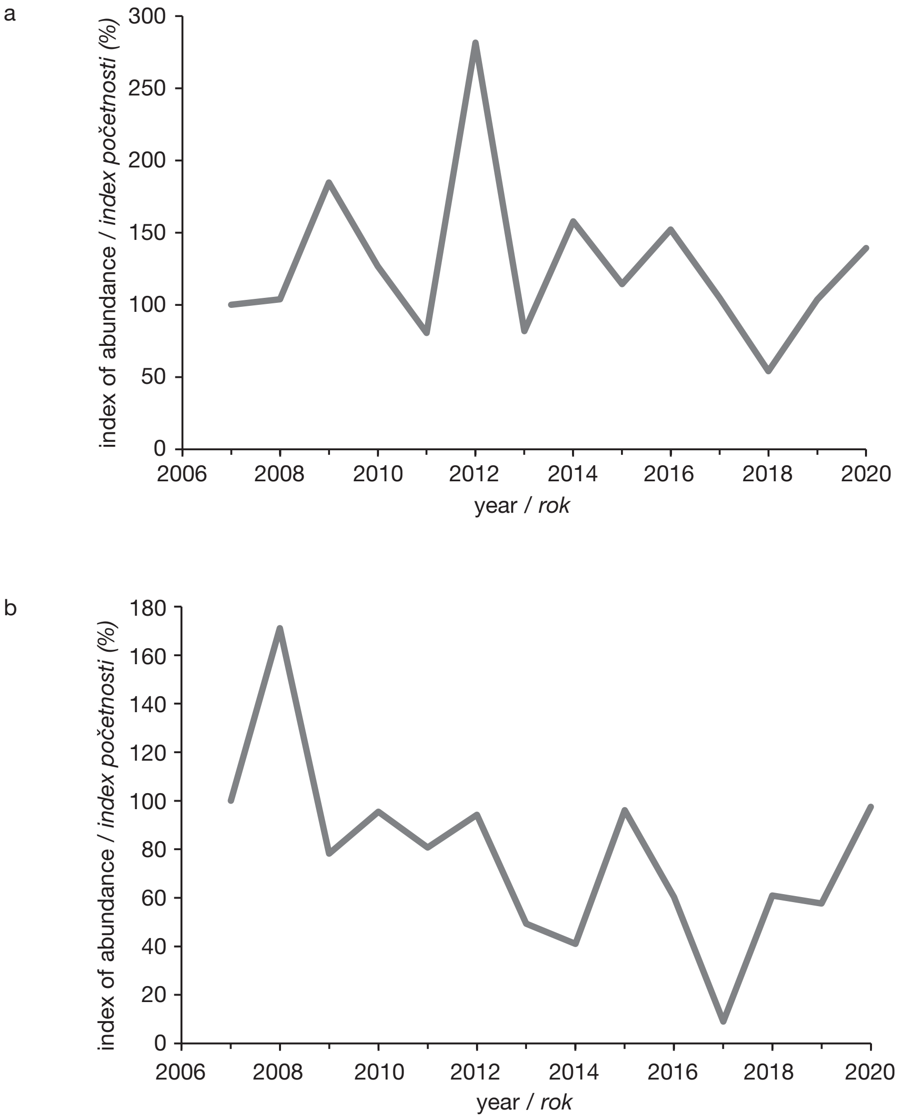
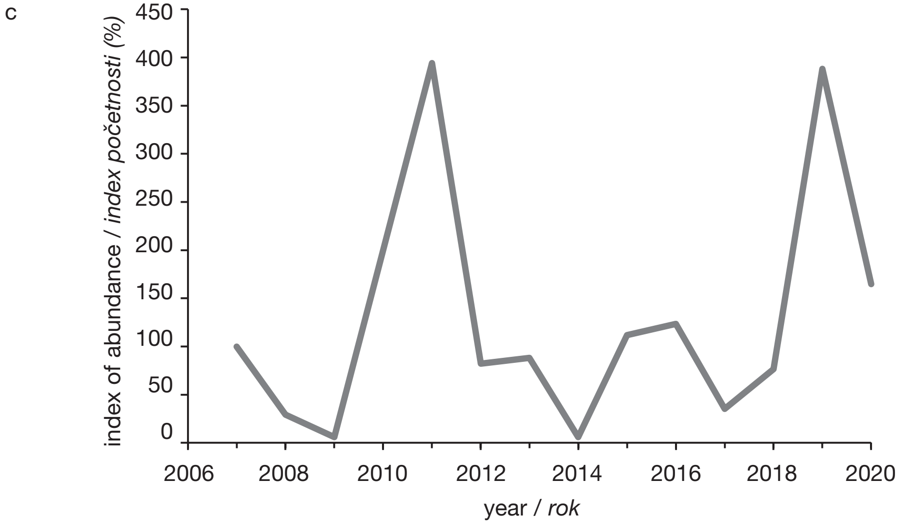
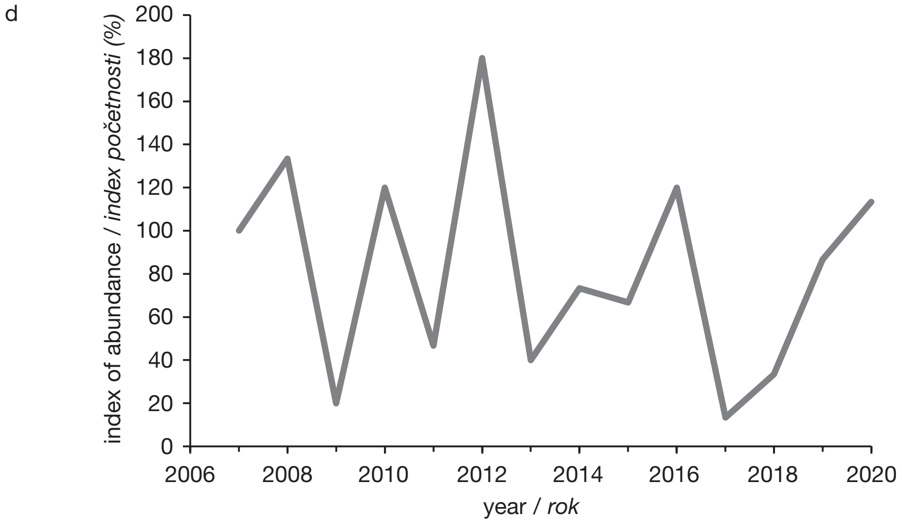


Fig. 3. Trends in numbers of the four most abundant waterbird species on the middle Hron River in January 2007–2020. Time indices compared with the year 2007 are shown (using TRIM 3.54): a) Mallard (*Anas platyrhynchos*), b) Great Cormorant (*Phalacrocorax carbo*), c) Common Merganser (*Mergus merganser*), d) Grey Heron (*Ardea cinerea*). (Continued on the next page.)

at ca 500 monitored sites in Slovakia (Baláž et al. 2020a).

The number of species recorded in the present study is similar to that found during a previous survey in the same study area in three winter seasons 2002/2003–2004/2005, when 30 waterbird species were found (Veľký et al. 2005). The higher species number in the previous survey, despite the shorter study period, can be explained by a longer counting season (November to March)





Obr. 3. *Trendy početnosti štyroch najpočetnejších druhov vodných vtákov na strednom toku Hrona v januári 2007–2020. Zobrazené sú časové indexy v porovnaní s rokom 2007 (analyzované v programe TRIM 3.54): a) kačica divá (*Anas platyrhynchos*), b) komorán veľký (*Phalacrocorax carbo*), c) potápač veľký (*Mergus merganser*), d) volavka popolavá (*Ardea cinerea*). (Pokračovanie z predchádzajúcej strany.)*

that covered some migrating taxa which do not regularly overwinter in the study area (e.g., Garganey, *Spatula querquedula*, or Charadriiformes). In both studies, the same three most abundant and frequent species were found (Mallard, Great Cormorant and Grey Heron; Veľký et al. 2005). For example, in a similar river area (30% smaller, 63 km long river section) in northern Slovakia (Váh River), 22 waterbird species were found in 2009–2016 (Baláž 2016).

Table 2. Spearman correlations of ice cover and abundance of 10 most abundant waterbird species and of pooled abundance of all recorded species at all 24 sites (144 ha), within the subset of 23 running river sites (81 ha) and at one site with stagnant water (the Kozmálovce reservoir, 63 ha) on the Hron River in 2007–2020. Only the species with the mean yearly abundance > 1.5 individuals were included. Significant results are shown in bold.
Tab. 2. *Spearmanove korelácie miery zamrznutia vodnej hladiny a početnosti 10 najpočetnejších druhov a všetkých druhov vodných vtákov na všetkých 24 lokalitách (144 ha), na 23 prúdivých úsekoch (81 ha) a na stabilnej vode (63 ha; vodná nádrž Kozmálovce) na rieke Hron v rokoch 2007–2020. Zahrnuté sú len druhy s priemernou ročnou abundanciou >1,5 jedinca. Štatisticky významné výsledky sú zvýraznené tučne.*

species / *druh*	all study sites / *všetky lokality*		running river sites / *prúdivé úseky*		stagnant water / *stabilná voda*	
	r_S	p	r_S	p	r_S	p
Anas platyrhynchos	0.19	0.511	**0.81**	**< 0.001**	–0.59	0.025
Phalacrocorax carbo	–0.20	0.501	0.04	0.899	**–0.69**	**0.006**
Mergus merganser	–0.46	0.100	–0.34	0.240	**–0.67**	**0.008**
Ardea cinerea	–0.10	0.729	–0.01	0.976	**–0.68**	**0.007**
Anas crecca	0.36	0.200	0.47	0.090	–0.42	0.132
Cygnus olor	0.19	0.519	**0.84**	**< 0.001**	–0.49	0.079
Ardea alba	0.13	0.660	0.40	0.157	–0.46	0.096
Bucephala clangula	**–0.68**	**0.007**	0.10	0.724	**–0.55**	**0.041**
Aythya ferina	–0.43	0.129	–	–	–0.38	0.185
Cinclus cinclus	0.36	0.209	0.42	0.140	–	–
all species / *všetky druhy*	0.13	0.646	**0.74**	**0.002**	**–0.62**	**0.017**

Altogether we counted 19,645 individuals in the entire study area (144 ha) during 14 years, with an annual mean of 1,405 individuals (extreme values 637–2,901). In a study carried out in northern Slovakia on the Váh River and Liptov area, covering a similarly sized area, a similar annual mean of waterbird abundance (1,500 individuals) with lower abundance extremes (1,009–1,989) was recorded in January 2009–2016 (Baláž 2016). Lower extremes found there can be explained by lower temperature extremes in the cooler Liptov area.

In the entire Slovakia in January 2014–2017 and 2018, respectively, altogether between 127,167 and 194,526 individuals were found in the particular years 2014–2017 (400–550 river and stagnant water sites monitored yearly) and 129,078 individuals in 2018 (664 sites) (Baláž et al. 2020b). In 2018 we recorded the minimum abundance on the Hron River (only 637 individuals), representing only 0.5% of all waterbirds counted in Slovakia.

In Slovakia, similarly as in the whole Europe (Wetlands International 2021), the Mallard is the most abundant wintering waterbird species with a stable long-term (1980–1999, resp. 1991–2018) abundance (Darolová & Krištín 2002, resp. Baláž et al. 2020a,b). For example, in the neighbouring Czech Republic, a moderate increase was found in 1966–2008 (Musil et al. 2011). On the Hron River, we found the mean yearly abundance of 1,212 individuals (2007–2020), with the relative abundance of 84.6%, which is comparable with a similar study area in northern Slovakia (Váh River), where the yearly mean abundance was 1,275 individuals and relative abundance 82.7% in the years 2009–2016 (Baláž 2016).

The Great Cormorant showed a steady increase in abundance in Central Europe and Slovakia in the winters 1980–2000 (Danko & Darolová 2002, Musil et al. 2011). A rapid growth of the wintering Great Cormorant abundance at the study area of the Hron River started in 1994–1999 (Krištín 1999, Zach 1999). However, we recorded a moderate decrease in Great Cormorant abundance in the present study (2007–2020) there. In the neighbouring Czech Republic, a significant site-specific increase in numbers was found over the long-term period of 1966–2015, caused mainly by a rapid increase of the European population numbers at the end of the 20th century (Musil et al. 2011, Musilová et al. 2018).

The abundance of the wintering Common Megranser increased on the middle Hron River at the beginning of the 21st century (Krištín & Sárossy 2001, Veľký et al. 2005), but in the studied 14 years no increase was confirmed. Regular wintering of the Common Merganser was followed by regular breeding occurrence on the middle-stream of the Hron River from 2004 and the breeding is related to the expansion of the Common Merganser's breeding area in the Central Europe in recent decades (Lešo & Kropil 2007, 2011, Hefti-Gautschi et al. 2009).

Effect of ice cover on abundance

The ice cover in the present study changed from year to year with maximum values recorded in 2008, 2013 and 2017, when the Kozmálovce site with stagnant water was completely frozen, and corresponding ice cover of the remaining sites with running water reached the mean values 60, 33, and 80%, respectively (Appendix 2). We found the opposite effects of ice cover on waterbird abundance between running and stagnant water. In the case of the stagnant water, we found a negative effect of ice cover, while in the running river sites there was a positive effect on the total abundance of all waterbird species and numbers of some abundant species. This difference in the effect of ice cover between running and stagnant water can be explained by moving of waterbirds to running river sites when the stagnant water becomes frozen, leading to a relatively stable abundance of waterbirds in the entire study area (cf. Musilová et al. 2015, Baláž 2016, Kajtoch et al. 2017). This result confirms the role of running, ice free river sites as "cold-weather refuges", i.e. sites where the selective pressures of winter harshness on bird abundance are reduced (Musilová et al. 2015).

The structure of wintering waterbird assemblages is highly affected by ice cover in different areas. Wintering waterbirds are unable to find enough food when water is covered with ice and have to migrate to areas/sites with ice-free water. For example, the proportion of diving waterbirds (Common Merganser and Common Goldeneye) on the running river sites in northern Slovakia was found to be positively associated with the amount of ice in water reservoirs (Baláž 2016, Baláž et al. 2018).

We assume that changes in the species composition of wintering waterbird assemblages and their abundance on the Hron River (as a region located at the edge of their wintering ranges) are related to their changes within the wider European area and are also affected by freezing of streams and reservoirs in northern Europe during cold winters (Adam et al. 2015, Musilová et al. 2015). Climate-driven changes in bird distributions and year-to-year south- or northwards shifts and fluctuations are currently ongoing and may be rapid (Maclean et al. 2008, Lehikoinen et al.

2013, Pavón-Jordán et al. 2019). It is thus important to continue with winter counts of waterbirds throughout the entire European latitudinal gradient.

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SÚHRN

Vodné vtáky sú významnými bioindikátormi mokradných habitatov. Ich početnosť a druhové zloženie je jedným z najčastejšie používaných kritérií na sledovanie zmien v prostredí, dopady klimatickej zmeny a ochranu významných mokradí (Wetlands International 2021). Pravidelné zimné sčítanie vodného vtáctva v rámci medzinárodného programu IWC (International Waterbird Census), zameraného na zistenie zmien distribúcie a početnosti druhov, sa od roku 1998 realizuje na regionálnej úrovni aj na strednom toku rieky Hron. Cieľom tejto práce bolo zistiť zmeny druhového zloženia a početnosti zimujúcich vodných vtákov a poznať vplyv zaľadnenia na početnosť druhov na strednom toku Hrona v januári 2007–2020. Študované územie (90 km toku medzi Sliačom a Kozmálovcami) pokrýva 24 lokalít (celkom 144 ha), z toho 23 prúdivých riečnych úsekov (63 ha; vrátane jednej prietokovej nádrže) a jednu vodnú nádrž so stabilnou hladinou vody (81 ha; obr. 1, príloha 1).

*Trendy početnosti zimujúcich vodných vtákov – stabilný, mierny alebo silný pokles/nárast – počas študovaných rokov boli hodnotené pomocou programu TRIM 3.54 (Pannekoek & Van Strien 2001). Rok 2007 bol použitý ako referenčný (100 % početnosť) pre hodnotenie zmien relatívnej početnosti v sledovaných rokoch. Trendy boli analyzované u štyroch najpočetnejších druhov: kačica divá (*Anas platyrhynchos*), kormorán veľký (*Phalacrocorax carbo*), potápač veľký (*Mergus merganser*) a volavka popolavá (*Ardea cinerea*), ako aj spolu u všetkých 25 zistených druhov.*

Na hodnotenie efektu ľadovej pokrývky (priemer z lokalít vážený ich plochou) na početnosť jednotlivých hodnotených druhov ako aj na celkovú početnosť vodných vtákov bol použitý Spearmanov korelačný koeficient. Efekt ľadovej pokrývky sa študoval na všetkých 24 lokalitách spolu a osobitne na stojatej vodnej nádrži Kozmálovce a na zvyšných 23 prúdivých riečnych úsekoch.

Celkom sme registrovali 25 druhov vodných vtákov (ročný priemer 11,2) a 19 645 jedincov (ročný priemer 1 405; tab. 1, príloha 2). Najpočetnejšími druhmi boli kačica divá (dominancia = 86,4 %), kormorán veľký (8,7 %), potápač veľký (1,6 %) a volavka popolavá (0,8 %; tab. 1). Počas študovaných 14 rokov početnosť signifikantne mierne klesala u kormorána veľkého, u kačice divej a celého zoskupenia 25 druhov bol trend stabilný, u zvyšných dvoch hodnotených druhov (potápač veľký a volavka popolavá) neurčitý (obr. 2, 3). Desať najpočetnejších druhov tvorilo 99,3 % početnosti zo všetkých 25 zistených vodných druhov vtákov.

V celom študovanom území (všetkých 24 lokalít spolu), sme zistili negatívnu koreláciu medzi ľadovou pokrývkou *a početnosťou len u hlaholky severskej (*Bucephala clangula*; tab. 2). Avšak, keď sme analyzovali efekt ľadovej pokrývky oddelene na 23 prúdivých lokalitách, zistili sme pozitívnu koreláciu ľadovej pokrývky a početnosti kačice divej a labute veľkej (*Cygnus olor*) ako aj celkovej početnosti všetkých 18 zistených druhov (tab. 2). Naopak, na lokalite stabilnej vody nádrže Kozmálovce, sme zistili negatívnu koreláciu ľadovej pokrývky a početnosti kačice divej, potápača veľkého, hlaholky severskej, kormorána veľkého a volavky popolavej, ako aj celkovej početnosti všetkých 21 zistených druhov (tab. 2). V práci diskutujeme možné vysvetlenia týchto rozdielov a podčiarkujeme význam tečúcich riečnych lokalít pre zimujúce vodné vtáctvo ako refúgií v chladných zimách v horských územiach Európy. Tieto opačné efekty ľadovej pokrývky na početnosť vodných vtákov na prúdiacej a stojatej vode vysvetľujeme klimaticky podmienenými presunmi medzi týmito typmi vôd, čo viedlo k relatívne stabilnej početnosti v celom študovanom území Hrona.*

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Appendix 1. Study sites on the middle Hron River (23 running river sections, including one reservoir with slowly running water *, and one stagnant water site – the Kozmálovce reservoir**); GPS coordinates of the centre of each particular site is given (GPS).
Príloha 1. *Prehľad študovaných lokalít na strednom Hrone (23 prúdivých riečnych úsekov, vrátane jednej vodnej nádrže s pomaly tečúcou vodou*, a vodná nádrž Kozmálovce so stabilnou vodou**). Uvedené sú súradnice stredu lokalít (GPS).*

ID	study site / *lokalita*	area / *plocha* (ha)	GPS N	GPS E
1	Sliač, port – bridge / *Sliač, prístavisko – most*	1.3	48°36'59.23"	19°08'25.09"
2	Sliač, bridge – Zvolen, bridge / *Sliač, most – Zvolen, most*	8	48°36'0.98"	19°07'51.49"
3	Zvolen, bridge – Kováčovský brook / *Zvolen, most – Kováčovský potok*	2	48°34'54.48"	19°07'13.10"
4	Zvolen SW, Slatina River / *Zvolen JZ, rieka Slatina*	0.6	48°33'57.01"	19°06'24.68"
5	Zvolen, Slatina River – Červ. medokýš / *Zvolen, Slatina – Červ. medokýš*	1.5	48°33'32.10"	19°06'06.53"
6	Zvolen, Červený medokýš	1.5	48°33'23.05"	19°05'25.2"
7	Budča, campsite / *Budča, vodácky kemp*	3.1	48°33'53.63"	19°03'49.09"
8	Budča, Ostrolúcky bridge / *Budča, Ostrolúcky most*	1.6	48°33'46.97"	19°02'41.63"
9	Budča, Ostrolúcky bridge – Hronská Dúbrava / *Budča, Ostrolúcky most – Hronská Dúbrava*	8.1	48°33'41.29"	19°01'47.25"
10	Hronská Dúbrava, hydropower station* / *Hronská Dúbrava, vodná elektráreň**	8	48°34'22.37"	18°59'20.15"
11	Hronská Dúbrava – Piteľová	3	48°35'14.27"	18°57'12.23"
12	Šášov – Žiar nad Hronom	1.5	48°35'27.58"	18°53'2.64"
13	Žiar nad Hronom – Lovča	3.3	48°34'28.81"	18°49'59.95"
14	Dolná Ždaňa, bridge / *Dolná Ždaňa, most*	2	48°32'30.36"	18°46'14.39"
15	Záhorce, bridge / *Záhorce, most*	6	48°30'51.22"	18°44'12.16"
16	Voznica	1.8	48°27'44.82"	18°41'36.58"
17	Voznica – Nová Baňa	5	48°26'7.32"	18°41'23.45"
18	Tekovská Breznica – Orovnica	6	48°22'22.04"	18°35'55.77"
19	Hronský Beňadik, bridge (R1) / *Hronský Beňadik, most (R1)*	4	48°21'44.92"	18°34'45.97"
20	Hronský Beňadik (Slovnaft)	2.3	48°20'17.34"	18°33'45.70"
21	Psiare	6	48°19'43.80"	18°33'29.90"
22	Kozárovce	2	48°18'34.17"	18°32'14.30"
23	Kozmálovce reservoir** / *Kozmálovce, vodná nádrž***	63	48°16'42.33"	18°31'31.46"
24	Kozmálovce south / *Kozmálovce juh*	2.5	48°16'0.13"	18°31'47.15"

Appendix 2. Species composition and abundance of wintering waterbirds and ice cover (%; means weighted by the particular site area) on the Hron River in January 2007–2020. Pooled data from all 24 study sites (values in brackets come from the Kozmálovce reservoir).
Príloha 2. *Druhové zloženie a početnosť zimujúcich vodných vtákov a miera zaľadnenia (%; priemery vážené plochou jednotlivých lokalít) na Hrone v januári 2007–2020. Zlúčené dáta zo všetkých 24 lokalít (v zátvorkách sú dáta z vodnej nádrže Kozmálovce).*

species / *druh*	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Anas	950	987	1756	1205	765	2676	778	1499	1086	1446	997	514	985	1325
platyrhynchos	[410]	[0]	[1010]	[482]	[272]	[1748]	[0]	[1047]	[627]	[778]	[0]	[137]	[26]	[990]
Phalacrocorax	156	267	122	149	126	147	77	64	150	94	14	95	90	152
carbo	[7]	[0]	[45]	[36]	[11]	[11]	[0]	[24]	[44]	[28]	[0]	[24]	[0]	[89]
Mergus	17	5	1	34	67	14	15		19	21	6	13	66	28
merganser	[6]	[0]	[0]	[9]	[13]	[2]	[0]		[8]	[3]	[0]	[3]	[0]	[12]
Ardea	15	20	3	18	7	27	6	11	10	18	2	5	13	17
cinerea	[3]	[0]	[0]	[1]	[1]	[5]	[0]	[2]	[1]	[5]	[0]	[1]	[0]	[2]
Anas	8	3	13	9	1	8	26	1		10	1		4	24
crecca	[0]	[0]	[0]	[0]	[1]	[0]	[0]	[0]		[2]	[0]		[0]	[0]
Cygnus	3	4	7		7	4	7		5	7	17		1	41
olor	[1]	[0]	[3]		[7]	[0]	[0]		[5]	[7]	[0]		[1]	[41]
Ardea		3	1	8	1	5				7	1		10	18
alba		[0]	[0]	[4]	[1]	[1]				[2]	[0]		[0]	[18]
Bucephala	4			8	12	4			12	5		2		
clangula	[4]			[7]	[12]	[4]			[12]	[5]		[2]		
Aythya	13				7			4	1					
ferina	[13]				[7]			[4]	[1]					
Tachybaptus		5	2			2		8		2	2			
ruficollis		[0]	[0]			[0]		[3]		[2]	[0]			
Fulica		5	1	3	1					1				6
atra		[0]	[0]	[2]	[1]					[0]				[6]
Larus				1	1	5		3	4			2		
michahellis				[1]	[0]	[5]		[3]	[3]			[2]		
Alcedo		1		1	1	3	1	1	1	1			1	4
atthis		[0]		[1]	[0]	[0]	[0]	[1]	[0]	[0]			[0]	[1]
Motacilla		2	1	1	3					5				
cinerea		[0]	[0]	[0]	[2]					[1]				
Cinclus		2	3	2		5	2		2	1	2	2	2	3
cinclus		[0]	[0]	[0]		[0]	[0]		[0]	[0]	[0]	[0]	[0]	[0]
Anser														23
anser														[23]
Anser														2
erythropus														[2]
Anser												4		
fabalis												[0]		
Mareca													4	
penelope													[0]	
Aythya	4													
fuligula	[4]													

species / *druh*	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Mergellus albellus				1 [1]										
Podiceps cristatus	1 [1]													3 [3]
Haliaeetus albicilla										2 [0]			1 [0]	
Larus canus					1 [1]	1 [1]			2 [2]					
Larus cachinnans										1 [1]	1 [0]			
no. of individuals / *počet jedincov*	1171 [449]	1304 [0]	1910 [1058]	1440 [544]	1000 [329]	2901 [1777]	912 [0]	1591 [1084]	1292 [703]	1621 [834]	1043 [0]	637 [169]	1177 [27]	1646 [1187]
no. of species / *počet druhov*	10 [9]	12 [0]	11 [3]	13 [10]	14 [12]	13 [8]	8 [0]	8 [7]	11 [9]	15 [11]	10 [0]	8 [6]	11 [2]	13 [11]
ice cover (%) / *miera zaľadnenia*	8 [10]	63 [100]	82 [70]	12 [5]	0 [0]	13 [5]	34 [100]	1 [0]	0 [0]	0 [0]	95 [100]	0 [0]	9 [98]	1 [0]