Waterbird counts on large water bodies: comparing ground and aerial methods during different ice conditions

Dominik Marchowski Corresp., [1] , **Łukasz Jankowiak** [2] , **Łukasz Ławicki** [3] , **Dariusz Wysocki** [2]

[1] Ornithological Station, Museum and Institute of Zoology, Polish Academy of Science, Gdańsk, Polsand
[2] Department of Vertebrate Zoology and Anthropology, Faculty of Biology, Szczecin University, Szczecin, Poland
[3] West Pomeranian Nature Society, Szczecin, Poland

Corresponding Author: Dominik Marchowski
Email address: dominikm@miiz.waw.pl

The paper compares the aerial and ground methods of counting birds in a coastal area during different ice conditions. Ice coverage of waters was the most important factor affecting the results of the two methods. When the water was ice-free, more birds were counted from the ground, whereas during ice conditions, higher numbers were obtained from the air. In ice-free conditions the group of waterbirds with the smallest difference between the two methods (< 6%) contained six species: Greater Scaup, Smew, Mute Swan, Goosander, Common Goldeneye and Tufted Duck; the group with a moderate difference (15%-45%) included another six species: Eurasian Coot, Whooper Swan, Mallard, Eurasian Wigeon, Great Crested Grebe and Common Pochard; while the group with a large difference (> 68%) included five species, all of the genus Anas: Gadwall, Eurasian Teal, Northern Shoveler, Northern Pintail and Garganey. In ice conditions, smaller numbers of most species were counted from the ground, except for Mallard, where the difference between two methods was small (7.5%). Under ice-free conditions, both methods can be used interchangeably for the most numerous birds occupying open water without any great impact on the results. When water areas are frozen over, air counts are preferable as the results are more accurate. The cost analysis shows that a survey carried out by volunteer observers (reimbursement of travel expenses only) from the land is 58% cheaper, but if the observers are paid, then the aerial survey is 40% more economical.

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Dominik Marchowski[1*], Łukasz Jankowiak[2], Łukasz Ławicki[3], Dariusz Wysocki[2]

[1] Ornithological Station, Museum and Institute of Zoology, Polish Academy of Science. Nadwiślańska 108, 80-680 Gdańsk, Poland

[2] Department of Vertebrate Zoology and Anthropology, Faculty of Biology, Szczecin University. Wąska 13, 71-415, Szczecin, Poland

[3] West Pomeranian Nature Society. Wąska 13, 71-415, Szczecin, Poland

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[*]Corresponding author: dominikm@miiz.waw.pl

Abstract

The paper compares the aerial and ground methods of counting birds in a coastal area during different ice conditions. Ice coverage of waters was the most important factor affecting the results of the two methods. When the water was ice-free, more birds were counted from the ground, whereas during ice conditions, higher numbers were obtained from the air. In ice-free conditions the group of waterbirds with the smallest difference between the two methods (< 6%) contained six species: Greater Scaup, Smew, Mute Swan, Goosander, Common Goldeneye and Tufted Duck; the group with a moderate difference (15%-45%) included another six species: Eurasian Coot, Whooper Swan, Mallard, Eurasian Wigeon, Great Crested Grebe and Common Pochard; while the group with a large difference (> 68%) included five species, all of the genus *Anas*: Gadwall, Eurasian Teal, Northern Shoveler, Northern Pintail and Garganey. In ice conditions, smaller numbers of most species were counted from the ground, except for Mallard, where the difference between two methods was small (7.5%). Under ice-free conditions, both methods can be used interchangeably for the most numerous birds occupying open water without any great impact on the results. When water areas are frozen over, air counts are preferable as the results are more accurate. The cost analysis shows that a survey carried out by volunteer observers (reimbursement of travel expenses only) from the land is 58% cheaper, but if the observers are paid, then the aerial survey is 40% more economical.

Introduction

Waterbirds are well-known indicators of the quality of aquatic environments. If a given site holds 1% or more of the flyway population of a given species, we say that this area is important for this population. A flyway is a flight path used in bird migration (Boere and Stroud 2006) and a flyway population is the number of individuals of a given species included in a given flyway area. The 1% criterion is used to qualify an area as a wetland of international importance under the Ramsar Convention on Wetlands and by the European Union to identify Special Protection Areas (SPAs) under the Birds Directive. It is also used by BirdLife International for identifying Important Bird Areas (IBAs) on wetlands worldwide (BirdLife International 2004, 2015; Wetland International 2010). Counting waterbirds on large open water areas, like marine areas, coastal lagoons and large lakes, is challenging, but accurate counts are critical for estimating population sizes. Different methods have been used to conduct censuses of birds in these open-water environments. Depending on the local conditions, there are three main census methods: counting from the ground, aircraft, or boats (Komdeur et al. 1992; Wetland International 2010). Results of censuses carried out by different methods are widely used in species population estimates over larger areas like the Baltic Sea (e.g. Skov et al. 2011; Aunis et al. 2013) or for the whole flyway population of species (Wetland International 2018). They are the basis for determining trends in species' abundances, which in turn affect conservation activities (e.g. Jensen et al. 2009). Some studies made the assumption that aircraft counts detected 85% of birds (Johnson et al. 1989). The accuracies of different field protocols for counting birds were tested at different locations (e.g. Briggs et al. 1985; Smith 1995; Frederick et al 1996; Kingsford 1999; Frederick et al. 2003; Green et al. 2008). Some papers on non-breeding populations compared the results of air and ground counts in Australia (Kingsford and Porter 2009), on tidal sea coasts on the Wadden Sea in Denmark

(Laursen et al. 2008) and Germany (Scheiffarth and Backer 2008), and in the Poyang Basin in China (Fawen et al. 2011), but they did not take ice coverage into account. This is a particularly important factor, considering that a large proportion of waterbird species overwinter in areas around the mid-winter 0˚C isotherm (van Erden and de Leeuw 2010.). Thus, relatively small variations in temperature significantly affect the conditions in which counting is undertaken. Like many other important Baltic bird wintering sites, our study area lies on the mid-winter 0°C isotherm. The Baltic Sea as a whole is the most important wintering area for waterfowl anywhere in the Western Palearctic (Durinck et al. 1996). Although birds originating from breeding grounds situated in the vast expanses of northern Europe and Asia congregate on the Baltic Sea during the winter, they are not evenly spread: there are few or no birds at all in some areas, but huge numbers of them in others (Skov et al. 2011). These latter 'hot spots' are in shallows on the open sea or in the estuaries of rivers where food, mainly mussels and fish, is plentiful (Ławicki et al. 2012; Marchowski et al. 2015). It happens that a significant percentage of the entire population of a species gathers in a few such optimal places: for example, 14% of the entire Greater Scaup population regularly overwinters in the Odra estuary (Marchowski et al. 2017). In the context of climate warming and the related northward and eastward shifts in the wintering range of waterbirds (Lehikoinen et al. 2013; Marchowski et al. 2017), the importance of the Baltic Sea as a wintering area for this group of birds is now far greater than just a few decades ago (Skov et al., 2011).

The investigation of such dynamic ecological processes requires precise research methods. Here, we compare two standard methods of counting birds (from an aircraft and from the ground) under different weather conditions in parts of the south-western Baltic Sea where very large numbers of waterbirds congregate. The specific aim is to test the accuracy of air counts vs. ground counts of waterbirds. Our study area is a key staging and wintering site for significant numbers of a few species of waterbirds from the NW Europe – W Siberia flyway, principally Greater Scaup *Aythya marila*, Smew *Mergellus albellus* and Goosander *Mergus merganser*. Other species, such as Common Pochard *A. ferina*, Tufted Duck *A. fuligula*, Common Goldeneye *Bucephala clangula*, Eurasian Coot *Fulica atra* and Great Crested Grebe *Podiceps cristatus* are also present in significant numbers (Ławicki et al. 2008, Marchowski & Ławicki 2011, 2012, Marchowski et al. 2013).

Although methodological publications mention the high cost of aerial surveys (e.g. Wetland International 2010; Meissner 2011), they do not make any specific calculations. Very few analyses compare the cost of air and ground counts; those that have been performed concern other geographical regions and are out of date (e.g. Kingsford 1999). Bird counts used for large-scale population estimates often rely on the work of volunteers (Wetland International 2010). This significantly reduces costs, which are limited to the reimbursement of travel costs to the surveyed area. In this article we carry out a cost-benefit comparison of the count method (air, ground) and the payment method (volunteering, paid service). This analysis relates to Poland: the financial outlay in other countries will obviously vary, depending on local labour and fuel costs, but the proportions may well be similar and thus more universal.

We pose the following research questions: 1) Which of the tested methods gives more accurate counts, and does this depend on ice cover and species? 2) Which method is the more effective and methodologically correct in the context of the financial outlay and ice conditions? Our hypotheses are that: 1) the overall result of a bird count in ice-free conditions is higher from the ground than from the air; 2) the overall result of a bird count in ice conditions is higher from the air than from the ground; 3) the difference in the counts between the two methods is greater during ice conditions; 4) some species are more sensitive to different census methodologies than others; 5) regardless of the payment method and ice conditions, an aerial survey is the most economical, methodologically justified form of censusing birds.

Material and methods

Study area

The study area lies in the south-western part of the Baltic Sea and forms the Polish part of the Odra River Estuary system. It covers a total area of 530 km^2 and includes the Great Lagoon (the Polish part of the Szczecin Lagoon), Świna Backward Delta, Kamień Lagoon, Dziwna Strait and Lake Dąbie (Fig. 1). The average and maximum depths of the Lagoon are 3.8 and 8.5 m, respectively (the dredged shipping lane cutting across the Lagoon from Baltic Sea to the port of Szczecin is 10.5 m deep). The waters of the Szczecin Lagoon, Kamień Lagoon and Lake Dąbie are brackish. The salinity in the central part of the Lagoon varies from 0.3 psu to 4.5 psu (mean = 1.4 psu) and declines with increasing distance from the sea. Periodic inflows of water from the Pomeranian Bay (salinity ~7 psu) take place through the Świna Strait and, to a lesser extent, through the Dziwna and Peene Straits (the latter in the German part of the estuary). The Odra estuary is subject to strong anthropogenic pressure, which is manifested by a high level of eutrophication (Radziejewska and Schernewski 2008).

Counts

We conducted ten aerial counts in parallel with ten ground counts in the non-breeding period during 2009-2014 (see S3 table for the raw data). Here we consider the following taxa: Great Crested Grebe, Eurasian Coot and Anatidae (Ducks, Geese and Swans). No observations were made during extreme weather conditions (heavy rain, wind, strong wave action). When referring to the census method, we sometimes use the term ‘platform’. All count results were raw data: numbers were not processed by any calculations, such as distance analysis. We used 'total count' methods with both platforms and compared the results obtained with both. Air and ground counts took place on the same day. This 'total count' method was also used in other studies (Joasen 1968, Savard 1982, Kingsford 1999, Voslamber and van Turnhout 1999, and Laursen et al. 2008). The same team of 17 trained and experienced observers was involved in all the counts. The research involved observing birds from a distance so as not to disturb the birds. In Poland, such studies do not require a special permit. As a whole area where we conducted the survey is freely accessible to the public, there was no need for special permit.

Aerial counts

A slow-flying, high-wing aeroplane was used for the aerial counts. Two observers identified and counted birds on both sides of the aircraft. The average flight speed was about 100 km/h and the average flying height was about 80 m above the water. This gave a roughly 1500 m wide band within which birds could be recorded. The flight route was designed to cover as much of the water surface as possible; we estimated that coverage was thus approximately 90% of the area surveyed. Only the birds in a very small part of the middle of the Szczecin Lagoon (the largest water body in the survey area - see fig. 1) were not counted: we knew from previous field experience that birds rarely used that area if at all. The aircraft took off from the Szczecin Aeroklub airfield in Szczecin Dąbie (Fig. 1), and then flew over Lake Dąbie, the Szczecin Lagoon, Kamień Pomorski and Świnoujście (Fig. 1). We used the same flight route for all the aerial surveys (Fig. 1). The detailed procedure for our research is described in Komdeur et al. (1992).

Ground counts

Ground counts were usually done on foot, although cars were also involved. Each observer was equipped with 10x40 or 10x50 binoculars and tripod-mounted telescopes with variable magnification, usually 20-60x. During the counts, observers walked along the same routes, stopping every few hundred metres to scan the area with binoculars and/or telescope and then count the birds. Alternatively, counts were conducted from vantage points accessible by car (Fig. 1). We used the most advantageous vantage points and routes, dividing the study area up into areas that were visible from such points or routes so that no counted areas overlapped and no parts of the study area were overlooked. All the counts were carried out from the same routes and observation points.

Statistical analysis

We used the generalized linear mixed-effect model (GLMM) to analyse the relationship between the results of the aerial and ground counts, as it enabled repetitiveness between subjects to be accounted for. The number of birds of a target species was the dependent variable, and species identities were the subject variables in the model. To check how the different counts of particular species and the changes in these numbers were affected by the two counting methods and the presence of ice, we applied two random effects – species (random intercept) and the ice*method interaction (random slope model). Because of the high overdispersion of the dependent variable, we used the negative binomial distribution with an identity link function. The occurrence of ice (1 – over 70% of surface covered by ice, 0 – no ice observed – see S3 table for details) and count type (Aircraft/Ground) were treated as categorical fixed effects. The mixed model was fitted using maximum likelihood. The statistics were performed using IBM SPSS Statistic version 20 software. The results were considered statistically significant for $P < 0.05$.

Results

All birds together

There were more birds during ice-free conditions (all species together and the aggregate number of all individuals, Fig 2 D). The numbers obtained from ground counts in such conditions were higher than from aerial ones, but the difference was not great (10%, see Table 1). During ice conditions, the overall number of birds was lower than when the water was free of ice, and the difference between the two census methods was much higher (50%, see Table 1). We found a significant interaction between the effect of count method and ice occurrence (Table 1). This indicates that when ice coverage was high, more birds were counted during aerial surveys than ground surveys, whereas when the water was ice-free, more birds were counted from the ground (Figure 2 D).

Species and groups of species

The method-related difference during ice conditions was considerable (Table 1), except in the case of Mallard (Fig 2A). When waters were free of ice, ground counts were generally higher. In only two cases were the results slightly higher from the air: the differences relating to Greater Scaup and Smew were 0.2% and 1.5% respectively (Fig 2, S1. Table). Greater Scaup must be considered in the broader context of the whole *Aythya* genus. A higher air count result is a consequence of the greater efficiency of species identification using this method. Hence, if we consider all the *Aythya* species together, i.e. *Aythya sp*. + *A. marila* + *A. ferina* + *A. fuligula*, the difference is slightly greater (2.8%), but the numbers are still higher from the ground than from the air, as they are for most species (Fig. 2, S1 Table).

The general range of differences for ice-free waters varied from 0.2% (Greater Scaup) to 93.6% (Pintail *Anas acuta*) (Fig. 2, S1 Table). Species with low levels of difference between the two counting methods, i.e. < 6% (0.2% to 5.5%), were: Greater Scaup, Smew, Mute Swan *Cygnus olor*, Goosander, Goldeneye and Tufted Duck. Species with a moderate difference level (15.0%-

45.0%) were placed in the next group: Coot *Fulica atra*, Whooper Swan *Cygnus cygnus*, Mallard, Wigeon *Anas penelope*, Great Crested Grebe and Pochard. Dabbling ducks (Gadwall *A. strepera,* Teal *A. crecca,* Shoveler *A. clypeata* and Pintail *A. acuta*) were the only group with a high level of difference (> 68.0%). Garganey *Anas querquedula* was detected only from the ground; as this species was generally rare during the counts, we did not include it in our calculations.

In ice conditions, only one species (Mallard) displayed a moderately small difference between the aerial and ground results (7.5%, see also Fig 2A). The other species in such conditions exhibited moderate to high differences – from 34.4% to 582.9% – and a very wide disparity in differences between species of a similar size and behaviour (e.g. Tufted Duck – 64.6% and Greater Scaup – 582.9%; see Fig. 2).

Cost estimate

All the counts for this study were carried out by volunteers; some persons even waived the reimbursement of travel costs to the counting site. The costs involved in this study were low – limited to the hiring fee for the aircraft and part of the fuel costs for ground observers' cars. They were even lower than the following calculations in relation to volunteers. However, if we include the fuel cost for all observers and the cost of aircraft hire, we obtain the real overall cost of voluntary counts. Reimbursing the twelve observers involved in the counting for their fuel outlay amounts to around 300 € and the aircraft hire fee is 720 €. The study area covers 530 km² and the coastline is 340 km long, so the cost of an air count is 136 € for 100 km² of a water body and 212 € for 100 km of coastline if the count is carried out by volunteers. The ground count costs are 57 €/100km² and 88 €/100km of coastline. If the observers are paid for their services, the costs increase to 1400 € for an air count and 2300 € for a ground count (see table 2 for details). These figures cover only the labour costs in the field and do not include the costs of subsequent processing and data analysis.

Regardless of the payment method and ice conditions, air counts are the more economical and methodologically justified technique. For core species, the results obtained from an aircraft are acceptable; better results are obtained from an aircraft when the water is ice-covered. There is only one disadvantage of an aerial count – it is slightly more expensive than the ground method if the observers are volunteers.

Discussion

The major factor influencing census results was ice cover. During ice-free conditions, ground counts gave better results than aerial ones. When ice was present, more birds were counted from the air, and the difference between the two methods was much greater than in ice-free conditions. This discrepancy shows clearly the importance of ice coverage on the water in impacting survey results in relation to the survey method. Taking all species together, we can state that it does not really matter which censusing method is used during ice-free conditions as the counts are not specially affected by this; the two methods can thus be used interchangeably. Similar conclusions were reached by Kingsford et al. (2008) in Australia, where the correlation of results from the land and from the air was highly significant. The results of air and ground counts also differed little in the Poyang Basin in China (Fawen et al. 2009).

In contrast, once there is significant ice cover of the waters (above 70%), the survey method does become important; this has not been demonstrated before. Our aerial census results under such conditions gave a much better indication of the real number of birds, whereas the ground surveys underestimated bird numbers. Wetland International (2010) recommends the aerial method in areas covered (incompletely) by ice but does not underpin this assertion with any concrete results; our work supports it. Again, in Australia, there are similarities, such as poorly-accessible lakes such as Lake Illawarra and Norring Lake, where aerial counts yielded much higher numbers of birds than ground ones (50.1% and 101.5% respectively; Kingsford et al. 2008). The similarity lies in the lack of access or visibility from the land of sites where significant numbers of birds congregate.

The differences in the results varied over a very wide range – from nearly identical, i.e. 0.2% for Greater Scaup under ice-free conditions, to 582.9%, also for Greater Scaup but in ice conditions. This very considerable difference under ice conditions in the case of Greater Scaup emerges from this species' preference to concentrate in a few places, i.e. in ice-free areas usually far from the shore (Johnsgard 1978; Mendel et al. 2008). During ice conditions, several thousand Greater Scaup have been recorded from aircraft in ice-free patches of water inaccessible and invisible to ground observers. . Visibility from the land in ice conditions is often difficult because piles of ice protrude above the waterline, a problem that ceases to exist when counting from the air. The much lower difference with regard to the (sympatric to Scaup) Tufted Duck is due to the tendency of this species to occupy anthropogenic sites like ports and harbours when ice covers more open sea areas (Jakubas 2003), as does Mallard (Meissner et al. 2015); they are thus more easily detected by ground observers. In ice conditions the numbers of most species were higher when counted from the air, Mallard being the exception. We recommend aerial surveys when waters are frozen over. Even if, as seen from the land, the entire water body appears to be frozen, from the air we can still find unfrozen patches, which are occupied by many birds.

The opposite situation prevails when waters are free of ice: ground count numbers are then generally higher. This corresponds with most papers on this topic, in which ice conditions were either not analysed or did not exist (e.g. Pollock and Kendall 1987, Kingsford 1999, Laursen et al. 2008). If we take into account particular species of birds, comparable results under ice-free conditions can be obtained by both methods with respect to the following species: Greater Scaup (difference 0.2%), Smew (1.5%), Mute Swan (3.9%), Goosander (4.9%), Common Goldeneye (5.3%) and Tufted Duck (5.5%); the differences are also acceptable regarding Eurasian Coot (15.6%) and Whooper Swan (16.3%) (see Supplementary materials (S1 Table)). These are the most numerous species of waterbirds in the study area and they make up the core of the waterbird community here. Our recommendation is that both methods can be used interchangeably in ice-free conditions for counting these species. Moreover, in ice-free conditions, comparable results are obtained for numerous birds occupying the open water. We can generalize that diving ducks (*Aythya, Mergus, Mergellus*, *Bucephala*) swans (*Cygnus*) and coots (*Fulica*) can be counted from the air without any significant differences between the methods. The differences between count numbers are higher for the less numerous birds occupying abundantly vegetated near-shore areas, so we do not recommend surveying these species from the air. Generally speaking, this applies to dabbling ducks (*Anatini*): here there are significant differences between the methods, with aerial counts being underestimated (see S1 Table for more details).

The most economical form of counting is to use volunteer observers on the ground: this is the method most commonly used in our study area. The disadvantage of this approach, however, is that we need a large group of qualified people equipped with good optical equipment who will not get paid for their services. This condition cannot always be met. Counting from an aircraft requires only two people and, assuming that they will not get paid for their services, the costs are also not high, but still 58% higher than for a ground count. If the observers are paid, then the aircraft method will be the most cost-effective: only two qualified people are needed and the cost is 40% less than for all the persons involved in a ground count (Table 2). In addition, aerial surveys can be used in both ice-free and ice conditions. The present calculation of costs relates to conditions in Poland; in other countries, costs will vary depending on local labour and fuel costs, but the proportions should be similar.

Conclusions

Overall, more birds are counted from the ground than from the air in ice-free conditions. But in ice conditions, the overall results of bird counts are higher from the air than from the ground. The differences in counts between the two methods are higher during ice conditions. In ice-free conditions, the results from both platforms for numerous birds occupying open water are comparable. In the same conditions there are significant differences between the methods as regards dabbling ducks (*Anatini*) – aerial counts underestimate their numbers.

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Literature Cited

Aunins A., Nilsson L., Hario M., Garthe S., Dagys M., Pedersen I.K., Skov H., Lehikoinen A., Roos M.M., Ranft S., Stipniece A., Luigujoe L., Kuresoo A., Meissner W., Korpinen S. 2013. HELCOM Core Indicator Report. Retrieved from http://www.helcom.fi/ on 23 October 2016.

BirdLife International. 2004. Birds in Europe, population estimate, trends and conservation status. BirdLife Conservation Series No. 12. Cambridge. UK.

BirdLife International. 2015. European Red List of Birds. Office for Official Publications of the European Communities. Luxembourg.

Boere G.C., Stroud D.A. 2006. The flyway concept: what it is and what it isn't. Waterbirds around the world. Eds. G.C. Boere, C.A. Galbraith & D.A. Stroud. The Stationery Office, Edinburgh, UK. pp. 40-47.

Briggs K.T., Tyler W.B., Lewis D.B. 1985. Comparison of Ship and Aerial Surveys of Birds at Sea. The Journal of Wildlife Management. 49 (2):405-411. DOI: 10.2307/3801542

Durinck J., Skov H., Jensen E.P., S. Pihl S. 1996. Important Marine Areas for Wintering Birds in the Baltic Sea. Colonial Waterbirds 19(1):157. DOI: 10.2307/1521834

Fawen Q., Changhao Y., Hongxing J. 2011. Ground and aerial surveys of wintering waterbirds in Poyang Basin. UNEP/GEF Siberian Wetland Project. Technical rep.

Frederick P.C., Towles T., Sawicki R.J., Bancroft G.T. 1996. Comparison of Aerial and Ground Techniques for Discovery and Census of Wading Bird (Ciconiiformes) Nesting Colonies. The Condor Vol. 98 (4): 837-841. DOI: 10.2307/1369865

Frederick P.C., Hylton B., Heath J.A., Ruane M. 2003. Accuracy and variation in estimates of large numbers of birds by individual observers using an aerial survey simulator. Journal of Field Ornithology 74(3):281-287. DOI: 10.1648/0273-8570-74.3.281

Green M.C., Luent M.C., Michot T.C., Jeske C.W., Leberg P.L. 2008. Comparison and Assessment of Aerial and Ground Estimates of Waterbird Colonies. Journal of Wildlife Management 72(3):697-706. DOI: 10.2193/2006-391

Grimm, P. 1985. Die Stellnetzfischerei als eine wichtige Form nicht nur der ornithofaunistischen Nachweisführung. – Naturschutzarb. Mecklenburg 28: 104-106.

Jakubas D. 2003. Factors affecting different spatial distribution of wintering Tufted Duck *Aythya fuligula* and Goldeneye *Bucephala clangula* in the western part of the Gulf of Gdańsk (Poland). Ornis Svecica 13: 75-84.

Jensen, F, P., Perennou, C., Lutz, M., 2009. European Union Management Plan 2009-2011. Scaup *Aythya marila*. Office for Official Publications of the European Communities. Luxembourg.

Joasen A.H. 1968. Wildfowl counts in Denmark in November 1967 and January 1968. Methods and results. Danish Review of Game Biology 9(1): 1-206.

Johnsgard P.A. 1978. Ducks, geese and swans of the World. University of Nebraska Press, Lincoln and London.

Johnson F.A., Pollock K.H., Montalbano F.III. 1989. Visibility bias in aerial surveys of mottled ducks. Wildlife Society Bulletin 17: 222-227.

Kingsford R.T. 1999. Aerial survey of waterbirds on wetlands as a measure of river and floodplain health. Freshwater Biology. DOI: 10.1046/j.1365-2427.1999.00440.x

Kingsford R.T., Brandis K., Porter J.L. 2008. Waterbird response to flooding in the northern Murray-Darling Basin 2008. School of Biological, Earth and Environmental Sciences, University of New South Wales.

Kingsford R.T., Porter J.L. 2009. Monitoring waterbird populations with aerial surveys – what have we learnt? Wildlife Research 36(1):29-40. DOI: 10.1071/WR08034

Komdeur J., Bertelsen J. Cracknell G. 1992. Manual for Aeroplane and Ship Surveys of Waterfowl and Seabirds. IWRB Special Publication 19: 8-23.

Laursen K., Frikke J., Kahlet J. 2008. Accuracy of 'total counts' of waterbirds from aircraft in coastal waters. Wildl. Biol. 14: 165-175.

Lehikoinen A., Jaatinen K., Vahatalo A.V., Preben C., Crowe O., Deceuninck B., Hearn R., Holt C.A., Hornman M., Keller V., Nilsson L., Langendoen T., Tomankova I., Wahl J., Fox A.D. 2013. Rapid climate driven shifts in wintering distributions of three common waterbird species. Global Change Biology: 19, 2071–2081, DOI: 10.1111/gcb.12200

Ławicki Ł., Czeraszkiewicz R., Guentzel S., Jasiński M., Kajzer Z., Kaliciuk J., Oleksiak A. 2008. Wintering of Waterbirds in the Western Pomerania in the years 2002–2008. Not. Orn. 49: 235–244. (in Polish with English summary).

Ławicki, Ł., Guentzel, S., Wysocki, D., (eds.). 2012. Projects of the conservation plans for SPAs Natura 2000: the Szczecin Lagoon PLB320009, the Kamien Lagoon and Dziwna PLB320011 and the Odra Mouth River and Szczecin Lagoon PLH320018. Report for the Maritime Office in Szczecin. Project No. POIS.05.03.00-00-280/10. ECO-EXPERT Sp.j., Szczecin, Poland. (in Polish).

Marchowski D., Ławicki Ł. 2011. Numbers of Waterfowl in Western Pomerania in the 2009/2010 season. Ptaki Pomorza 2: 159–166. (in Polish with English summary).

Marchowski D., Ławicki Ł. 2012. Numbers of Waterfowl in Western Pomerania in the season 2010/2011. Ptaki Pomorza (Birds of Pomerania) 3: 129–134 (in Polish with English summary).

Marchowski D., Ławicki Ł., Guentzel S. 2013. Numbers of Waterfowl in Western Pomerania in the season 2011/2012. Ptaki Pomorza (Birds of Pomerania) 4: 149–169. (in Polish with English summary).

Marchowski D., Neubauer G., Ławicki Ł., Woźniczka A., Wysocki D., Guentzel S., Jarzemski M. 2015. The importance of non-native prey, the Zebra Mussel *Dreissena polymorpha*, for the declining Greater Scaup *Aythya marila*: a case study at a key European staging and wintering site. PLoS ONE. DOI: 10(12): e0145496.

Marchowski D., Jankowiak Ł., Wysocki D., Ławicki Ł., Girjatowicz J., 2017. Ducks change wintering pattern due to changing climate in the important wintering waters of the Odra River Estuary. PeerJ 5:e3604. DOI: 10.7717/peerj.3604.

Meissner W. 2011. Methods of waterbirds counts. The birds wintering on inland water and the coastal zone of the Baltic Sea. (Metody liczenia ptaków wodnych. Ptaki zimujące na wodach śródlądowych oraz w strefie przybrzeżnej Bałtyku.) Fundacja Wspierania Inicjatyw Ekologicznych. Kraków. (In Polish).

Meissner W., Rowiński P., Polakowski M., Wilniewczyc P., Marchowski D. 2015. Impact of temperature on the number of mallards, Anas platyrhynchos, wintering in cities. North-western Journal of Zoology. 11 (2):213-218.

Mendel B., Sonntag N., Wahl J., Schwemmer P., Dries H., Guse N. et al. 2008. Profiles of seabirds and waterbirds of the German North and Baltic Seas. Distribution, ecology and sensitivities to human activities within the marine environment. BFN. Bonn–Bad Godesberg.

Pollock K.H., Kendall W.L. 1987. Visibility bias in aerial surveys: A review of estimation procedures. Journal of Wildlife Management. 51: 502-510.

Radziejewska T., Schernewski G. 2008. The Szczecin (Oder) Lagoon. In: Schiewer U., editor. Ecology of Baltic Coastal Waters. Berlin Heidelberg: Springer. pp. 116–117.

Savard J-P.L. 1982. Variability of waterfowl aerial surveys: observer and air – ground comparisons. A preliminary report. Canadian Wildlife Service, no.127: 1-6.

Scheiffarth, G., Becker, P.H. 2008. Roosting waterbirds at the Osterems, German Wadden Sea: seasonal and spatial trends studied by aerial and ground surveys. Marine Biodiversity 38 (2): 137–142, 4 DOI10.1007/BF03055289

Skov, H., Heinänen, S., Žydelis, R., Bellebaum, J., Bzoma, S., Dagys, M., Durinck, J., Garthe, S., Grishanov, G., Hario, M., Kieckbusch, J.J., Kube, J., Kuresoo, A., Las son, K., Luigujoe, L., Meissner, W., Nehls, H.W., Nilsson, L., Petersen, I.K., Roos, M.M., Pih l, S., Sonntag, N., Stock. A., Stipniece, A., Wahl. J., 2011. Waterbird Populations and Pressures in the Baltic Sea. Nordic Council of Ministers, Copenhagen.

Smith G.W. 1995. A Critical Review of the Aerial and Ground Surveys of Breeding Waterfowl in North America. Technical rept. Available at: http://www.dtic.mil/dtic/tr/fulltext/u2/a322667.pdf

van Erden M.R., de Leeuw J.J. 2010. How Dreissena sets the winter scene for water birds: dynamic interactions between diving ducks and zebra mussels. In: van der Velde G., Rajagopal S., bij de Vaate A. 2010. The Zebra Mussel in Europe. Backhuys Publishers, Leiden. Margraf Publishers, Weikersheim.

Voslamber B., van Turnhout C. 1999. Vergelijkende studie van land- en vligtuigtellingen van watervogels in het Ijsselmeergebied. RIZA-rapport BM99.01. SOVON-onderzoeksrapport 1999/08, 66 pp.

Wetlands International. Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting. Wetlands International, Wageningen. 2010. Available from: http://www.wetlands.org.

Wetlands International (2018). "Waterbird Population Estimates". Retrieved from wpe.wetlands.org on Saturday 24 Feb 2018.

Legends to figures and tables

Figure 1. The study area – the Odra River Estuary, NW Poland.

Figure 2. Predicted values of the fitted generalized mixed model. This shows differences between the results of waterbird counts during the non-breeding period in the Odra River Estuary carried out with two research platforms, i.e. from the ground and from the air. A, B, C show different predicted count numbers of target species according to different ice conditions and count methods. D shows the estimated mean values of all species; whiskers indicate 95% confidence intervals.

Table 1. Mean number of waterbirds during the non-breeding period in the Odra River Estuary (NW Poland); standard error and confidence intervals, taking into account the method and weather conditions (ice=0 – no ice, ice=1 – ice cover over 70%)

Table 2. Waterbird counts in the non-breeding season – calculation of costs. Calculation of labour costs in the field; payment methods and study methods are distinguished

S1. Table. Group of waterbird species used to test the accuracy of air and ground counts (1); mean ± standard errors of ground counts (2); 95% confidence intervals of ground counts (3); mean ± standard errors of air counts (4); 95% confidence intervals of air counts (5); method error –

difference between mean numbers of birds recorded during ground and air counts (ground minus air) (6); method error – difference between mean numbers of birds recorded during ground and air counts; the value from column 7 is given as the percentage of the mean number of birds obtained from the ground (7).

S2 Table. Test of the effect of count method and ice occurrence on the number of target species (GLMM)

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Figure 1

The study area – the Odra River Estuary, NW Poland.

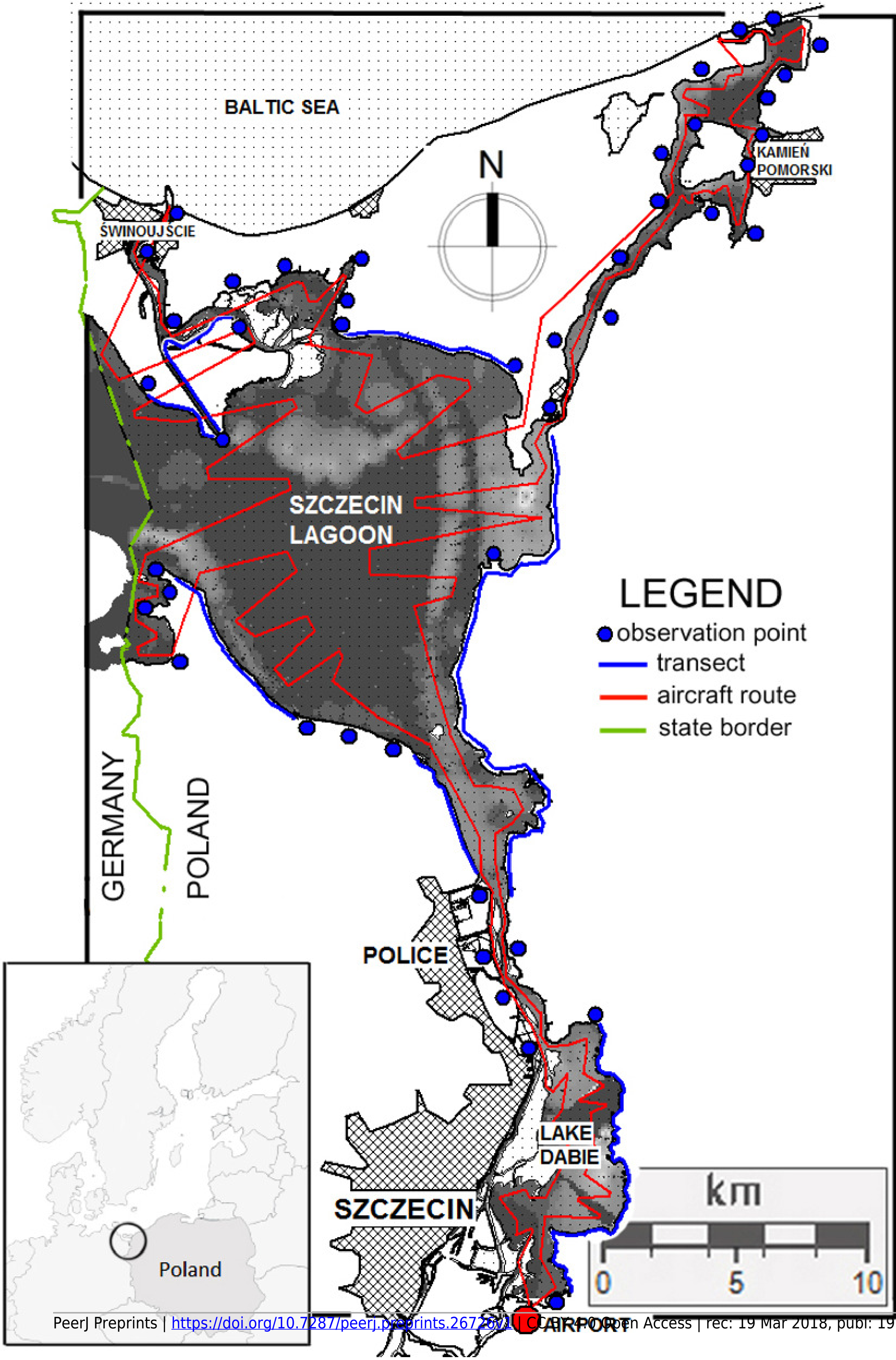
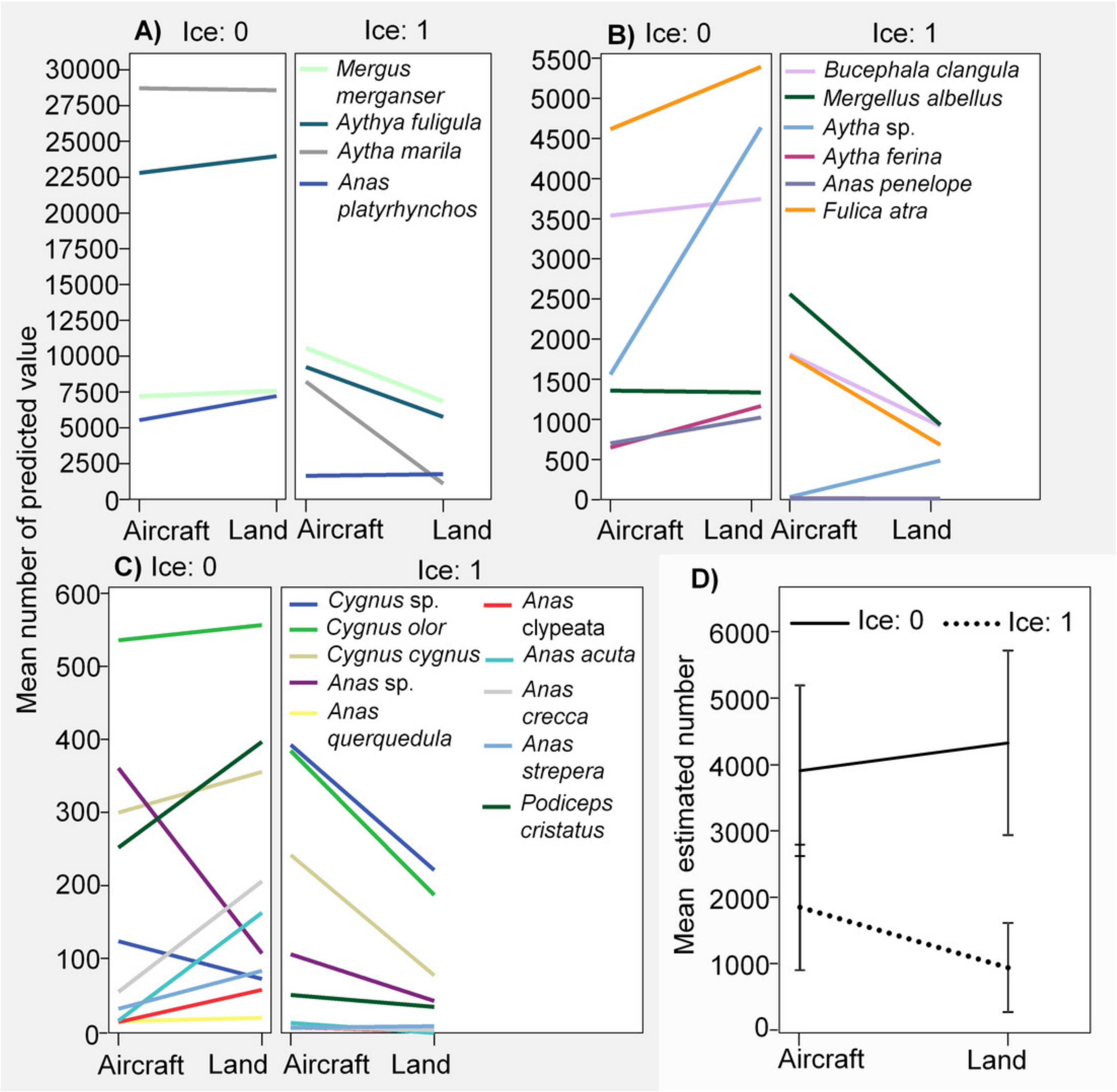

BALTIC SEA
N
KAMIEŃ
POMORSKI
ŚWINOUJSCIE
SZCZECIN
LAGOON
LEGEND
observation point
transect
aircraft route
state border
GERMANY
POLAND
POLICE
LAKE
DABIE
SZCZECIN
AIRPORT
km
0
5
10
Poland

Figure 2

Predicted values of fitted generalized mixed model. It shows differences between the results of waterbirds counts during the non-breeding period in the Odra River Estuary carried out with two research platforms, from the ground and from the aircraft.

A, B, C show different predicted count number of analysed species according to different ice condition and count method. D shows estimated mean values of all species, whiskers indicate 95% confidence intervals.



A) Ice: 0
Ice: 1
Mergus merganser
Aythya fuligula
Aytha marila
Anas platyrhynchos
B) Ice: 0
Ice: 1
Bucephala clangula
Mergellus albellus
Aytha sp.
Aytha ferina
Anas penelope
Fulica atra
Mean number of predicted value
C) Ice: 0
Ice: 1
Cygnus sp.
Cygnus olor
Cygnus cygnus
Anas sp.
Anas querquedula
Anas clypeata
Anas acuta
Anas crecca
Anas strepera
Podiceps cristatus
D)
Ice: 0
Ice: 1
Mean estimated number
Aircraft
Land

Table 1(on next page)

Mean number of waterbirds during the non-breeding period in the Odra River Estuary (NW Poland)

Standard error and confidence intervals, taking into account the method and weather conditions (ice=0 – no ice, ice=1 – ice cover over 70%)

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Table 1. Mean number of waterbirds during the non-breeding period in the Odra River Estuary (NW Poland); standard error and confidence intervals, taking into account the method and weather conditions (ice=0 – no ice, ice=1 – ice cover over 70%)

Method	Ice	Mean	Standard error	Confidence intervals 95%	
				Lower limit	Upper limit
Aircraft	0	3 907.064	653.361	2 622.483	5 191.645
	1	1 848.523	480.258	904.283	2 792.764
Land	0	4 323.867	706.905	2 934.012	5 713.722
	1	944.410	341.824	272.346	1 616.475

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Table 2 (on next page)

Waterbird counts in the non-breeding season – calculation of costs.

Calculation of labour costs in the field; payment methods and study methods are distinguished.

Table 2. Waterbird counts in the non-breeding season – calculation of costs. Calculation of labour costs in the field; payment methods and study methods are distinguished.

Form of payment	Form of counting	Cost of one count in the study area (530 km² and 340 km of coastline) in Euros	Cost of one count over a 100 km² water body in Euros	Cost of one count along a 100 km coastline in Euros
Voluntary	Aircraft	720	136	212
Voluntary	Ground	300	57	88
Paid service	Aircraft	1400	264	412
Paid service	Ground	2300	434	677

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