# Towards improved population size estimates for wintering waterbirds

Szabolcs Nagy, Tom Langendoen, Teresa M. Frost, Gitte Høj Jensen, Nele Markones, Johan H. Mooij, Jean-Yves Paquet, Marie Suet

Wintering population size estimates of waterbirds are often based on simply adding up the counts from the International Waterbird Census. This approach implicitly assumes that the whole population has been censused, which is an invalid assumption for many species. Consequently, the population sizes of wintering waterbird populations both at national and flyway levels are underestimated. This has serious implications for population trend analyses, population status assessments, and for management of huntable species. To illustrate how different approaches are used in different EU Member States, we compared the estimates reported to the European Commission under Article 12 of the Birds Directive with the IWC national totals from the same countries and from the same years. To stimulate the use of more reliable population size estimates, we provide a review of the existing methods and make some recommendations for their use in Europe.

Biogeographic or flyway populations play an important role in the conservation and management of many waterbird species (Atkinson-Willes 1976, Atkinson-Willes et al. 1980). First, the 1% thresholds for the application of Criterion 6 of the Ramsar Convention on Wetlands to identify Ramsar sites and for the selection of Special Protection Areas under the EU Birds Directive are calculated from the flyway or biogeographic population estimates. Second, reliable population estimates are also important in the context of sustainable harvest management (Madsen et al. 2015), regulating hunting to facilitate the recovery of declining huntable species (Johnson et al. 2020) or to manage populations (Johnson and Koffijberg 2021). Third, reliable population estimates are also important as weighting factors when combining national trends at international level (van Strien et al. 2001). As many waterbird populations can be separated only on their wintering grounds (Hearn et al. 2018, Nagy et al. 2021), reliable wintering population estimates are very important in these contexts.

The International Waterbird Census (IWC) was launched in 1967 to estimate the sizes as well as the changes in the numbers and distribution of waterbird populations (Atkinson-Willes 1969). The scheme focuses on counting waterbirds at their wintering grounds where many of them concentrate in conspicuous groups and are easier to count than on their remote and hardly accessible breeding grounds (Delany et al. 1999). In theory, the IWC applies the principles of a full census method, as many waterbird species concentrate on a relatively small number of sites and individuals can be counted completely. However, this assumption is only valid in areas with almost complete coverage of all suitable habitats for waterbird species and only in case of the species that are highly congregatory. Rüger et al. (1986) have highlighted the problems that differences in coverage of sites by observers represent for estimating population sizes. Missing counts are another problem, as not every site is counted every year (Fig. 1). In addition, the different detectability of species, especially the low detectability of cryptic species (e.g., Common Snipe *Gallinago gallinago*, Western Water Rail *Rallus aquaticus*), presents further problems and is usually not addressed during the normal IWC counts (Vallecillo et al. 2022).

Flyway-level population estimates of wintering waterbirds often rely on aggregating national population estimates across the wintering range of the flyway. Consequently, the completeness of the flyway-level population estimates is strongly influenced by the completeness of the contributing national population estimates. The European Commission, BirdLife International and the AEWA (African-Eurasian Migratory Waterbird Agreement) Secretariat all provide guidelines for the reporting processes under the Birds Directive Article 12, for the European Red List and the AEWA national population status reports. However, none of these guidelines addresses the issue how to derive population estimates for wintering waterbirds.

In this paper, we aim to compare the national wintering population estimates reported to the European Commission under Article 12 of the Birds Directive with the national IWC count totals. The objective of these comparisons is to see whether all EU Member States applied similar corrections to the IWC data when they estimated the national population sizes. This insight will allow us to assess whether the aggregation of national estimates provides realistic estimates at the EU or flyway level. To stimulate the use of better national population estimates, we also provide a review of available and tested methods to estimate full population sizes, and we formulate some recommendations for the future.

# 1. Methods

## 1.1. National population estimates

In 2019, all EU Member States (MS) reported wintering population estimates for key wintering species (Table 7 in DG Environment 2017). BirdLife International collected wintering population estimates from other European countries. Data from both processes were used for the 2021 edition of the European Red List of Birds (BirdLife International 2021). As the reporting on wintering population estimates was less consistent from eastern European countries outside of the EU, we only used the population estimates reported by the EU Member States under the EU Birds Directive Article 12 process, which we extracted from the European Red List of Birds dataset provided by BirdLife International.

The countries could report «minimum», «maximum» and «best single value» estimates for a period. This period usually (but not always) covered the years from 2013 to 2017. We used the «best single value» if this was reported. Otherwise, we calculated the geometric mean of the minimum and maximum of each national population estimate.

## 1.2. IWC data

We extracted the IWC site-level counts reported to Wetlands International by the national IWC coordinators for the same periods as indicated for the national wintering population estimates reported to the European Commission. From these data, we calculated the «national IWC count totals» by adding up the reported site-level counts in a given year. To obtain numbers comparable to the numbers reported by the Member States (see National population estimates above), we calculated the geometric mean of the minimum and maximum estimates from the same study years that were reported under the EU Article 12 process from the country.

In addition, we looked at the number of IWC sites counted (or reported, this cannot be distinguished in our dataset) in 26 EU Member States during the period of 2013–2017, as this was the period reported by most countries. We used data only from 26 countries because no data were available from Luxembourg and Romania for the assessed period in the IWC database. We also assessed the number of IWC sites surveyed in 2017 in comparison to all sites surveyed during the period 2013–2017. This indicates the magnitude of completeness of counts in 2017 compared to the sites actively surveyed in the reporting period. In addition, we counted the number of IWC sites in the IWC database with no data for the period of 2013–2017. This shows the number of sites with missing surveys in the reporting period. This group includes a mixture of (i) existing unique sites that are not surveyed anymore, (ii) sites that do not exist anymore and (iii) sites that were reorganised and reported under a different name.

## 1.3. Comparison of national population estimates to IWC count totals

Based on the geometric mean of the minimum and maximum IWC counts we calculated a population estimate coefficient (PEC) that expresses the relationship between the national IWC count totals and the reported national population estimates.

$$PEC = \frac{POPEST}{\sqrt{MIN * MAX}}$$

Where:

- PEC: population estimate coefficient
- POPEST: population estimate reported by this report (see above)
- MIN: minimum of the national IWC count total
- MAX: maximum of the national IWC count total

If the PEC is equal to 1, the country has likely used only the uncorrected IWC count total, while if it is larger than 1, some sort of adjustment was made.

## 1.4. Classification of waterbird species by main habitat

We classified waterbird species based on their habitat use (Table 1). Many species use multiple habitats and cannot be clearly assigned to only one habitat type. Therefore, we classified the species based on the implications of their habitat use for counting their populations in winter; for example, geese, swans, and cranes are difficult to count during normal IWC counts because they often use farmlands, and divers and seaducks because they mainly winter in marine waters.

Table 1. Classification of waterbird species listed as key wintering species (DG Environment 2017) by habitat, based on monitoring needs. Subspecies listed in the original table are merged at species level.
*Klassifizierung der Wasservogelarten, die als wichtige überwinternde Arten aufgeführt sind (DG Environment 2017), nach Lebensraum, basierend auf dem Überwachungsbedarf. Die in der Originaltabelle aufgeführten Unterarten werden auf Artniveau zusammengefasst.*

| Species | | Habitat |
|---|---|---|
| Brent Goose | *Branta bernicla* | coastal |
| Common Shelduck | *Tadorna tadorna* | coastal |
| Greater Flamingo | *Phoenicopterus roseus* | coastal |
| Eurasian Oyster-catcher | *Haematopus ostrale-gus* | coastal |
| Pied Avocet | *Recurvirostra avosetta* | coastal |
| Grey Plover | *Pluvialis squatarola* | coastal |
| Common Ringed Plover | *Charadrius hiaticula* | coastal |
| Kentish Plover | *Charadrius alexandrinus* | coastal |
| Greater Sandplover | *Charadrius leschenaultii* | coastal |
| Eurasian Curlew | *Numenius arquata* | coastal |
| Bar-tailed Godwit | *Limosa lapponica* | coastal |
| Ruddy Turnstone | *Arenaria interpres* | coastal |
| Red Knot | *Calidris canutus* | coastal |
| Curlew Sandpiper | *Calidris ferruginea* | coastal |
| Sanderling | *Calidris alba* | coastal |
| Dunlin | *Calidris alpina* | coastal |
| Purple Sandpiper | *Calidris maritima* | coastal |
| Little Stint | *Calidris minuta* | coastal |
| Common Redshank | *Tringa totanus* | coastal |
| Whooper Swan | *Cygnus cygnus* | farmland |
| Tundra Swan | *Cygnus columbianus* | farmland |
| Barnacle Goose | *Branta leucopsis* | farmland |
| Red-breasted Goose | *Branta ruficollis* | farmland |
| Greylag Goose | *Anser anser* | farmland |
| Bean Goose | *Anser fabalis* | farmland |
| Pink-footed Goose | *Anser brachyrhyn-chus* | farmland |
| Greater White-fronted Goose | *Anser albifrons* | farmland |
| Eurasian Wigeon | *Mareca penelope* | farmland |
| Common Crane | *Grus grus* | farmland |
| Great White Egret | *Ardea alba* | farmland |
| Eurasian Golden Plover | *Pluvialis apricaria* | farmland |
| Northern Lapwing | *Vanellus vanellus* | farmland |
| Spur-winged Lapwing | *Vanellus spinosus* | farmland |
| Long-tailed Duck | *Clangula hyemalis* | marine |
| Common Eider | *Somateria mollissima* | marine |

| Species | | Habitat |
|---|---|---|
| Steller's Eider | *Polysticta stelleri* | marine |
| Velvet Scoter | *Melanitta fusca* | marine |
| Common Scoter | *Melanitta nigra* | marine |
| Common Goldeneye | *Bucephala clangula* | marine |
| Red-breasted Merganser | *Mergus serrator* | marine |
| Greater Scaup | *Aythya marila* | marine |
| Horned Grebe | *Podiceps auritus* | marine |
| Red-throated Loon | *Gavia stellata* | marine |
| Arctic Loon | *Gavia arctica* | marine |
| Common Loon | *Gavia immer* | marine |
| Iceland Gull | *Larus glaucoides* | marine |
| Glaucous Gull | *Larus hyperboreus* | marine |
| White-headed Duck | *Oxyura leucocephala* | inland wetland |
| Mute Swan | *Cygnus olor* | inland wetland |
| Lesser White-fronted Goose | *Anser erythropus* | inland wetland |
| Smew | *Mergellus albellus* | inland wetland |
| Goosander | *Mergus merganser* | inland wetland |
| Marbled Teal | *Marmaronetta angustirostris* | inland wetland |
| Red-crested Pochard | *Netta rufina* | inland wetland |
| Common Pochard | *Aythya ferina* | inland wetland |
| Tufted Duck | *Aythya fuligula* | inland wetland |
| Northern Shoveler | *Spatula clypeata* | inland wetland |
| Gadwall | *Mareca strepera* | inland wetland |
| Mallard | *Anas platyrhynchos* | inland wetland |
| Northern Pintail | *Anas acuta* | inland wetland |
| Common Teal | *Anas crecca* | inland wetland |
| Little Grebe | *Tachybaptus ruficollis* | inland wetland |
| Great Crested Grebe | *Podiceps cristatus* | inland wetland |
| Black-necked Grebe | *Podiceps nigricollis* | inland wetland |
| Red-knobbed Coot | *Fulica cristata* | inland wetland |
| Common Coot | *Fulica atra* | inland wetland |
| Eurasian Spoonbill | *Platalea leucorodia* | inland wetland |
| Little Egret | *Egretta garzetta* | inland wetland |
| Dalmatian Pelican | *Pelecanus crispus* | inland wetland |
| Pygmy Cormorant | *Microcarbo pygmaeus* | inland wetland |
| Great Cormorant | *Phalacrocorax carbo* | inland wetland |
| Black-tailed Godwit | *Limosa limosa* | inland wetland |
| Armenian Gull | *Larus armenicus* | inland wetland |

# 2. Results

## 2.1. Magnitude of missing counts

On average, 66% of the IWC sites that were surveyed in 2013–2017 were also surveyed in 2017. Table 2 and Fig. 1 show very large differences among countries, and among regions within countries, concerning the regularity of surveys (or of reporting surveys). 75% or more of the sites surveyed in the period of 2013–2017 were also surveyed in 2017 in 12 countries, but less than half of the sites were surveyed (or reported) in Germany and Bulgaria (Column D in Table 2). This shows a rather high proportion of missing surveys even in the 2013–2017 period.

On average, less than 24% of all IWC sites ever surveyed were also surveyed in the period of 2013–2017 (Column E in Table 2). The long-term consistency of site definitions was high in the Netherlands (98%) and France (79%), but it was below 50% in 17 countries. This shows a generally low consistency of site definitions over the long term and highlights the importance of careful site selection for further analyses.

Table 2. Number of IWC sites surveyed in 26 EU Member States in 2017, compared to the number of sites surveyed in the period 2013–2017, and to all sites in the IWC database: A = number of sites with counts reported in 2013–2017; B = number of sites in the database with no counts reported in 2013–2017; C = number of sites with counts reported in 2017; D = % reported sites surveyed in 2017 (C) of sites surveyed in the period of 2013–2017 sites (A); E = % reported sites surveyed in 2017 (C) of all sites (A + B).
*Anzahl der im Jahr 2017 in 26 EU-Mitgliedstaaten untersuchten IWC-Standorte im Vergleich zur Anzahl der im Zeitraum 2013–2017 untersuchten Standorte und zu allen Standorten in der IWC-Datenbank: A = Anzahl Standorte mit gemeldeten Zählungen im Zeitraum 2013–2017; B = Anzahl Standorte in der Datenbank ohne gemeldete Zählungen im Zeitraum 2013–2017; C = Anzahl Standorte mit gemeldeten Zählungen im Jahr 2017; D = % der gemeldeten, untersuchten Standorte im Jahr 2017 (C) von Standorten, die im Zeitraum 2013–2017 erhoben wurden (A); E = % der gemeldeten Standorte, die 2017 erhoben wurden (C) von allen Standorten (A + B).*

| Country | A | B | C | D (C/A*100) | E (C/(A + B)) |
|---|---|---|---|---|---|
| Austria | 274 | 185 | 228 | 83 | 50 |
| Bulgaria | 252 | 122 | 115 | 46 | 31 |
| Cyprus | 63 | 25 | 55 | 87 | 63 |
| Czech Republic | 964 | 364 | 663 | 69 | 50 |
| Germany | 1008 | 3658 | 357 | 35 | 8 |
| Denmark | 49 | 284 | 49 | 100 | 15 |
| Estonia | 191 | 1174 | 156 | 82 | 11 |
| Spain | 1040 | 2273 | 638 | 61 | 19 |
| Belgium | 837 | 2125 | 683 | 82 | 23 |
| Finland | 88 | 2496 | 66 | 75 | 3 |
| France | 511 | 70 | 459 | 90 | 79 |
| United Kingdom | 2922 | 4173 | 2111 | 72 | 30 |
| Greece | 336 | 157 | 203 | 60 | 41 |
| Croatia | 489 | 263 | 263 | 54 | 35 |
| Hungary | 26 | 374 | 25 | 96 | 6 |
| Ireland | 148 | 617 | 105 | 71 | 14 |
| Italy | 633 | 171 | 477 | 75 | 59 |
| Lithuania | 60 | 4 | 41 | 68 | 64 |
| Latvia | 406 | 1380 | 259 | 64 | 15 |
| Malta | 20 | 6 | 10 | 50 | 38 |
| Netherlands | 187 | 0 | 184 | 98 | 98 |
| Poland | 354 | 166 | 332 | 94 | 64 |
| Portugal | 88 | 122 | 46 | 52 | 22 |
| Sweden | 1560 | 3383 | 832 | 53 | 17 |
| Slovenia | 122 | 48 | 119 | 98 | 70 |
| Slovakia | 894 | 516 | 476 | 53 | 34 |
| Total | 13 522 | 24 156 | 8952 | 66% | 24% |

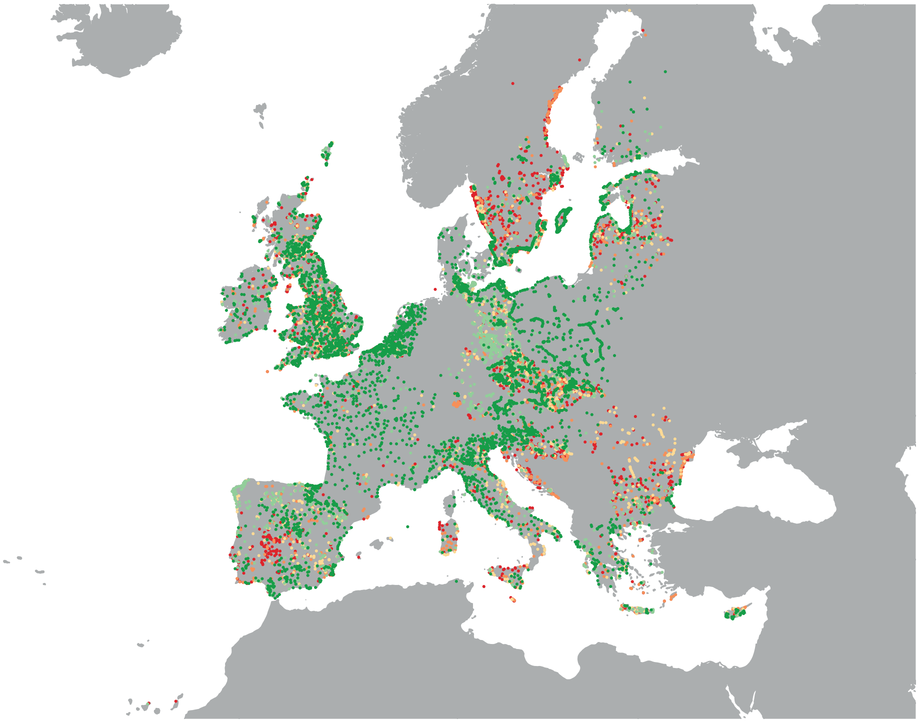

Figure 1. Number of visits at IWC sites in January between 2013 and 2017, based on IWC data submitted to Wetlands International: red = 1; orange = 2; yellow = 3; light green = 4; green = 5.
*Anzahl der Besuche an IWC-Standorten im Januar zwischen 2013 und 2017, basierend auf IWC-Daten, die an Wetlands International übermittelt wurden: rot = 1; orange = 2; gelb = 3; hellgrün = 4; grün = 5.*

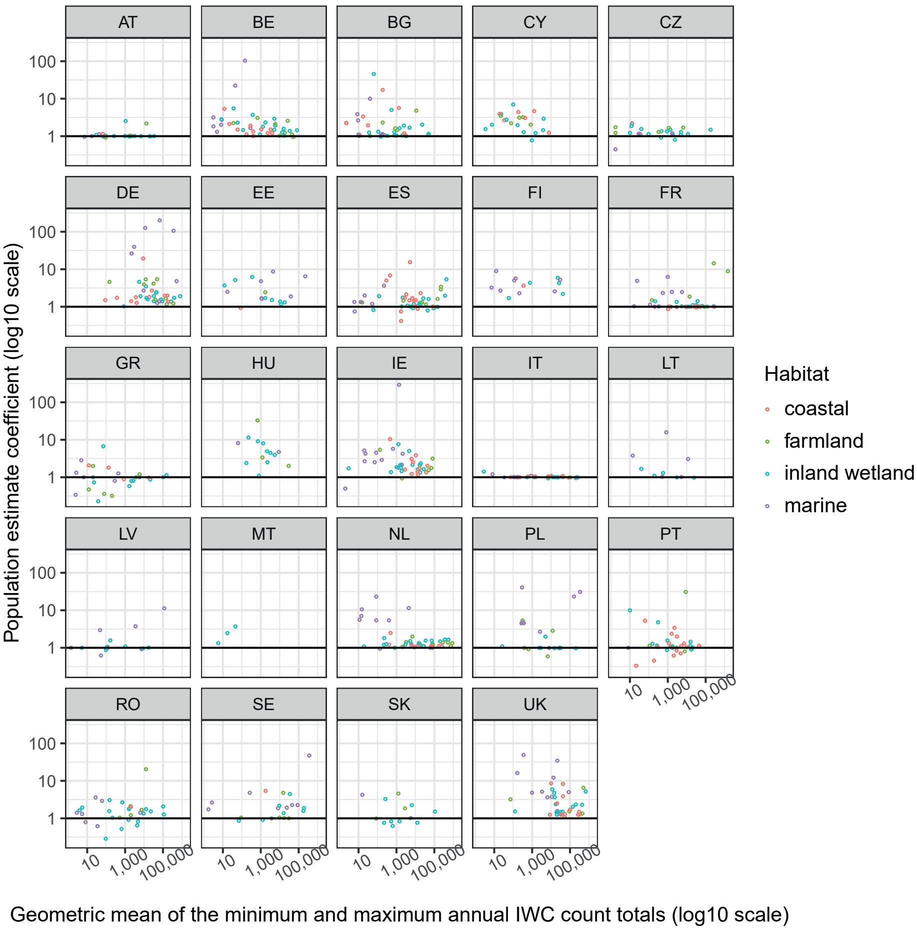


Figure 2. Comparison of population estimates reported under the EU Birds Directive Article 12 process and the national IWC count totals. The coefficients are presented on the logarithmic scale because of the wide range of values.
*Vergleich der im Rahmen des Verfahrens nach Artikel 12 der EU-Vogelschutzrichtlinie gemeldeten Bestandsschätzungen mit den nationalen IWC-Zählungen. Die Koeffizienten werden aufgrund der grossen Spannweite der Werte auf einer logarithmischen Skala dargestellt.*

## 2.2. Comparison of national IWC count totals with the national population estimates

Fig. 2 shows that different countries have taken rather different approaches. Average country PEC values ranged from 1.0 (Italy) to 13.8 (Germany), with a mean country PEC of 3.9 (SD = 2.99), showing a strong skew to the left. For some countries (e.g., Austria, the Czech Republic, France, Greece, Italy, Latvia, Lithuania, the Netherlands), the population estimates were rather close to the IWC count totals, at least for inland wetland (mean PEC = 2.0), coastal (mean PEC = 2.2) and farmland species (mean PEC = 2.9). For other countries (e.g., Belgium, Bulgaria, Cyprus, Hungary, Ireland, United Kingdom) and for the marine species in most countries (mean PEC = 10.2), more corrections were applied, indicated by the higher population estimate coefficients. In some countries (e.g., Greece and Romania), many of the reported estimates were smaller than the IWC count totals, which should not happen if the estimates were informed by the IWC counts. These differences suggest large differences in approaches to producing population size estimates. It is unsurprising that the reported figures are higher in marine species, as these estimates were derived from sampling and modelling (Camphuysen et al. 2004). The relatively low level of corrections for inland wetland, coastal and farmland species suggests that in most of these cases only imputing methods for missing counts were applied. However, some countries such as the UK have also tried to estimate wintering numbers outside of the IWC site network (Frost et al. 2019).

# 3. Discussion

Our results suggest that countries differed a lot in their approaches to produce national population estimates: some applied very little correction and accepted the IWC results as minimum estimates of population sizes, while others tried to estimate the whole wintering population in the country. It is likely that the national population sizes in the countries where the population estimates were nearly equal or lower than the IWC were given as total counts. This results in underestimating the EU or flyway population sizes, when such estimates are based on aggregating the national results.

The analysis of missing surveys shows that a rather high proportion of sites are not surveyed annually. Such a high level of missing surveys indicates that the IWC count totals substantially underestimate the numbers even within the site network covered by the IWC. Therefore, it is important to further improve the reporting guidance under the EU Article 12, the European Red List of Birds and the AEWA national population status reporting processes, and to think strategically about the further development of national and international waterbird monitoring schemes such as the East Atlantic Flyway monitoring (van Roomen et al. 2013).

In the following sections, we review the available methods and give recommendations for producing comprehensive national population estimates that can be best used for international reviews providing input for flyway-scale conservation and management.

## 3.1. What national data on the wintering population size to collect for international reviews?

Currently, countries report a mixture of wintering population size data. Some countries, e.g., the UK and the Netherlands, report the seasonal maxima over the reporting period. Others report mid-winter (January) numbers. Using the seasonal maxima is highly relevant in the national context, to assess the coverage of the wintering population by the network of Special Protection Areas (SPAs) or other protected area networks. As data from Frost et al. (2019) show, there could be large differences between the seasonal maxima and the mid-winter numbers (Table 3). Using seasonal maxima, however, can be problematic for analyses at the flyway level. As the seasonal maxima cover a longer time period of the year, and the birds are often moving from one country to another during this period, using seasonal maxima is likely leading to double counting, if most countries would report such values. Data from a shorter fixed time period, when synchronised counts take place across the wintering range of the population, can provide a less biased estimate of population size; but

Table 3. Comparison of means of January and seasonal maxima estimates for the UK, based on Frost et al. (2019).
*Vergleich der Mittelwerte für Januar und saisonale Maxima für das Vereinigte Königreich, basierend auf Frost et al. (2019).*

| Species | | Mean of January | Mean of seasonal max. | Difference |
|---|---|---|---|---|
| Mute Swan | *Cygnus olor* | 45 000 | 50 000 | 11% |
| Common Shelduck | *Tadorna tadorna* | 47 000 | 47 000 | 0% |
| Common Pochard | *Aythya ferina* | 22 000 | 23 000 | 5% |
| Northern Shoveler | *Spatula clypeata* | 19 000 | 19 000 | 0% |
| Gadwall | *Mareca strepera* | 30 000 | 31 000 | 3% |
| Eurasian Wigeon | *Mareca penelope* | 440 000 | 450 000 | 2% |
| Mallard | *Anas platyrhynchos* | 620 000 | 670 000 | 8% |
| Common Teal | *Anas crecca* | 420 000 | 430 000 | 2% |
| Little Grebe | *Tachybaptus ruficollis* | 11 000 | 15 000 | 36% |
| Great Crested Grebe | *Podiceps cristatus* | 12 000 | 17 000 | 42% |
| Common Coot | *Fulica atra* | 170 000 | 200 000 | 18% |
| Great Cormorant | *Phalacrocorax carbo* | 45 000 | 62 000 | 38% |
| Eurasian Oystercatcher | *Haematopus ostralegus* | 260 000 | 290 000 | 12% |
| Pied Avocet | *Recurvirostra avosetta* | 7 800 | 8 700 | 12% |
| Grey Plover | *Pluvialis squatarola* | 29 000 | 33 000 | 14% |
| Eurasian Curlew | *Numenius arquata* | 100 000 | 120 000 | 20% |
| Eurasian Curlew | *Numenius arquata* | 100 000 | 120 000 | 20% |
| Bar-tailed Godwit | *Limosa lapponica* | 42 000 | 50 000 | 19% |
| Black-tailed Godwit | *Limosa limosa* | 30 000 | 39 000 | 30% |
| Ruddy Turnstone | *Arenaria interpres* | 36 000 | 40 000 | 11% |
| Red Knot | *Calidris canutus* | 210 000 | 260 000 | 24% |
| Sanderling | *Calidris alba* | 18 000 | 20 000 | 11% |
| Dunlin | *Calidris alpina* | 320 000 | 340 000 | 6% |
| Common Redshank | *Tringa totanus* | 77 000 | 94 000 | 22% |

the maximum values of January counts over a reporting period still represent some double counting because the annual distribution of wintering birds is changing according to local weather conditions (Ridgill and Fox 1990). Therefore, it would be advisable that international reviews are based on the mid-winter counts and not on seasonal maxima.

## 3.2. A conceptual framework for estimating wintering population sizes at national level

The IWC was launched to monitor the sizes of wintering populations. However, there are several problems that hinder this. First, not all IWC sites are surveyed every year. Hence, the IWC count totals are always lower than the real population size within the IWC site network due to such missing counts. Second, the IWC is an incomplete census. There is no country even in the EU where all suitable habitat for waterbirds is completely surveyed. Coverage of the suitable habitats varies according to observer capacity, scheme design and habitat types. Inland wetlands tend to be better covered than coastal, farmland, and marine habitats. Hence, the IWC counts always underestimate true population sizes, except for a few species that fully concentrate on a few sites. It is therefore necessary to devise sampling and analytical methods that help to estimate the size of the population outside of the IWC site network for those species where the count coverage is particularly incomplete. Fig. 3 presents a conceptual framework for estimating wintering population sizes at the national level. The centre represents the actual counts at the IWC sites. First, it is necessary to account for missing counts in the network indicated by the middle circle. Second, counts from the IWC network need to be complemented by either increased efforts to achieve truly total counts or use sampling-based methods to estimate the population size outside of the IWC site network. This step is represented by the outer circle.

## 3.3. Accounting for missing counts within the IWC network at national level

As shown in Table 2, the proportion of missing counts is very high in some countries. Traditionally, missing counts were estimated using the sum of the site-level five-year means (Monval and Pirot 1989, Rüger et al. 1986). More recently, some countries are using imputed values produced with the Underhill-index (Prŷs-Jones et al. 1994) or TRIM (van Strien et al. 2001). Such imputing can work well if the number of missing counts is very limited but can easily lead to spurious results if there are a lot of missing counts. If the trend analysis is only carried out on a selection of sites that are more regularly surveyed, i.e., monitoring sites (van Roomen et al. 2013), it should be recognised that the imputed totals will be valid only for this subset of sites. Therefore, our recommendation is that if the proportion of sites with missing counts is higher than about 10%, applying the site-level five-year means is a more robust approach than using the results of imputing from trend analyses. In addition, the site inventory has to be carefully checked before imputing for (partly) duplicated sites and for sites that do not exist anymore; otherwise, there is a very high risk of overestimating the population size. For example, the officially reported wintering number of Greylag Goose *Anser anser* in Spain (210 000–239 000 individuals) is much higher than it was ever recorded in the country, and it is well known that the wintering population is declining in Spain (Ramo et al. 2015).

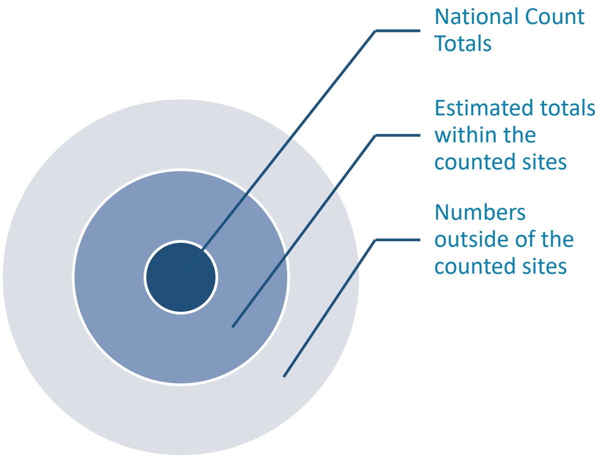


Figure 3. Conceptual framework for estimating population sizes of wintering waterbirds (see text for details).
*Konzeptioneller Rahmen für die Schätzung der Populationsgrössen überwinternder Wasservögel (Einzelheiten siehe Text).*

## 3.4. Estimating population sizes outside of the IWC site network

Marine, coastal and farmland habitats are usually not well covered by the IWC counts, either because of their large extent or because they are difficult to access for volunteer observers. However, estimating population sizes for some widespread and common species (such as Mallard *Anas platyrhynchos*, Common Coot *Fulica atra*, or Common Moorhen *Gallinula chloropus*) and cryptic species (such as Western Water Rail, Common and Jack Snipe *Lymnocryptes minimus*) at inland wetlands is usually also not possible through the IWC counts. Available methods applied for different habitat types are reviewed below.

## 3.5. Waterbirds at sea

Some seaducks (e.g., Long-tailed Duck *Clangula hyemalis*) winter in off-shore areas, and their population sizes cannot be monitored well from the shores. Land-based surveys may deliver reasonable numbers for restricted areas close to the shore (Pehlak et al. 2006). Often, however, population sizes of seaducks are underestimated in land-based surveys (Nilsson 1975, Markones et al. 2019) and population trends in the nearshore area may not be representative for the whole population (ICES 2017, Markones et al. 2019). In the Baltic Sea, for example, seaducks, divers and some grebes (Red-necked Grebe *Podiceps grisegena*, Horned Grebe *P. auritus*) do not occur in representative proportions in coastal waters, and thus their population size and trends cannot be assessed in a reasonable way with IWC data only (ICES 2017). For these species, offshore bird surveys have to be carried out by boat or plane, to access and cover core areas of offshore waterbird occurrence. Surveying waterbirds at sea is well established, and several coordinated counts have taken place in the Baltic Sea in 1992–1993 (Durinck et al. 1994), 2007–2009 (Skov et al. 2011) and also in 2016 and 2020/2021 (ICES 2020). Regular off-shore surveys also take place in some of the North Sea countries (e.g., in Belgium, Denmark, Germany, and the Netherlands), but not in others, despite on-going impact assessment studies at off-shore windfarms (Frost et al. 2019). The survey methodology is well established, based on line-transect methods using distance sampling (Camphuysen et al. 2004). Population estimates for offshore areas can be produced using species distribution models linking bird numbers to environmental factors (Skov et al. 2011, Heinänen et al. 2017, Mercker et al. 2021). Estimates of numbers and trends are improved by accounting for imperfect detection, effects of distance, state of the sea, flock size, and choice of survey platform (Buckland et al. 2001, 2012, 2015, Mercker et al. 2021).

## 3.6. Coastal birds

The coastline of just the European Union is 68 000 km long (European Environment Agency 2020). Understandably, not all these areas can be covered by observers. The IWC mainly covers estuaries and coastal lagoons, where waterbirds congregate in large numbers. However, several species winter dispersed along the rocky shores and sandy beaches (e.g., Ruddy Turnstone *Arenaria interpres*, Sanderling *Calidris alba*, Eurasian Oystercatcher *Haematopus ostralegus*, Grey Plover *Pluvialis squatarola*). The Winter Shorebird Count was undertaken in 1984–1985 to assess population sizes of waders wintering along the non-estuarine coast of the UK (Moser and Summers 1987). In 1997/98 the first European Non-Estuarine Coastal Waterbird Survey (NEWS) covered 12 European countries along the Atlantic and West Mediterranean coasts (Rehfisch et al. 2008a). This was followed by two other NEWS surveys in the UK and Ireland in 2006/07 (Austin et al. 2009, Crowe et al. 2012) and 2015/16 (Austin et al. 2017, Humphreys et al. 2020), but no coordinated survey has taken place in the last 25 years despite the original intentions (Rehfisch et al. 2008b) and the launch of the East Atlantic Flyway Monitoring programme in 2014 (van Roomen et al. 2013). Consequently, even the more recent population estimates for waders based on wintering counts (van Roomen et al. 2015) are likely to remain underestimates.

## 3.7. Farmland foraging waterbirds

In the context of this paper, farmland birds refer to waterbird species that feed predominantly or extensively on farmlands away from major wetlands. Many of these species (e.g., geese, cranes, gulls, Great White Egret *Ardea alba*) still gather for roosting at wetland sites and can be counted when flying in or out from the roost sites (e.g., Cranswick 2011a). Counting multispecies flocks may be difficult particularly in the case of geese and gulls. Therefore, often large numbers of unidentified birds are reported, so it is necessary to apply some sort of sub-sampling during such counts and to report extrapolated numbers at species level (e.g., Cuthbert et al. 2018). Cormorants are not farmland birds, but they are also often counted at roost sites in farmland areas (Parz-Gollner et al. 2015).

Another approach is to count waterbirds foraging on farmlands at their feeding areas. This method is applied to geese, to overcome some of the problems associated with identification problems when counting large moving flocks at dawn or dusk, to swans (Cranswick 2011b, Hall et al. 2016, Beekman et al. 2019, Laubek et al. 2019), to Eurasian Golden Plover *Pluvialis apricaria* (Rasmussen and Gillings 2007, Kleefstra et al. 2009, Gillings et al. 2012), and more occasionally to Northern Lapwing *Vanellus vanellus*. Covering large areas of farmland, even if only targeting regularly used sites, requires a huge observer effort. Therefore, international censuses for swans or Golden Plovers are only carried out periodically, once in every five or six years, and achieving full coverage is usually not possible, especially in eastern Europe (Rasmussen and Gillings 2007, Gillings et al. 2012). Similar cycles of total counts and more limited counts at monitoring sites are also proposed to monitor geese and swans in Germany (Wahl et al. 2022).

Integrated Population Models (IPMs) have been used to produce more precise estimates of the size of the biogeographic populations of Pink-footed Goose *Anser brachyrhynchus* (Johnson et al. 2020), Taiga Bean Goose *A. fabalis fabalis* (Johnson et al. 2020) and Barnacle Goose *Branta leucopsis* (Baveco et al. 2021, McIntosh et al. 2021). IPMs represent an advanced approach to modelling, in which all available demographic data are incorporated into a single analysis (Schaub and Abadi 2011) and have many advantages over traditional modelling approaches, including higher precision of population size estimates, and the ability to handle missing data. However, although IPMs can account for random error in counts, they cannot account for systematic bias (e.g., imperfect detection) without additional information (Kéry and Schaub 2011).

## 3.8. Inland wetlands not covered during the IWC

Although many inland wetlands are covered by the IWC, this is nowhere complete, even in countries with high numbers of observers such as the UK, Germany, or the Netherlands. Large fractions of many common waterbird species (e.g., Mallard, Gadwall *Mareca strepera*, Tufted Duck *Aythya fuligula*, Common Coot, Common Moorhen, Common Sandpiper *Actitis hypoleucos*, Green Sandpiper *Tringa ochropus*) occur at smaller wetlands such as small farm ponds, urban ponds, or ditches. Therefore, it has always been a challenge to estimate population sizes based on only IWC counts for some species (Rüger et al. 1986, Monval and Pirot 1989, Scott and Rose 1996, Delany et al. 2009, Clausen et al. 2019). Often there are large discrepancies between the breeding population estimates and the wintering counts (Thorup et al. 1997). If both the breeding and the wintering areas of the populations are considered being separate, this problem can be overcome by using the breeding estimates to estimate the sizes of biogeographic populations (Hearn et al. 2018). However, this approach would not work for populations whose breeding grounds overlap (e.g., most of the duck species; Scott and Rose 1996), or would not be useful to estimate national wintering population sizes under the various international population status reporting processes, using different national criteria for site selection (e.g., Stroud et al. 2001). It is necessary to find ways to produce a better population estimate of the wintering populations in such situations, and various approaches have been applied.

One approach is to produce extrapolation factors based on intensive local studies (Kirby 1995, Kershaw and Cranswick 2003). Under this approach, the total numbers from a complete count of the study area are compared to the numbers from the standard sites only. Although the approach has several drawbacks such as being highly labour intensive, leading to small sample size, and limited representativity across landscape and habitat types (further details in Musgrove et al. 2011), it might be a sensible first step in countries with limited observer capacity. Extending this approach, Musgrove et al. (2011) estimated, for example, an extrapolation factor of 2.61 for Mute Swan *Cygnus olor*, 4.00 for Mallard, 2.12 for Little Grebe *Tachybaptus ruficollis*, 16.78 for Common Moorhen and 1.36 for Common Coot in the UK.

The Dispersed Waterbird Survey (Jackson et al. 2006) used stratified random sampling of 1-km grid squares across Great Britain to estimate the population sizes of 20 widespread waterbird species. For most species, the estimates were higher than the published national population estimates based on the Wetland Bird Survey (WeBS, the national IWC scheme in the UK), but for some species they were smaller (e.g., Great Crested Grebe *Podiceps cristatus*, Common Pochard *Aythya ferina*, Common Moorhen). However, the confidence intervals of most estimates were rather wide, reflecting the large variation in wintering waterbird numbers across the landscape.

The environmental stratification method (Méndez et al. 2015) has been developed also in Great Britain, to estimate the population sizes of 19 widespread wintering waterbird species. They defined 64 environmental strata based on four environmental layers: freshwater (eleven variables grouped into three principal components), urban coverage (low/high), mean winter temperature, and landscape type, and classified each 5-km grid square of Great Britain into these strata. They used the wintering atlas (Balmer et al. 2013) and WeBS data to estimate the population sizes.

Johnston et al. (2013) used general linear (GLM) and general additive models (GAM) to estimate the wintering numbers of waterbirds at site level in the UK, based on IWC data from the UK, Ireland, France, and the Netherlands, to predict present and future numbers at protected areas under various climate change scenarios. A similar approach could be applied also to estimate the total sizes of national populations.

Suet et al. (2021) used remote-sensed data (Modified Normalized Difference Water Index, MNDWI) to model waterbird numbers as a function of open water and other covariates in the arid areas of Sudan. However, remote sensed data on ice and snow cover could also be used to target mid-winter waterbird surveys at the northern edge of their wintering range, where weather-dependent changes can lead to severe distortion of waterbird population and trend estimates if the monitoring site network does not account for such changes (Fox et al. 2019).

## 3.9. Conclusions and recommendations

To improve the international wintering population size estimates, we recommend that the international bodies collect specifically the mid-winter (January) count data for waterbird species, unless there is another internationally agreed time period such as for the European Golden Plover (Rasmussen and Gillings 2007, Gillings et al. 2012) or for several geese species (Madsen et al. 1999).

We also recommend using the sum of the site-level five-year means of mid-winter counts (Rüger et al. 1986, Monval and Pirot 1989) to estimate population sizes within the network of sites covered by the IWC scheme when there are a lot of missing counts, instead of using the imputed totals.

The core IWC counts should be complemented by additional counts to produce better population estimates for widespread waterbird species or for species extensively using marine, coastal, or farmland habitats. As in the EU Member States, the IWC site coverage is fairly stable year-to-year; the year for international surveys focusing on waterbirds at sea and on farmlands do not matter much, as long as there is an agreed year when such surveys are implemented in each range state, as most of the species concerned are restricted to Europe and North Africa. It would be beneficial to coordinate the timing of «total counts» of wintering geese, swans and waders on farmlands among countries. Such coordinated international counts could be organised on three- or six-year cycles.

Ideally, the sampling-based surveys of coastal and inland waterbirds should be aligned with the timing of the East Atlantic flyway «total counts». The next total count will take place in 2023 and then every three years thereafter, which is strategically timed to provide input for the six-yearly EU Article 12, AEWA and European Red List of Birds reporting (the next reporting is due in 2025, covering the period 2019–2026). Such an alignment would make it possible to coordinate the collection of data in Europe with the collection of data also in sub-Saharan Africa.

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## Zusammenfassung


Nagy S, Langendoen T, Frost TM, Jensen GH, Markones N, Mooij JH, Paquet J-Y, Suet M (2022) Verbesserte Schätzungen der Populationsgrösse von überwinternden Wasservögeln. Ornithologischer Beobachter 119: 348–361.

Schätzungen der Grösse überwinternder Wasservogelpopulationen beruhen häufig auf der einfachen Addition der Zählungen aus der internationalen Wasservogelzählung. Dieser Ansatz setzt implizit voraus, dass die gesamte Population gezählt wurde, was bei vielen Arten nicht zutrifft. Infolgedessen werden die Populationsgrössen der überwinternden Wasservogelpopulationen sowohl auf nationaler Ebene als auch auf Ebene der Flyways unterschätzt. Dies hat schwerwiegende Auswirkungen auf die Analyse von Populationstrends, die Bewertung des Populationsstatus und das Management jagdbarer Arten. Um zu veranschaulichen, wie unterschiedlich die Ansätze in den einzelnen EU-Mitgliedstaaten sind, haben wir die Schätzungen, die der Europäischen Kommission gemäss Artikel 12 der Vogelschutzrichtlinie gemeldet wurden, mit den nationalen Gesamtzahlen der IWC aus denselben Ländern und aus denselben Jahren verglichen. Wir geben einen Überblick über die bestehenden Methoden, die zuverlässigere Schätzungen der Populationsgrösse erlauben, und sprechen einige Empfehlungen für ihre Verwendung in Europa aus.


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# Authors

Szabolcs Nagy is the coordinator of the African-Eurasian Waterbird Monitoring Partnership (AEWMP) and of the African-Eurasian Waterbird Census at Wetlands International. Tom Langendoen is the Data Manager of the African-Eurasian Waterbird Census. Teresa M. Frost is managing the Wetland Bird Survey (WeBS) and Goose and Swan Monitoring Programme (GSMP) at the British Trust for Ornithology. Gitte Høj Jensen is a postdoctoral researcher at the Centre for Adaptive Nature Management of the Aarhus University and represents the Data Centre of the AEWA European Goose Management Platform in the AEWMP. Nele Markones coordinates wintering offshore seabird surveys in Germany and represents the OSPAR-HELCOM-ICES Joint Working Group on Marine Birds (JWGBIRD) in the AEWMP. Johan H. Mooij is a retired head of the Biological Station of the Wesel District, editor of the Goose Bulletin and former chair of the AEWMP. Jean-Yves Paquet is the head of Department of Studies at Natagora in Wallonia, Belgium. He represents the European Bird Census Council (EBCC) in the AEWMP. Marie Suet has worked as a GIS expert at Tour du Valat and supported data management and analysis work of the RESSOURCE project and the Mediterranean Waterbird Network. Currently she is a Support and Training Officer at the Regional Geographic Information Centre of Auvergne-Rhône-Alpes.

Szabolcs Nagy, Tom Langendoen, Wetlands International, Horapark 9, 6717 LZ Ede, The Netherlands, e-mail szabolcs.nagy@wetlands.org;
Teresa M. Frost, British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU, UK;
Gitte Høj Jensen, AEWA European Goose Management Platform Data Centre, Aarhus University, Frederiksborgvej 399, Roskilde, Zealand 4000, Denmark;
Nele Markones, Federation of German Avifaunists (DDA), c/o Research and Technology Centre (FTZ), Hafentörn 1, 25761 Büsum, Germany;
Johan H. Mooij, Biologische Station im Kreis Wesel, Piestweg 4, D-46509 Xanten Wardt, Germany;
Jean-Yves Paquet, Département Études Natagora, Traverse des Muses, 1, 5000 Namur, Belgium;
Marie Suet, Tour du Valat, Le Sambuc, 13200 Arles, France