Conservation of Arctic Flora and Fauna

CIRCUMPOLAR BIODIVERSITY MONITORING PROGRAM

A Global Audit of the Status and Trends of Arctic And Northern Hemisphere Goose Populations

ARCTIC COUNCIL

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Conservation of Arctic Flora and Fauna

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Key Findings

- This audit suggests that there are between 39.0 and 39.2 million wild geese in the northern hemisphere belonging to 68 populations of 15 species.
- All but one of the populations number between 1000 and 10 million individuals. Only the Western Palearctic population of the Lesser White-fronted Goose lies on the brink of extinction with just over 100 individuals, and only the midcontinent population of lesser snow geese in North America exceeds 10 million adults.
- "White" geese (*Chen*) are most numerous (17.2 million individuals of 3 species) and all 6 populations have increased in the last 10 years.
- "Black" geese (*Branta*) number c.13.7 million individuals of 27 populations from 5 species, of which 19 populations show stable or increasing trends over the last 10 years.
- "Grey" geese (*Anser*) comprise 35 populations of 8.1-8.4 million individuals, of which 15 have declined in the last 10 years, especially in East Asia.
- Most estimates derive from total counts of all individuals, 8 populations combine some form of capture-mark-recapture approach (almost exclusively in North America) but 15 populations are based upon expert opinion, mostly in East and Central Asia. Less than half of the estimates for all populations were thought to fall within 10% of the true totals.
- Most populations showed increasing or stable trends over the last 10 years, but our ability to truly judge these trends is highly variable among populations.
- In North America, population estimates are good; trends are generally of the best quality and most populations are increasing or stable.
- Most European populations are increasing or stable, yet several populations lack effective count coordination networks to generate annual assessments of total population size and trends.
- In Central and Eastern Asia, where the greatest declines are suspected, good population estimates and count data series over sufficient long time horizons to offer a robust basis for generating trends are generally lacking, with the notable exception of excellent count data from Korea and Japan. However, the situation is rapidly improving in China, where count networks and coordination with flyway partners are being established.
- Many populations with the poorest population information are those which we suspect are showing the greatest declines.
- The most urgent priorities for the future are to (i) improve our knowledge of population distributions to better inform our definitions of discrete flyway populations; (ii) implement effective mechanisms to at least periodically measure abundance for all northern hemisphere goose populations to assess trends over time; (iii) initiate research to identify factors responsible for declining trends in populations of concern, and (iv) evaluate potential negative effects of overabundant goose populations on habitat and sympatric species.
- To interpret changes in population size, there is an increasing need to understand whether these are due to shifts in range, changes in reproductive success or changes in annual survival.
- For this reason we urge wider gathering of age ratio data, and marking programmes to provide annual assessments of reproductive success and survival, particularly amongst populations showing declines.
- There is a very clear need to establish or expand annual reporting on population size and demographic trends to make such information accessible to decision makers and stakeholders in a timely fashion.

Canada Geese. Photo Leslie Scopes Anderson

1. Overview

This report attempts to review the abundance, status and distribution of natural wild goose populations in the northern hemisphere. The report comprises three parts that 1) summarise key findings from the study and the methodology and analysis applied; 2) contain the individual accounts for each of the 68 populations included in this report; and 3) provide the datasets compiled for this study which will be made accessible on the Arctic Biodiversity Data Service.

The Arctic Biodiversity Assessment (ABA) (CAFF 2013) found that many Arctic migratory species were threatened by overharvest and habitat alteration outside the Arctic (ABA key finding 3), and noted that current knowledge of many Arctic species, ecosystems and their stressors is fragmentary, making detection and assessment of trends and their implications difficult for many aspects of Arctic biodiversity (ABA Key finding 8). This study is a direct response to the ABA implementation of recommendation 8 as reflected in Action 10.1 of "Actions for Arctic Biodiversity 2013-2021: Implementing the recommendations of the Arctic Biodiversity Assessment" (CAFF 2015).

2. Introduction

Recognising the global importance of Arctic biodiversity and that much of macro-environmental change happening on this planet is occurring faster in the Arctic than elsewhere, there is a clear need for monitoring and assessment of change in this region. Recommendation 13 in the Arctic Biodiversity Assessment (CAFF 2013) states the need to: *"Increase and focus inventory, long-term monitoring and research efforts to address key gaps in scientific knowledge identified in this assessment to better facilitate the development and implementation of conservation and management strategies"*. Areas of particular concern identified through the ABA include components that are critical to ecosystem functions. The current limited capacity to monitor and understand these changes was identified in the Arctic Climate Impact Assessment (ACIA 2004) which recommended an expansion and enhancement of Arctic biodiversity monitoring. As a result, the Arctic Council directed the Conservation of Arctic Flora and Fauna (CAFF) to develop a programme to address these needs which has taken the form of the Circumpolar Biodiversity Monitoring Programme (CBMP).

To establish conservation, mitigation and adaptation policies to promote the sustainability of living resources in the Arctic, it is essential that knowledge of the status and trends in Arctic biodiversity is available at the circumpolar level, together with an understanding of the natural and anthropogenic drivers that are shaping these trends. Armed with such knowledge, local communities and policy makers can implement evidence based policy to sustain and protect biodiversity for themselves and future generations. These requirements underpin the structure, objectives and activities of the CBMP.

The CBMP is already collecting information from existing monitoring efforts in place across the Arctic to provide more robust and timely information on what is happening in the Arctic environment. Harmonizing and integrating efforts to monitor the Arctic's living resources will allow decision makers to develop responses to challenges facing the Arctic environment in a more efficient and effective manner. The CBMP coordinates marine, freshwater, terrestrial and coastal monitoring activities while establishing international linkages to global biodiversity initiatives including the UN Convention on Biological Diversity (CBD) and the Group on Earth Observations Biodiversity Observation Network (GEOBON). The CBMP emphasizes data management (through the Arctic Biodiversity Data Service), capacity building, reporting, coordination and integration of Arctic monitoring, as well as communications, education and outreach. Experts are currently developing and implementing coordinated and integrated Arctic Biodiversity Monitoring Plans to help guide circumpolar monitoring efforts. Results will be channelled into effective conservation, mitigation and adaptation policies supporting the Arctic. These plans represent the Arctic's major marine, freshwater, terrestrial and coastal ecosystems. Although the Coastal Plan is currently under development, the other Plans have been established and are being implemented. These umbrella Plans work with existing monitoring capacity to facilitate improved and cost-effective monitoring through enhanced integration and coordination.

The Terrestrial Expert Monitoring Group (TEMG) was established under CBMP to develop an integrated terrestrial biodiversity monitoring plan to guide coordination between existing biodiversity monitoring programmes and networks. The aim of the plan was to more effectively synthesise results and more efficiently deliver monitoring results and their implications to decision makers, stakeholders and the general public. The challenges posed to biodiversity monitoring in the Arctic are enormous. Arctic ecosystems are already showing dramatic responses to existing change, especially as climate change progresses faster than predicted and more southern species show rapid encroachment on northern areas (see Key Finding 2 in CAFF 2013: *"Climate change is by far the most serious threat to Arctic biodiversity and exacerbates all other threats"*). The pace of human development, particularly oil, gas and mineral exploitation has increased, as have agricultural, industrial and urbanisation pressures and hydroelectric projects which bring problems associated with disturbance, pollution, habitat loss and fragmentation. The remoteness and enormity of the areas involved create major logistic challenges to monitoring these processes and the hitherto fragmented baseline monitoring all add to the difficulties of delivering a meaningful package of monitoring protocols that can deliver results quickly and effectively against all of the objectives set for the task.

CAFF's CBMP recognises that the limited functional redundancy in relatively simple Arctic food webs poses particular risks in the region from loss of even individual species, which can potentially have cascading effects on ecosystem state and function. It also recognises the need for the integration of single species monitoring (especially functionally important species) with an ecosystem approach to better understand ecosystem function, which includes an assessment of the performances of functional species contributing significantly to those systems and their responses to change.

2.1 So why this review about geese?

An added complication for the CBMP is that the population status and trends of many long-distance migratory bird species breeding in the Arctic are affected by other pressures and stressors throughout their annual cycle, many of which may be applied outside the geographic confines of the Arctic. Geese, for instance, are keystone herbivores that greatly impact upon the nature of Arctic plant communities by virtue of their disturbance, grazing and manuring, especially where they breed in dense colonies, as well as providing prey for predators, including many local human communities across the Arctic.

Actions relating to geese are already enshrined in the Arctic Migratory Bird Initiative (Johnston et al. 2015) which recognises the need for coordination of Lesser White-fronted Goose *Anser erythropus* conservation and for research on the impacts of white goose habitat alteration on shorebird populations. Almost all goose species, however, winter outside of the Arctic region, where they provide similar ecosystem services in sub-arctic and temperate ecosystems and where they are often important quarry species for human communities during the non-breeding season (Buij et al. 2017).

Unlike so many avian species that have suffered over-exploitation, habitat loss and degradation, many (but certainly not all) goose populations have shown more favourable conservation status than many other taxa over the last 50 years (for Europe see Fox et al. 2010, for North America see US Fish and Wildlife Service 2015, Canadian Wildlife Service 2015). Indeed, some goose populations have increased in abundance to a point where they are now considered to constitute a "problem" for diverse human interests (Fox and Madsen 2017). Foremost amongst such conflict is where geese feed upon agricultural land, where their feeding on grass, grain and root crops reduces yields (Fox and Abraham 2017, Fox et al. 2017a). However, when large numbers concentrate in the vicinity of airports, geese can create a threat to air safety, since air strikes cost large amounts of money and constitute a major risk to human life (e.g. York et al. 2000; Bradbeer et al. 2017). Furthermore, in urban areas, resident geese can cause a nuisance by fouling amenity grasslands and territorial males can cause havoc by attacking people (Lowney et al. 1997). Finally and perhaps most relevant in the present context, by the nature of their recent abundance, geese have been proven to cause trophic cascades in delicate Arctic ecosystems caused by the effects of their foraging (e.g. Ankney 1996, Jefferies and Rockwell 2002). For this reason, geese have become ecosystem engineers in a fashion not always conducive to maintaining Arctic biodiversity given the destructive nature of their localised impacts which have knock-on effects for the flora and fauna of sites affected (e.g. Milakovic and Jefferies 2003; Rockwell et al. 2003; Abraham et al. 2005, 2012; Johnston et al. 2015; Buij et al. 2017).

We are also fortunate that because of their shared nature, some Arctic nesting goose populations have been subject to monitoring for some time. The pioneering Migratory Bird Convention/Treaty of 1916 laid down the basis for regulation of hunting of game birds including geese in Canada and the United States, and Mexico, Japan and the Russian Federation have since been engaged to secure coordinated management of goose populations throughout their ranges. Regulation requires monitoring to demonstrate its effectiveness, and the philosophy of the recent North American Waterfowl Management Plan (US Fish and Wildlife Service 2015), which aims to combine hunting and other regulation with coordinated habitat restoration and human dimensions research, necessitates detailed knowledge of goose population status and trends to gauge effectiveness of management, regulatory and conservation actions. Similarly in Europe, concerns about catastrophic declines in waterbird abundance (Berry 1939), led in the 1950s to the development of continent-wide assessments of the status and trends in abundance of ducks, geese and swans there (Boyd 1963, Atkinson-Willes 1969, Fox et al. 2010, Fox and Madsen 2017).

Snow Geese. Photo Chantal Lepire

One of the core aims of the CBMP is to ensure that Arctic ecosystem monitoring is coordinated and that the initiative is truly circumpolar, and while goose monitoring has continued apace in recent years, it is evident that the effort has not been coordinated and that, seen in a circumpolar perspective, in some areas, the monitoring is deficient compared to other biogeographical regions. For this reason, it was felt that a major review of the status of the goose populations breeding in the Arctic was long overdue and that a major effort should be invested in gathering available information on all circumpolar goose populations. The major objective of this initiative was to establish a current assessment of the size of each discrete "flyway" population (whether biologically defined or established for the expedience of effective management). The secondary objective, wherever possible, was to determine a rate of change in overall abundance in recent years, preferably over a short (10 year) time span and an assessment of change in abundance over the longest span of years available to set the time series in perspective.

These estimates in themselves are complex and achieved in different ways. For some species and populations, it is possible to determine the absolute numbers of individuals in a population by coordinated counts at all known sites, whilst for others, an estimate is only possible by counts at many sites and extrapolation to an informed estimate. A few less well documented or poorly counted populations have had to be estimated based on nothing more than the best assessment or estimate of an expert. For yet others, where sufficient capture-mark-recapture or band recovery data have been available, it has been possible to generate so called Lincoln estimates (Lincoln 1930) of total population size, where the absolute abundance is not possible to assess using traditional count and survey techniques (Alisauskas et al. 2009). There is also variation in at what stage within the annual cycle an assessment of total population abundance is undertaken: some occur in spring after the rigours of winter (and therefore after the majority of hunting and natural mortality has occurred) but others, driven by expedience, may be undertaken in autumn or mid-winter. For a very few populations, we rely upon breeding estimates to generate population abundance estimates. However, this exercise in itself is important in context because by default it provides a gap analysis of the entire range of northern hemisphere goose species and flyway populations to establish for which of these we have good data and for which we need to radically improve coverage (and in what way) to better contribute to circumpolar coverage.

A third objective was to attempt to assess the demographic drivers behind population changes where these are known. In populations where it is known that hunting mortality has a major effect on survival, assessing annual survival in relation to known levels of hunting exploitation provides potential for manipulation of survival rates to incorporate into effective management plans (e.g., through an adaptive management framework, Madsen and Williams 2012). Likewise, management actions to restore improved conservation status to populations suffering declines because of reductions in breeding success are more likely to be effective when these are implemented on nesting areas where limiting factors operate to restrict breeding success. Hence, knowledge of demographic factors affecting population changes can be of immediate value for implementing conservation actions. Inevitably, levels of demographic assessment are far less widely available, because assessing annual breeding success requires specialist knowledge and the ability to sample age ratios in populations where first year individuals can be distinguished in the field in sufficient numbers to provide such assessments. Likewise, gathering information on adult and sub-adult annual survival over long time periods necessitates investment in expensive and ornate capture-mark-recapture programmes which are not usually the norm, but can be highly instructive where such long term data exist. Reviewing the existence and utility of such approaches is also extremely important in undertaking an audit of the existing data, establishing the degree to which such data are available for all the populations and in helping to establish best practice where such schemes are being implemented.

2.2 Some working definitions

There has been, and there will continue to be, considerable debate about what constitutes discrete goose populations around the northern hemisphere. For some species and specific populations, we confess that our knowledge is very rudimentary (even in Europe and continental North America) and we are certain the suggestions for defining populations we have put forward here will change and will need to be better refined in the future. Our starting point has been the structure established by the Waterbird Population Estimates online database, managed by Wetlands International (2015), but in cases where we have found that the biogeographical definitions of some populations are perhaps less than optimal, we have tried to come up with constructive alternatives. Obvious cases include the Central Flyway and Western Canada Geese (see sections N9 and N10) that mainly breed in prairie/parkland ecoregions of western Canada and the United States and were formerly managed as five separate wintering units. Nonetheless, we are the first to concede that this type of process is a work in progress and the situation will continue to evolve as long as more information is forthcoming.

For each of these defined flyway populations, we have invited expert authors to contribute a block of standard text, detailing breeding areas, wintering areas, an estimate of population size and trend, as well as trends in reproductive success and survival. The extent of available and accessible knowledge varies enormously, but whilst we urged contributing authors to keep their accounts as short as possible, in the case of some of the less well-known populations, much novel and unpublished material was collated and synthesised for the first time, with the result that the style and length of the accounts varies enormously with the nature and knowledge of each population. Nevertheless, we hope you the reader will forgive what appears to be very uneven coverage of different populations.

We have also been highly uneven in our treatment of established, released and feral populations. In North America, temperate-nesting Canada Geese are of major interest and importance for hunting and so we have included these in our accounts. However, we have chosen not to feature the status and trends associated with feral populations of most Greylag, Canada and other geese escaped or introduced in parts of mainland Europe, because of the lack of good monitoring data. We have made an exception of the Greylag Geese in Britain, where a management policy decision has recently been made to amalgamate native and introduced Greylag Geese within the United Kingdom (see Mitchell et al. 2012). As a result, in this case, monitoring programmes are in place to effectively monitor these geese within the UK, whereas this is not the case for other species and other parts of Europe. This is not to imply that such information is not vital with respect to tracking the growing problems associated with such introduced native and especially alien species, including geese. However, given the problems associated with gathering data on these poorly covered and less well understood populations, it was decided that it was too difficult to assess their status and trends in any meaningful way at the present time. We likewise have not included treatments of Aleutian Islands nesting Cackling Geese reintroduced from Japan and Lesser Snow Geese reintroduced to Arctic Russia. We recognise the importance of monitoring the progress of development of such goose populations in the future and urge all range states to initiate and develop monitoring mechanisms so that it might be possible to address this need in the immediate future. Although this audit has been carried out under the Arctic Council banner with CAFF and the CBMP, it was decided to include all northern hemisphere goose species (with the exception of the near-tropical Nene or Hawaiian Goose *Branta sandwichensis* about which there is a rich existing literature). We feel this was a logical decision given the fact that in North America, some Canada Goose *Branta canadensis* and Cackling Goose *B. hutchinsii* populations straddle both Arctic and sub-Arctic regions and the same is true of species like the Bean Goose *Anser fabalis* and the Greylag Goose *A. anser* in Eurasia. Omitting the very few remaining non-Arctic species of the tribe Anserini, such as the Swan Goose *A. cygnoides* and Bar-headed Goose *A. indicus*, seemed not to make sense in such an exhaustive review (especially as they winter sympatrically with many Arctic goose species) and are therefore included here for completeness.

3. Methods

3.1 Geographical scope

This report includes all Northern Hemisphere goose populations, with the exception of the non-migratory near-tropical Hawaiian Goose that has an existing rich literature (e.g. Kear and Berger 1980, Black et al. 1997, Banko et al. 1999, US Department of the Interior 2004). This has the primary aim of reporting on the status and trends of all species populations that spend some time in the Arctic (as defined by CAFF) during their annual cycle, but has resulted in the inclusion of a very few species for whom the Arctic does not form part of their natural range. The latter category includes species such as the Swan Goose and the Bar-headed Goose as well as some southern forms of Taiga Bean Goose and Greylag Geese which nest and winter south of Arctic Regions in Eurasia and Canada Geese that do the same in North America.

3.2 Taxonomic treatment

A full list of the species and their component populations is given in Table 1 of the Analysis section of this report and in Tables 1, 2 and 3 below. The taxonomic basis for the species classification used throughout follows the Handbook of the Birds of the World (del Hoyo et al. 1992) except for the North American forms where we adopt the latest version of the American Ornithologists' Union Checklist which splits the Canada Goose *Branta canadensis* into small-bodied forms previously treated as subspecies of *B. canadensis* and recognized now as *B. hutchinsii* and the larger bodied forms which remain as *B. canadensis* (Banks et al. 2004). This means that we have retained the large-bodied forms within the category Canada Goose *B. canadensis*, which here we include as the subspecies *canadensis, interior, fulva, occidentalis, parvipes, maxima*, and *moffitti*, differentiated from those of the Cackling Goose *Branta hutchinsii* which we here take to include subspecies *B. h. hutchinsii, leucopareia, taverneri* and *minima* as formerly recognized by Delacour (1954) within "Canada Geese". We also retain the genus *Chen* for the Emperor Goose and the white geese of North America. Information on subspecies of other species largely follows del Hoyo et al. (1992), although we have chosen to drop the existence of *Anser fabalis johanseni* for which there seems little current genetic or ecological justification as a separate taxon (Heinicke 2010, Ruokonen and Aarvak 2011).

3.3 Definition of populations

Our true knowledge and understanding of what functions as genuine biological populations amongst goose species remains extremely rudimentary. Our goal here has been to define populations that constitute a discrete entity using a "flyway" or corridor of breeding, moulting, staging and wintering areas which define the range for a given set of individuals that use these sites and routes annually (after Atkinson-Willes et al. 1982). Since our aim has been to provide an assessment of change in abundance over short periods of the immediate past (specifically over the last ten years and for longer periods where available), to some extent this constrains us to what has previously been considered discrete "populations" from a pragmatic viewpoint. These definitions in many cases are based upon knowledge from extensive marking programmes that over many years have established relationships between discrete breeding, moulting, staging and wintering areas. For many of the populations described here, there are maps plotting band recoveries on a continental scale to justify such definitions. For many populations, there exists a good working definition in the Waterbird Population Estimates online database, managed by Wetlands International (2015). For some populations, our knowledge is very much still evolving as in the case of the Western Taiga Bean Goose *Anser fabalis fabalis*, which despite its relatively small numerical size has a complex set of relationships between extensive dispersed breeding areas and a reasonably limited wintering range. In this case, the radically contrasting population trends between different elements of the breeding population have underlined the need to establish a better understanding and a series of telemetry studies is beginning to shed light on the flyway population structure of this subspecies as we write. We are the first to concede that our biogeographical definitions of some populations fall very far short of what we need to know. However, we have tried to do our best to create a constructive framework, usually by trying to aggregate the limited knowledge we may have, as for example in the case of some of the Greylag Goose populations across Eurasia, where there is little information from banding data to relate breeding areas to winter quarters. In the particular case of the Greylag, we have tried to aggregate geese counted on discrete areas of the wintering grounds that constitute expedient "management units" in the sense that these can be monitored as discrete units, and in the fullness of time managed, in a coordinated fashion even if time shows these groupings not to reflect the biological reality of major population structure. As stressed in the Introduction, we consider this an evolving process. Hence while knowledge of some of the well-studied flyways will not change, many others will become far better understood and our ability to monitor these more effectively will improve with time. We hope that by establishing such a framework, this report offers a foundation for the continuing improvement of our understanding as more information flows in.

3.4 Population estimates

The estimates presented here are provisional and time stamped based on the accumulated wisdom of the authors concerned and the hard data which they present in each of the population accounts. Most coincide with the current Wetlands International (2015) Waterbird Population Estimates online database, some represent our improved knowledge as a result of the analyses presented in this report. As will be evident from tables in the Analysis sections, these estimates are not necessarily directly comparable across species. Most are derived from mid-winter counts, but coordinated count inventories of some populations by necessity are done at other times. Since survival during migration and through the hunting season may have substantial effects on total population size, these factors should be born in mind when comparing between populations. Most of the estimates of population size are derived from total counts, which may or may not be a good means of estimating overall abundance. Others use capture-mark-recapture and Lincoln estimate approaches combining marking, resightings and hunting effort and recovery data to estimate total population size which has the advantage of generating confidence intervals on estimates. Such approaches invariably produce estimates in excess of estimates based on head counts. Some populations (both based on total counts or other methods) have been reported as representative means derived from a defined period of several years, rather than a specific number in a given year. For some populations, we have very little idea of the true number of individuals and for a very few populations, the estimates are not recent. Despite the different methods for deriving abundance estimates, each is presented with the data trail for its derivation, so the nature of the estimate and the method by which it was obtained are clear and in the tables in the Analysis section we have also attempted to provide an explanation of the type of the estimate presented and an associated quality score so it is possible to assess the nature and reliability of each estimate.

3.5 Population trend estimates

Wherever possible, we have sought to provide some assessment of the direction of rate of change and its magnitude. For a few species, this is difficult, but for many populations we have good data to construct trends in abundance over more than 20 years. Nevertheless, robust trends require systematic collection of good quality data, and inevitably some populations lack long term or systematic gathering of data to enable such analysis. As was the case for judging absolute contemporary population size, the quality of data varies considerably between populations, some have long time series upon which to base the assessment of their rate of change, others have only been monitored in sufficient detail in part of their total range or only a short time span. For others, our knowledge is so poor that we can only suggest that numbers are far greater or less than at the time other observers were clearly able to show they were relatively more or less common. Hence, for capture-mark-recapture and Lincoln estimates we can provide detailed modelled assessments of population change and we can fit regression or general linear models to total count or incomplete count data to generate rates of change where possible. These approaches are also described in the individual population accounts and are itemised in the summary tabulations.

Snow Goose goslings. Photo Katelyn Luff

3.6 Assessment of changes in breeding success and survival

As a tentative first step towards understanding the changes in relative abundance of what we define to be a closed population, it is helpful to be able to compile some long term assessment of relative change in breeding success as a measure of birth rate and mortality as a measure of death rate removing individuals from a given population. For some populations we have very good measures of these parameters, especially in species where the first winter offspring of the year are readily distinguishable in the field from older adult birds. For others, there exist age ratios generated from detailed monitoring of nesting success and/or ratios of young caught in banding drives as indices of annual productivity. For some populations, regular banding and hunting recovery data and capture-mark-recapture studies of marked geese in non-hunted populations generate long term series of annual survival data. Such information is invaluable in providing supporting information about the demographic processes contributing to overall changes in population size. Unfortunately, such data exist for relatively few of the populations, but where these runs of data are available the authors have presented these here as a contribution to understanding population processes.

Nesting Emperor pair. Photo Casey Setash

4. Analysis

4.1 Why gather such information anyway?

Beyond human curiosity, there are very good reasons for assessing the size of goose populations, but also for wishing to understand more about their relative rates of change over time and the processes that drive these changes. As we have seen, many goose populations are becoming super-abundant as a result of the provision of a surfeit of food, particularly on the wintering grounds, provided by a landscape created by us as a result of modern forms of agriculture. In contrast, yet other forms (such as those goose populations that still overwinter on wetlands, which are suffering habitat loss and degradation, as in China, Yu et al. 2017) are suffering from declines in number that require conservation actions to maintain and enhance their abundance. For these reasons, there are good grounds for attempting to at least generate actual estimates of the abundance of total flyway populations of geese. Where this is not possible, we may need to rely upon expert opinion, or perhaps best of all possibilities, by generating Lincoln-Peterson estimates of population size: these are based on capture-mark-recapture designs that produce robust population estimates with confidence intervals that enable specific determinations of population trajectories and hence determine definitively whether populations are significantly increasing, decreasing or remaining stable. Counting at the same sites on a regular basis can also contribute to time series of abundance that can yield growth rates over time with error bands around such estimates.

Having established a direction and crude rate of change, management actions require a more basic understanding of the processes driving this change. Throughout this report, we have attempted to describe population change for units of geese that we consider in some way discrete, as flyway populations. We tend to think of these as being largely closed, in the sense that the changes in their annual abundance are almost exclusively the result of the balance between changes in reproductive success (birth rate) and mortality (death rate) in a given year. For this reason, knowledge of long term changes in annual survival and reproductive success can be fundamental to understanding the reason why a population is increasing or declining. In the case of the Greenland White-fronted Goose *Anser albifrons flavirostris*, it is the case that stable survival over 30 years has failed to balance a more recent reduction in overall annual production in this particular population in the last 15-20 years. As a result, after a period of expansion in numbers when net reproductive success exceeded annual survival, the population has shown a consistent decline in very recent years when this situation was reversed. Such insight not only enables the identification of the potential causes of the declines, but may also provide a basis for direct management interventions, as in the case of restricting hunting in a population where it is evident that mortality exceeds annual reproductive success. Equally such knowledge and understanding can provide insight to increase the harvest on a population where reproductive success and survival conspire to provide undesirable levels of year on year increase in population size.

With the increasing awareness of the need for adaptive management of goose populations to restore populations of unfavourable conservation status to former levels of abundance and potentially to maintain rapidly increasing populations at levels compatible with their long term survival, the need for such information is becoming ever more urgent. This is nowhere better expressed than in Madsen et al. (2014) where the case is made very strongly for the need to derive all the parameters discussed above (specifically robust estimates of population size and error estimates, annual age specific and year specific survival rates and annual reproductive success, as well as age at first breeding and annual breeding propensity as further desirable parameters for modelling population change).

For this reason, in this section, we review the extent, quality and existence of these sources of data across all the populations reported here to assess the extent of knowledge and to identify the gaps in our current monitoring efforts.

Blue Snow Goose. Photo Reg Aupperle

4.2 Tables of results

In order to provide a set of overviews for comparison, in Tables 1, 2 and 3, we summarise the available census data for all the goose populations subject to detailed treatment. In a few cases we provide data for sections of the wintering areas for which we have finer grained detail than at the flyway level. This is especially the case for goose populations that winter in Japan and Korea where time series of count data are available for which there are no detailed annual counts from the rest of the wintering range. Otherwise these populations are treated as the rest of the populations addressed in the text. For each population we have tried to provide a uniform set of assessments relating to population size estimation.

4.3 Population size estimation

In an ideal world, we would wish to generate population estimates for each defined goose population from a series of independent sources to confirm the veracity of each assessment. The most optimal means for generating population estimates would be a carefully designed, random stratified sampling approach that generated error- and bias-free annual estimates with assessments of their associated uncertainty. These provide the potential not only to generate robust estimates but also provide a statistical basis for making comparisons over time to show significant increases, decreases or lack of change over appropriate time periods. For several populations in North America, such estimates are derived from data generated from aerial surveys of the nesting areas and are identified in the following tables as derived from "Survey". For the Greater Snow Goose, the primary source of annual abundance data is a complete photographic survey conducted each spring in southern Quebec during staging. All flocks are photographed, and a subsample is counted and extrapolated to estimate population size. This contributes what are probably the most reliable estimates of population size for any goose population in North America, greatly aided by its narrow geographic distribution at that time of year.

Other estimates for North American populations are carried out on the basis of capture-mark-recapture techniques (e.g. *elgasi* Greater White-fronted Geese) and Lincoln estimates generated from harvest estimates and band recovery data to estimate total population size which are also identified clearly in the tables.

Unfortunately, such assessments very rarely exist and in Europe at least, the tradition has tended to be that attempts are made to count as many geese within each defined population as possible in mid-January (represented as "Count" in the following tabulations), when most aggregated and therefore easiest to count (see Fox et al. 2010). On the positive side, because such inventories have been carried out in some cases back to the 1950s, there can be unusually long runs of historical data upon which to make contemporary comparisons of population size and distribution. However, even such inventory approaches are fraught with problems, because such counts are inevitably often subject to distributional changes related to winter severity, changes in agricultural cropping and rely heavily on careful international cooperation and coordination where populations are distributed across neighbouring range state borders. Some populations have traditionally been counted at times other than mid-January because for various reasons, they are easier to count simultaneously at other points in the annual cycle and are identified by the month or season in which these take place.

For some of these populations, we provide a lower and an upper estimated population size where these best equate to the level of our current knowledge, but in fact most populations are given as a single value rather than an estimated band. We provide a year for the assessment or a span of years where the authors have considered it better to provide an average assessment over a period of years. We have reasonable estimates of all Northern Hemisphere goose population sizes from the last 5-10 years, with the notable exception of the central Asian wintering population of Taiga Bean Geese and the Caspian Sea/Iraq wintering population of White-fronted Geese *Anser albifrons* for which there has been no more recent population assessment than in the mid-1990s. Although we are very open to concede that the quality of counts supporting the estimates of many populations are poor (see below), we can at least be confident that many of the assessments presented here are based on the latest available data.

For each population estimate and trend assessment, we have provided a six-point quality code based on the following categories from Fox et al. (2010):

Extent of data	Data underlying estimate
0. Expert guess	None or very little
1. Poor data quality	Few actual counts, no representative counts and/or count covering insignificant sections of the population
2. Partly based on good survey data	Well described counts and surveys, allowing extrapolation with some confidence, at least for >5% of the population
3. Some regions well covered, covering >50% of the total estimate	Counts cover 5-50% of estimated total population
4. Good coverage of >50% of total estimate	At least half of the population covered by counts or surveys
5. Full coverage, estimate likely to be within 10% of true total	Almost all of the estimated population accounted for from regular coordinated counts or surveys

Table 4.1. Full summary tabulation of the estimated population sizes of all global grey goose *Anser* populations as reviewed in this report. Columns provide the year of the estimate, the nature of the data used to generate the estimate and their quality (see the list of codes on page 12 for a full explanation of the quality codes). Also shown are the month from which data were used to generate population estimates (1 = January, 2 = February or season as appropriate). The current (last 10 years) and longer term (>10 years but time series depending on population) trends are then provided, with the method used to identify these trends, the direction and scale of annual percentage change (where known) for identified periods of years with a quality code

Flyway Population	Population estimate					Population trend					
	Size	Year	Nature	Quality	Month/ season	Current trend (10 year)	Long term trend (>10 year)	Method	Rate (% per annum)	Period	Quality
***Anser fabalis* (Bean Goose)**											
A1 *fabalis*, North-east Europe/North-west Europe	52,000	2015	Count	4	1	DEC	DEC	Total	-6.0	2006-2015	4
A1 *fabalis*, W Siberia/central Asia	1,000-5,000	2008	Expert	2	Winter	DEC	DEC	Expert			1
A2 *rossicus*, Siberia/NE & SW Europe	600,000	2013	Count	5	1	INC	INC	Total	+2.6	1990-2013	4
A3 *middendorffi*, Okhotsk/Kamchatka-Japan	6,000	2007-2011	Count	4	1	DEC	DEC	Expert			4
A3 *middendorffi*, Yakutia/E Asia	6,000	2007-2011	Best guess	0	1	DEC	DEC	Expert			0
A3 *middendorffi*, Sayan/E China	6,000	2007-2011	Expert	2	Winter	DEC	DEC	Expert			0
A4 *serrirostris*, Russia/Japan	2,000	2007-2011	Count	4	1	?STA	?STA	Expert			4
A4 *serrirostris*, Russia/Korea	60,000	2007-2011	Count	4	1	?STA	?STA	Expert			4
A4 *serrirostris*, Russia/China	52,000 – 156,000	2007-2011	Expert	2	Winter	?STA	?STA	Expert			1
***Anser brachyrhynchus* (Pink-footed Goose)**											
B1 East Greenland & Iceland/UK	540,000	2015	Count	5	11	INC	INC	Total Total	+3.9 +2.8	1960-2013 2004-2013	5 5
B2 Svalbard/North-west Europe	76,000	2014	Count	5	Spring	INC	INC	Total Total	+3.6 +5.4	1965-2013 2004-2013	5 5
***Anser albifrons* (Greater White-fronted Goose)**											
C1 *albifrons*, Russia/North-west Europe	1,000,000	2012	Count	4	1	STA	INC	Total Sample Sample	+7.7 +2.5 +0.8	1958-2008 1988-2012 2003-2012	4 4 4
C1 *albifrons*, Western Siberia/Central Europe	163,000	2013	Count	4	1	INC	INC	Sample Sample	+7.5 +6.5	1988-2012 2003-2012	4 4
C1 *albifrons*, Western Siberia/Black Sea & Turkey	245,000	2013	Expert	1	1	INC	INC	Sample Sample	+1.4 +9.2	1988-2012 2003-2012	3 3
C1 *albifrons*, Northern Siberia/Caspian & Iraq	15,000	1995	Best guess	0	1	DEC	DEC	Sample Sample	-8.9 -36.9	1988-2012 2003-2012	3 3

Flyway Population	Population estimate					Population trend					
	Size	Year	Nature	Quality	Month/ season	Current trend (10 year)	Long term trend (>10 year)	Method	Rate (% per annum)	Period	Quality
C2 *flavirostris*, Greenland/Ireland & UK	18,800	2016	Count	5	3	DEC	STA	Total Total	-2.8 0	1999-2014 1983-2014	5 5
C3 *elgasi*, Alaska/California	<10,000	2015	CMR	4	Winter	STA	STA	CMR	0	2003-2015	4
C4 *frontalis*, Alaska/California	685,500	2016	Survey	5	Autumn	INC	INC	Sample Sample	+5.2 +1.5	1985-2015 2006-2015	5 5
C5 *frontalis*, Mid-Continent	2,600,000	2006-2015	Lincoln adults	5	7	STA	INC	Lincoln Lincoln	+5.2 -0.5	1975-2014 2005-2014	4 4
C6 *frontalis*, China	55,000	2015	Expert	3/4	Winter	DEC	DEC	Total	-	2002-2014	1
C6 *frontalis*, Japan	138,000	2007-2011	Count	5	1	INC	INC	Total Total	+10.1 +10.7	2002-2011 1996-2011	5 5
C6 *frontalis*, Korea	85,000	2007-2011	Count	5	1	INC	INC	Total	+11.2	1999-2011	5
***Anser erythropus* (Lesser White-fronted Goose)**											
D1 C & E Siberia/China	16,000	2015	Count	3/4	Winter	DEC	DEC	Expert			2
D2 Fennoscandia	105 - 120	2016	Count	4	4/5	INC	DEC	Total Total	-5.0 +15.1	1993-2008 2007-2016	5
D3 W Siberia/Caspian & SW Asian	30,000	2016	Count	3	Autumn	DEC	DEC	Expert			1
***Anser anser* (Greylag Goose)**											
E1 *anser*, Iceland/UK & Ireland	95,400	2016	Count	5	11/12	INC	INC	Total Total	+1.5 +1.2	1960-2013 2004-2013	5 5
E2 *anser*, UK	140,000	2011	Index	5	1	INC	INC	Sample	+9.4	1988-2008	4
E3 *anser*, NW Europe/South-west Europe	960,000	2014	Count	4	1	INC	INC	Total	+8.5	1980-2008	4
E4 *anser*, Central Europe/North Africa	100,000	2014	Index	3	1	INC	INC	Sample	+6.8	1995-2008	2
E5 *rubrirostris*, Black Sea & Turkey	25,000-50,000	2014	Expert	1	1	DEC	DEC	Expert			0
E6 *rubrirostris*, Western Siberia/Caspian & Iraq	150,000-200,000	2014	Expert	0	Winter	DEC	DEC	Expert			0
E7 *rubrirostris*, Central Asia	25,000	2014	Expert	0	Winter	DEC	DEC	Expert			0

Flyway Population	Population estimate					Population trend					
	Size	Year	Nature	Quality	Month/ season	Current trend (10 year)	Long term trend (>10 year)	Method	Rate (% per annum)	Period	Quality
E8 rubrirostris, Far East Asia	15,000	2014	Expert	0	Winter	DEC	DEC	Expert			0
***Anser cygnoides* (Swan Goose)**											
F1 C & E Asia	75,000	2012	Expert	3	Winter	DEC	DEC	Expert			1
***Anser indicus* (Bar-headed Goose)**											
G1 C, S & SE Asia	97,000 - 118,000	2016	Expert	1	Winter	STA	STA	Expert			1

Table 4.2. Full summary tabulation of the estimated population sizes of all global white goose *Chen* populations as reviewed in this report. Columns provide the year of the estimate, the nature of the data used to generate the estimate and their quality (see the list of codes page 12 for a full explanation of the quality codes). Also shown are the month from which data were used to generate population estimates (1 = January, 2 = February or season as appropriate). The current (last 10 years) and longer term (>10 years but time series depending on population) trends are then provided, with the method used to identify these trends, the direction and scale of annual percentage change (where known) for identified periods of years with a quality code.

Flyway Population	Population estimate					Population trend					
	Size	Year	Nature	Quality	Month/ season	Current trend (10 year)	Long term trend (>10 year)	Method	Rate (% per annum)	Period	Quality
***Chen canagica* (Emperor Goose)**											
H1 North America	98,000	2015	Count	5	Spring	INC	STA	Count Count	+0.4 +1.7	1985-2015 2006-2015	5
***Chen caerulescens* (Snow Goose)**											
I1 *caerulescens*, Midcontinent	12,600,000	2006-2015	Lincoln adults	5	August	INC	INC	Lincoln Lincoln	+6.3 +1.1	1970-2014 2005-2014	5
I2 *caerulescens*, Western Arctic	1,000,000*	2006-2015	Lincoln adults	5	August	INC	INC	Lincoln Lincoln	+5.8 +7.2	1971-2014 2005-2014	5
I3 *caerulescens*, Wrangel Is	300,000	2016	Count	5	Spring	INC	INC	Count Count	+2.1 +6.4	1975-2015 2006-2015	5
I4 *atlanticus*	876,000	2016	Count	5	Spring	STA	INC	Count Count	+6.4 -0.2	1965-2015 2006-2015	5
***Chen rossii* (Ross's Goose)**											
J1 North America	2,350,000	2006-2015	Lincoln total	5	August	INC	INC	Lincoln Lincoln	+11.7 +8.5	1975-2014 2005-2014	5

*Lincoln estimates from the combined Western Arctic/Wrangel Island population produce estimates of 1,160,000 individuals in 2014, rounded here to 1,000,000 for the Western population, the population trend provided here is also therefore for both units combined, whereas the Wrangel Island trend is based only on spring census data for their population trend

Table 4.3. Full summary tabulation of the estimated population sizes of all global black goose *Branta* populations as reviewed in this report. Columns provide the year of the estimate, the nature of the data used to generate the estimate and their quality (see the list of codes on page 12 for a full explanation of the quality codes). Also shown are the month from which data were used to generate population estimates (1 = January, 2 = February or season as appropriate). The current (last 10 years) and longer term (>10 years but time series depending on population) trends are then provided, with the method used to identify these trends, the direction and scale of annual percentage change (where known) for identified periods of years, with a quality code.

Flyway Population	Population estimate					Population trend					
	Size	Year	Nature	Quality	Month/ season	Current trend (10 year)	Longterm trend (>10year)	Method	Rate (% per annum)	Period	Quality
***Branta bernicla* (Brent Goose)**											
K1 *bernicla*, Western Siberia/ Western Europe	211,000	2011	Count	5	1	STA	INC	Count Count	+5.6 +0.6	1956-2010 2002-2011	5 5
K2 *hrota*, Svalbard/Denmark & UK	10,000	2017	Count	5	Winter	STA	INC	Count Count	+2.4 0	1987-2015 2006-2015	5
K3 *hrota*, Canada & Greenland/ Ireland	32,000	2014	Count	5	10	DEC	INC	Count Count	+5.4 -1.0	1996-2014 2005-2014	5
K4 *hrota*, US Atlantic Coast	209,000	2001-2015	Lincoln adults	5	Winter	DEC	STA	Count Count Lincoln	+0.3 -2.1 -2.3	1961-2016 2007-2016 2005-2014	5
K5 *hrota/nigricans*, western Canadian high Arctic	9,000	2012	Expert	3	Winter	STA	STA	Count	0	1991-2011	3
K6 *nigricans*, Japan, Korea, China (non-bre)	10,000	2015	Best guess	0	Winter	?STA	?STA	Expert			0
K7 *nigricans*, E Pacific (non-bre)	150,000	2016	Count	5	1	STA	INC	Count Count	-0.1 +1.4	1960-2015 2006-2015	5
***Branta leucopsis* (Barnacle Goose)**											
L1 East Greenland/Scotland & Ireland	80,700	2015	Count	5	Spring	INC	INC	Count Count	+3.6 +3.9	1959-2012 2003-2012	5
L2 Svalbard/South-west Scotland	38,000	2016	Count	5	1	INC	INC	Count Count	+6.6 +4.4	1956-2013 2004-2013	5
L3 Russia/Germany & Netherlands	1,200,000	2015	Count	4	1	INC	INC	Count Count	+7.8 +9.9	1960-2014 2000-2014	4
***Branta ruficollis* (Red-breasted Goose)**											
M1 Northern Siberia/Black Sea & Caspian	50,000-100,000	2016	Expert	2	1	INC	INC	Count	+4.2	1954-2008	5

Flyway Population	Population estimate					Population trend					
	Size	Year	Nature	Quality	Month/ season	Current trend (10 year)	Longterm trend (>10year)	Method	Rate (% per annum)	Period	Quality
***Branta canadensis* (Canada Goose)**											
N1 Atlantic flyway resident (various subspecies)	1,200,000	2016	Survey	5	Spring	DEC	INC	Survey	-1.5	2006-2015	5
N2 *canadensis/interior*, "North Atlantic"	162,000	2016	Survey Adults	5	Spring	INC	STA	Survey Survey	-0.5 +3.2	1996-2015 2006-2015	5
N3 *canadensis/interior*, "Atlantic"	663,500	2016	Survey	5	Spring	DEC	INC	Survey Survey	+6.6 -3.9	1988-2015 2006-2015	5
N4 *fulva*, Vancouver	25,000	1997-2002	Survey	5	Winter	STA	STA	Count	0	1997-2002	4
N5 *interior*, Eastern Prairie	185,600	2015	Survey	5	Spring	STA	STA	Survey Survey	+0.9 -0.9	1972-2015 2006-2015	5
N6 *interior*, Mississippi Valley	346,000	2015	Survey breeding adults	5	Spring	DEC	DEC	Survey Survey	-1.5 -3.7	1989-2015 2006-2015	5
N7 *interior*, S James Bay (breeding)	61,000	2015	Survey	5	Spring	DEC	STA	Survey Survey	+0.2 -4.9	1990-2015 2006-2015	5
N8 *maxima*, Giant (Mississippi flyway)	1,530,000	2016	Survey	4	Spring	STA	INC	Survey Survey	+2.9 +0.8	1993-2015 2006-2015	4
N9 *moffitti*, Central Flyway	2,800,000	2016	Survey adults	5	Spring	INC	INC	Survey Survey	+3.9 +4.2	1955-2015 2006-2015	5
N10 *moffitti*, Pacific Flyway	508,000	2015	Survey adults	5	Spring	INC	INC	Survey Survey	+4.7 +2.4	1955-2015 2006-2015	5
N11 *occidentalis* Dusky	13,230	2016	Survey adults	5	Spring	INC	DEC	Survey Survey	-1.2 +6.5	1986-2015 2006-2015	5
N12 *parvipes* Lesser	3,100	2015	Survey	5	Spring	DEC	STA	Survey Survey	-0.2 -10.4	1964-2015 2006-2015	5
***Branta hutchinsii* (Cackling Goose)**											
O1 *leucopareia*, Aleutian-California	156,000	2016	CMR	5	August	INC	INC	Count Lincoln	+14.0 +6.9	1975-2015 2006-2015	5
O2 *minima* Cackling	328,000	2016	Survey adults	5	Spring	INC	INC	Survey Survey	+4.8 +2.2	1985-2015 2006-2015	5
O3 *hutchinsii* Midcontinent population	3,600,000	2005-2014	Lincoln adults	5	August	INC	INC	Lincoln Lincoln	+6.9 +2.2	1975-2014 2005-2014	5
O4 *taverneri* Taverner's	35,400	2015	Survey	5	Spring	DEC	DEC	Survey Survey	-1.4 -5.0	1986-2015 2006-2015	5

On the basis of these data, we can see that the majority of the goose populations fall within 10,000 to 1 million individuals, with only one (the Fennoscandian Lesser White-fronted Goose) numbering just over 100 individuals and only one population (Midcontinent Lesser Snow Goose *Chen caerulescens caerulescens*) exceeding 10 million individuals (Figure 1).

4.4 Nature of the population estimates

For each assessment, we provide a description of the nature of the estimate. Again, these differ substantially between the different global flyway regions, reflecting the different nature of the solutions found to assessing annual population size for these birds. Many, especially in Europe, are generated from assembling total counts (usually undertaken on the wintering grounds) and attempting to correct for those individuals not covered. For species returning to the same regularly used wintering resorts, this is probably a reasonably good method

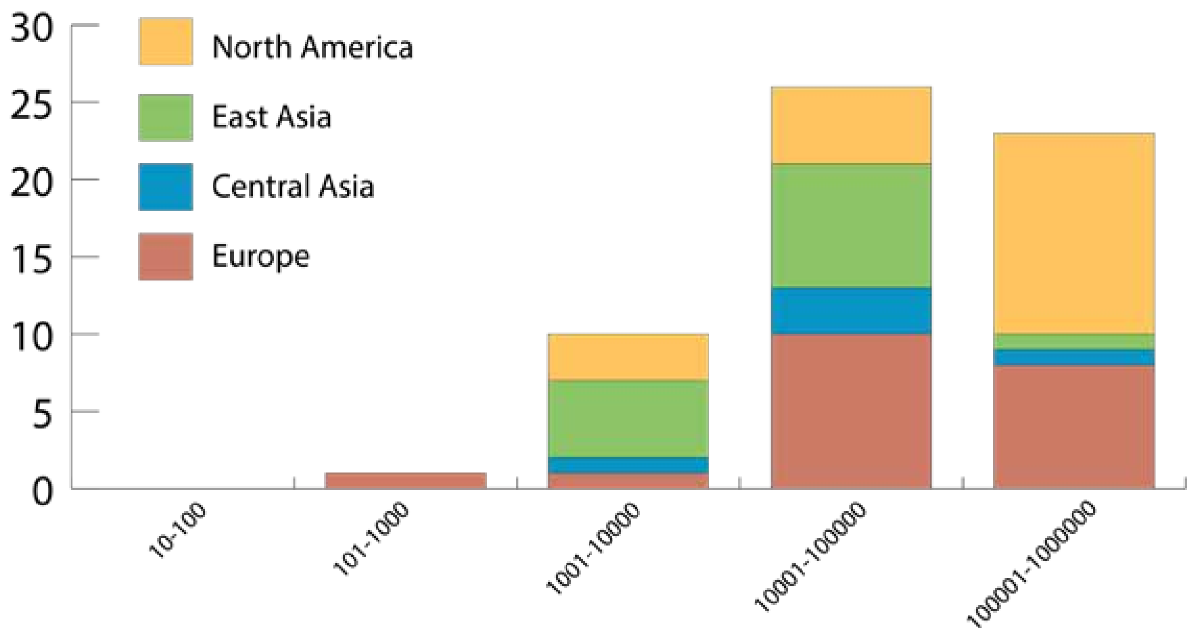


Figure 1. Frequency distribution of goose population size by numerical abundance and global flyway region.

Barnacle goose. Photo Bengt Nyman

to apply as long as all sites are covered and techniques are available to estimate missing counts. For many other populations, total abundance estimates are generated by survey, either by generating systematic counts on the winter quarters and using various techniques to generate estimates for areas not covered, or at autumn staging areas or from aerial line transects corrected for detection probability and extent of available suitable habitat.

4.5 Data quality

4.5.1 Estimates of population size – methods

Different methods have been used to derive population estimates in different parts of the Northern Hemisphere. In Europe, it has been the tradition that counts have been carried out on the wintering grounds where birds are aggregated into large concentrations (as for example flying to roosts or feeding in dense flocks on farmland), generating count totals with bias and error associated with such methods. Hence, the assessment of total population abundance consists of the sum of all counts with the addition of an assessment of those missed during the counts. In North America, intensive investment in capture-mark-recapture and assessment of direct recovery and ring reporting rates enable other techniques to be used to generate independent estimates of population size along with variance of these estimates. Other North American goose populations are regularly enumerated using aerial survey transects, where goose densities can be generated and related to detection error and habitat associations to generate breeding pair and (incorporating groups of non-breeders) total population size on the breeding areas. The latter two methods are less used in Europe and Asia, where for the less well known species, expert opinions are used for our best available assessment of population size at the present time (Figure 2)

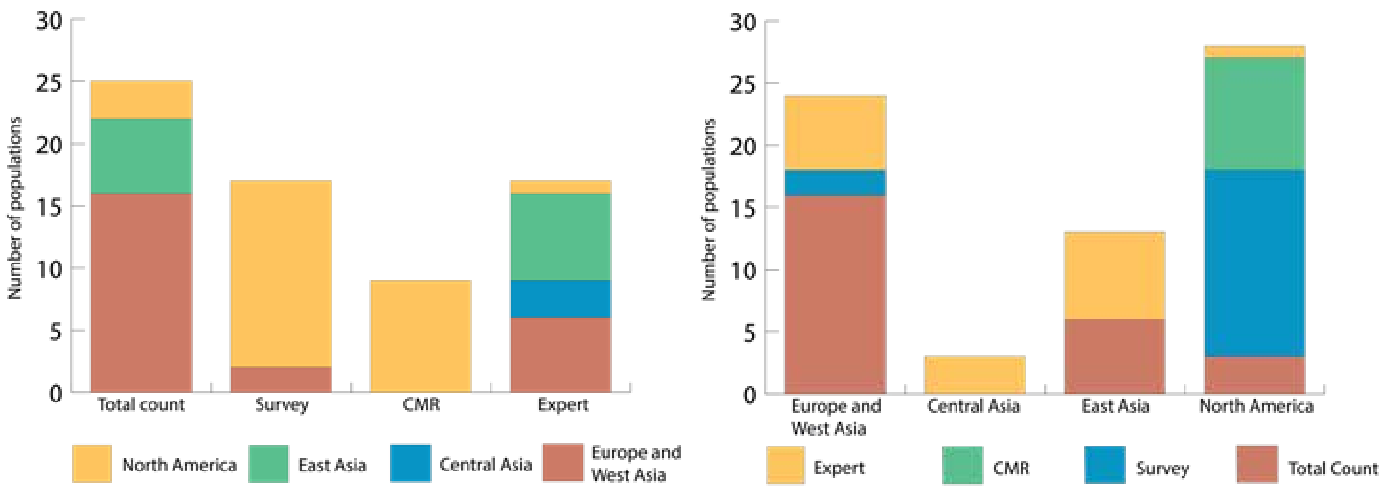


Figure 2. Left: Relative contributions of total counts, survey, capture-mark-recapture and expert assessment to the estimation of total population sizes in the four flyway regions. Right: Relative use of the four different techniques to estimating total population size in each of the four flyway regions.

Greater Snow Geese. Photo Chantal Lepire

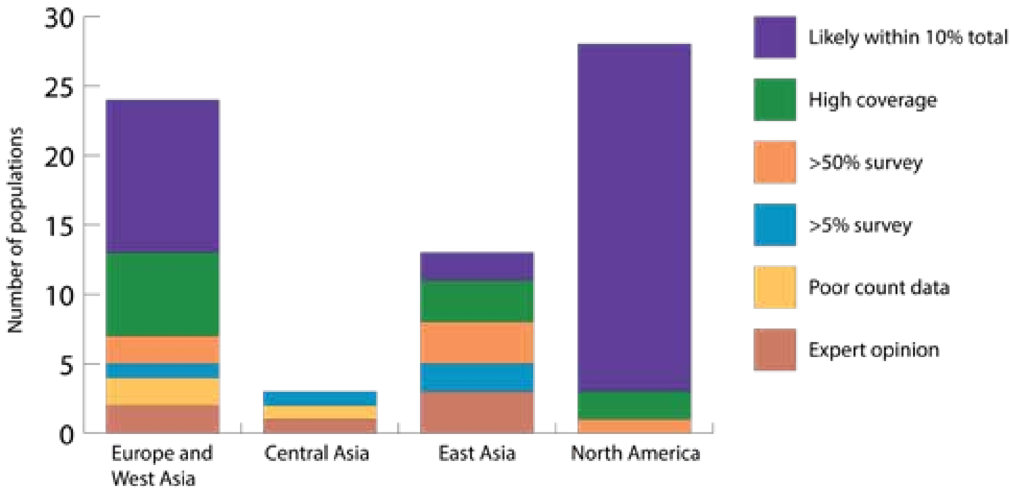


Figure 3. Frequency distribution of the different accuracy assessment codes of goose population size broken down by global flyway region.

4.5.2 Reliability of the estimates of population size
We have attempted to provide quality codes for each of the population abundance estimates, using a rather subjective six point score from 0 to 5 (see Section 4.3 for full details of the classification). While it is clear that North America and Europe have very good assessments for many of their populations, the situation is less good in Central and East Asia (Figure 3).

However, in absolute terms, the reality is that over 50% of all populations have estimates that likely fall close to the true population size and relatively few populations have assessments that are based on knowledge of <5% of their suspected total size, indeed, only six are completely based on expert opinion (Figure 4).

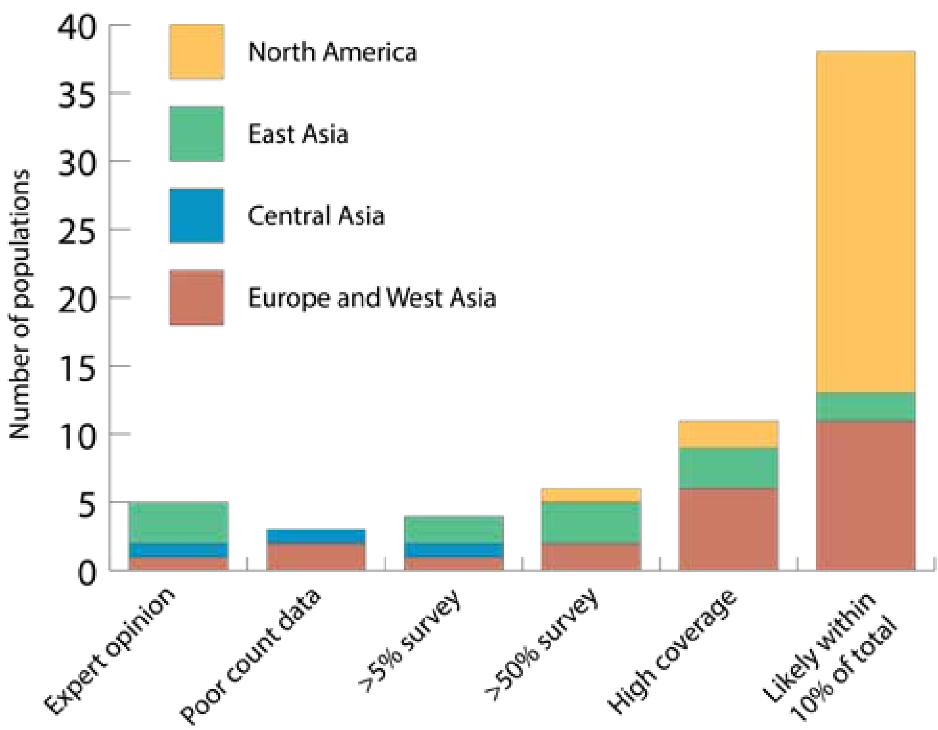


Figure 4. Frequency distribution of the different accuracy assessment codes of goose population size.

4.6 Timing of the counts used to estimate population size

The vast majority of estimates of the abundance of goose populations are based on mid-winter counts and surveys, especially in Europe, since this was traditionally the period when the birds were most aggregated, accessible and countable (Figure 5). In recent decades in North America, there has been increased effort to undertake aerial surveys in spring on nesting areas, when many Canada goose populations are thought to be most discrete geographically. Thus, this period contributes disproportionately on that continent and recent Lincoln estimates of population size are based on estimates of birds alive in July and August (when they are captured and marked) which contribute to the coverage at this time of year (Figure 5).

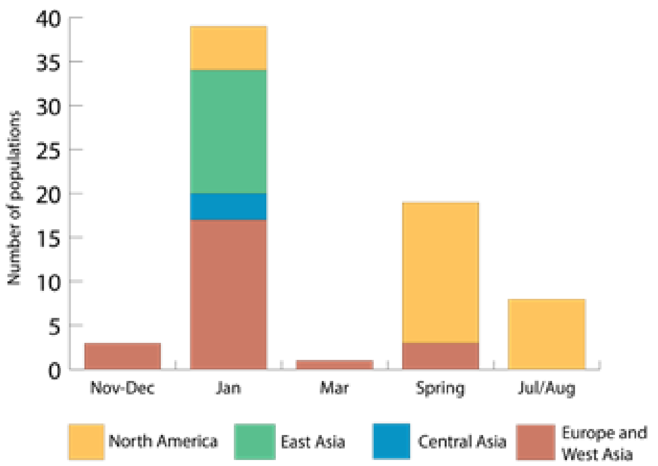
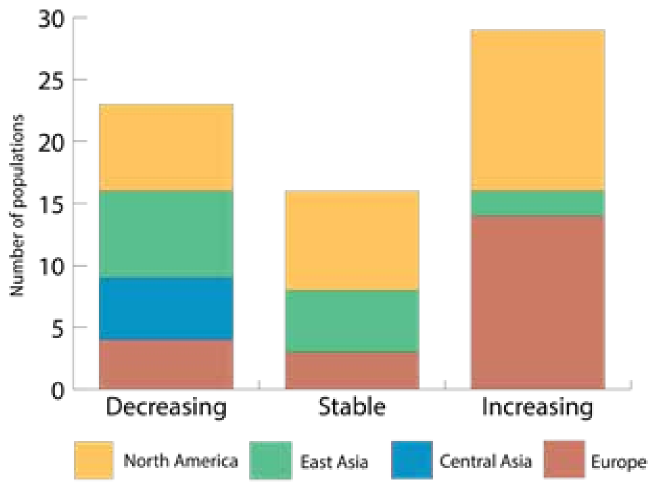


Figure 5. Frequency distribution of the timing of goose population abundance broken down by global flyway region.

4.7 Summary of short- and long term trends

The majority of Northern Hemisphere goose populations are increasing or showing stable trends in the last 10 years (Figure 6). All Central Asian goose populations are considered to be declining and the majority of East Asian populations are either stable or declining. In contrast, the majority of European and North American goose populations are stable or increasing over both time periods.



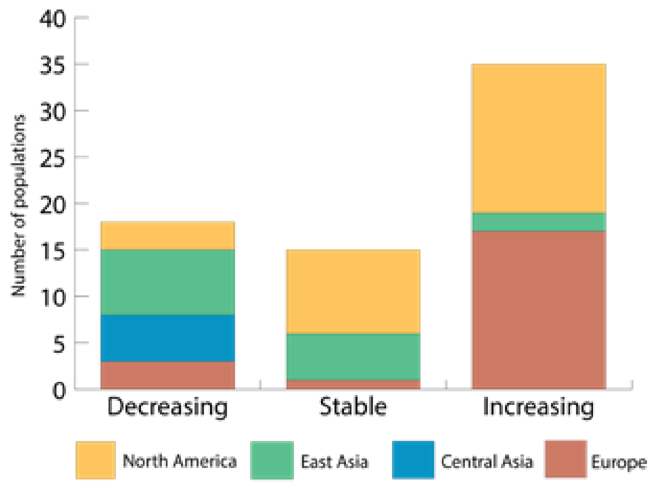


Figure 6. Top: Frequency distribution of Northern Hemisphere goose populations showing decreasing, stable and increasing trends over the last 10 years. Bottom: Frequency distribution of Northern Hemisphere goose populations showing decreasing, stable and increasing trends over the periods for which data were available in excess of 10 years. Note the number of populations, especially in North America that have shown stable trends in the last 10 years after preceding periods of increase.

Black Brant Geese . Photo Chris Nicolai

4.8 Reliability of the estimates of short (10 year) and longer term (>10 years) trends in population size

We have also attempted to provide quality codes for each of the population trend estimates, using a similar six point score from 0 to 5, there being no difference in quality assessments between the two sets of estimates for populations for which both are available (see Section 4.3 for full details of the classification). For the longer term trends, while it is clear that North America and Europe have very good assessments for many of their populations, the situation is less good in Central and East Asia (Figure 7).

None the less, over 50% of all populations have estimates that likely fall close to the true population size, few populations have assessments that are based on knowledge of <5% of their suspected total size, indeed, only seven are completely based on expert opinion (Figure 8).

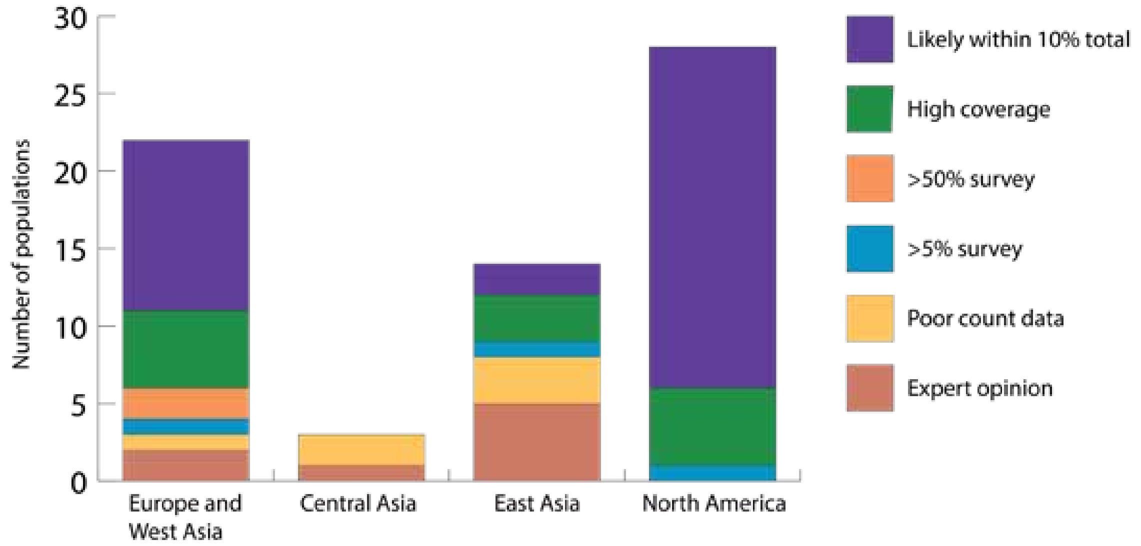


Figure 7. Frequency distribution of the different accuracy assessment codes for the reliability of trends in goose population size across the global regional flyways.

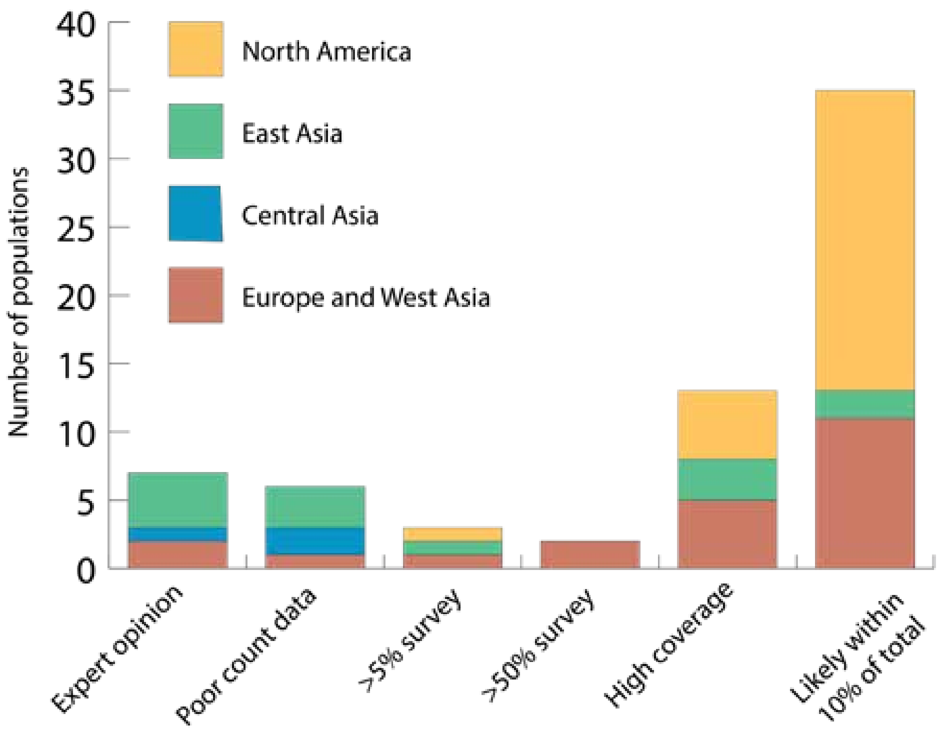


Figure 8. Frequency distribution of the different accuracy assessment codes for the reliability of trends in goose population size.

4.9 Availability of data on reproductive success and survival

Clearly there is considerable virtue in monitoring demographic parameters of goose populations in order to interpret the processes driving overall changes in abundance of Northern Hemisphere goose populations. Increases in abundance can come about by enhanced reproductive output, elevated survival rates or a combination of both. Equally, faced with severe overall declines in abundance, it is helpful to know if excessive harvest is the reason for adverse changes (and which therefore can be managed) rather than reduced breeding success. When built into an adaptive management framework, these parameters become vital elements in assessing the effects of coordinated management interventions, providing feedback to management decisions about what actions have an effect and which ones do not. Building long time series of such data are invaluable for providing a baseline for scale and variation, but the scale of availability of such data varies considerably.

In Europe, there has been a tradition of gathering field age ratios through "Citizen Science" networks that voluntarily contribute to counting of geese, but also sampling the numbers of first winter birds (based on plumage differences where possible) following standard protocols. In North America, such data are available through a number of mechanisms which for some species involve assessments of nesting success and numbers of young counted on breeding areas, as well as by measuring the proportions of young in the hunting bag in fall and winter. The latter are also carried out in Iceland and Denmark, but regrettably nowhere else in Europe. As a result, the majority of North American goose populations have some long-term assessment of annual reproductive success extending over reasonable time scales (>20 years) and this is reasonably the case for Europe as well. In those species from the Central and East Asia flyways where such information is most important, such data are almost totally lacking, but some data are now being collected and will gather to form an important resource in the future (Figure 9).

In North America, neck collar marking to generate capture-mark-recapture assessments of first year and adult survival amongst specific goose populations has mostly been dropped because of negative effects of collars on survival probability, but there continues to be large scale investment in metal leg banding (mostly through large scale banding programmes on breeding areas during flightless moult). When it comes to monitoring goose populations in North America, "Citizen Science" contributes vast amounts of data in the form of leg band recoveries, as well as information about species- and age-specific harvest of geese by hunters. When combined with age-specific estimates of harvest in defined geographic areas, band recovery data from the same geographic area can be used to estimate population size of both juvenile and adult age classes at the time of marking, as well as providing information about seasonal distribution, and annual survival and harvest rates (e.g., Alisauskas et al. 2006, 2011). In Europe, there has been a more recent pattern of field-readable collar and leg band marking that generates high levels of resighting probability through Citizen Science networks that voluntarily contribute to the discovery and reporting of marked geese, but these estimates inevitably suffer from the problems associated with such marking methods. Therefore, for approximately half of all populations on both continents, there exist annual survival rates that extend over reasonable (>20 year) periods with which to assess long term changes in survival. As a result, the majority of North American goose populations have some long-term assessment of annual survival extending over several years although this is less the case in Europe. Again, in the species from the Central and East Asia flyways where such information is arguably the most important because of general lack of knowledge on status, distribution and changes in abundance over time, such data are almost totally lacking. However, capture and marking of geese in the East Asia flyway is beginning, which means that information is now being gathered that will contribute to an important set of data in the future.

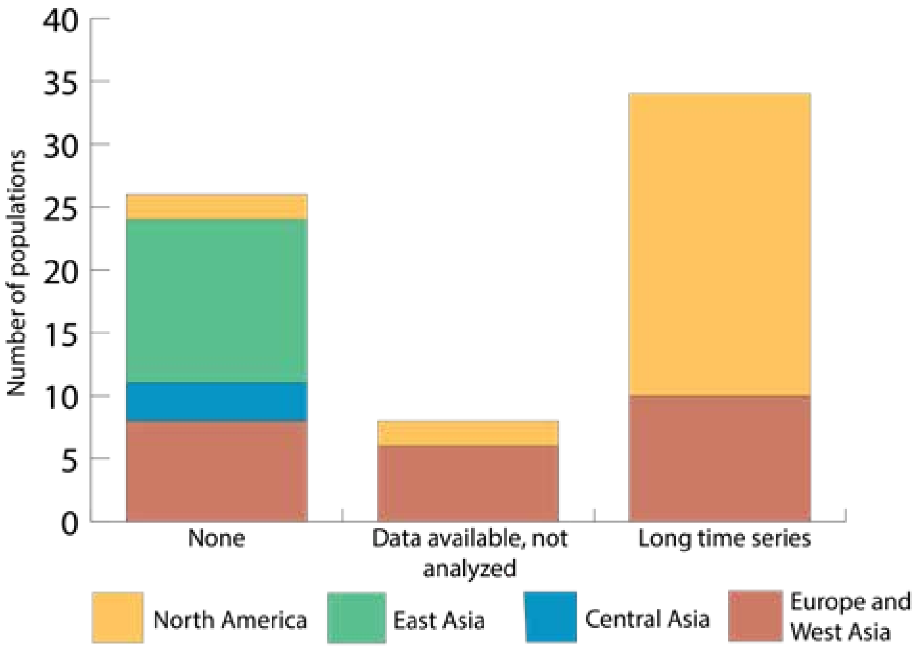


Figure 9. Frequency distribution of the availability of long-term annual assessments of reproductive success amongst goose populations in the different global flyway regions.

4.10 Number and size of goose populations in the northern hemisphere

4.10.1 Grey geese

In this report, in the detailed population accounts, we have worked on the basis of 4 populations of Bean Geese, 2 of Pink-footed Geese *Anser brachyrhynchus*, 6 Greater White-fronted Geese, 3 Lesser White-fronted Geese, 8 Greylag Geese, 1 Swan Goose and 1 Bar-headed Geese amongst the "grey" geese of the genus *Anser*. Improvements in knowledge which are already coming from telemetry studies of geese, especially in East Asia, are likely to provide better definitions of flyways and further separations of these units, but for the time being, in the body of this report we present 25 detailed accounts. In the tabulations, we have further subdivided some East Asian populations into their wintering numbers in Japan, Korea and Russia for the purpose of presenting contrasting trends. These further subdivisions result in 4 further Bean Geese


Greylag Geese . Photo Dani Kauf

and 3 Greater White-fronted Geese sub-units for which we can generate trends, plus 3 additional Greater White-fronted Geese sub-units in western Eurasia for which there appear to be contrasting population trends in recent years. This therefore results in an estimated total of between 8.14 and 8.35 million grey geese in the northern hemisphere at the present time. In the last ten years, it is considered that 15 of these populations have declined, 7 show stable or fluctuating trends and 13 are increasing. Over longer (but variable) time periods which are therefore not so comparable, 15 of these populations declined, 6 showed stable or fluctuating trends and 14 increased.

4.10.2 White geese

Throughout the report about population accounts, we have worked on the basis of 6 populations of three species of "white" geese of the genus *Chen*. These include 1 population of the Emperor Goose, 4 of the Snow Geese and 1 Ross's Goose without further subdivision. This results in an estimated total of 17.2 million white geese in the northern hemisphere at the present time. All these populations are considered to be increasing, both over the last ten years and over longer time periods.

4.10.3 Black geese


Ross's goose. Photo Reg Aupperle

The report addressed 27 separate populations of "black" geese of the genus *Branta* from 5 species: 7 Brent Geese (*Branta bernicla*), 3 Barnacle Geese (*B. leucopsis*), 1 Red-breasted Goose (*B. ruficollis*), 12 Canada Geese and 4 Cackling Geese. Overall, we estimate a total population of 13.7 million birds in the northern hemisphere. In the last ten years, it is considered that 8 of these populations have declined, 8 show stable or fluctuating trends and 11 are increasing. Over longer (but variable) time periods which are therefore not so comparable, 3 of these populations declined, 8 showed stable or fluctuating trends and 16 increased.


Brant Geese. Photo Christopher Sharp

5. Conclusions

This audit found evidence to suggest that during 2011-2016, there were at least 39.0 million geese in the northern hemisphere belonging to 68 populations of 15 different species. Of these, the most numerous were the "white" geese of the genus *Chen* which numbered an estimated 17.2 million individuals of 3 species, most of which are restricted to North America and all of which have increased in the last 10 years. The "black" geese *Branta* numbered an estimated 13.7 million individuals of 27 populations from 5 species, showed more variable trends, but all but 8 of these populations showed stable or increasing trends over the last 10 years. The "grey" geese comprise 35 populations which totalled an estimated 8.1-8.4 million individuals and, with the exception of the circumpolar Greater White-fronted Goose, are confined to Eurasia. Fifteen of these populations showed declines in the last 10 years, especially in East Asia. The majority of populations fell between 1000 and 1 million individuals in size, and only the Western Palearctic population of the Lesser White-fronted Goose lay on the brink of extinction with just over 100 individuals.

However, this report is by no means any sort of final statement on the true distribution and abundance of northern geese, this remains very much a work in progress, with massive room for improvement, even in Europe and North America. Our knowledge of the size of many of these goose populations at the present time varies enormously and we have attempted to review the range of different techniques and methods used to assess each of the population sizes across the northern hemisphere. Most estimates derived from attempts to obtain total counts of all individuals, lesser numbers used systematic sampling and extrapolation to obtain estimates, and for 8 populations, some form of capture-mark-recapture approach was used (almost exclusively in North America). Regrettably, for more than 15 populations we have had to rely upon expert opinion, mostly in East and Central Asia, because until recently assessment networks for these populations have not existed in some parts of these regions. Furthermore, less than half of the estimates for all populations were thought to fall within 10% of the true totals. With increasing numbers of many populations and catastrophic declines in others, it is becoming increasingly important that the most rudimentary of population monitoring be established for all populations as soon as possible. This is especially the case for populations thought to be showing the most rapid declines in abundance. It is also important to review the methods and systems adopted to assess total population size estimations in the future. Agreement on best practice and the most effective methods for delivery of robust population estimates will ensure better harmonisation of approach and increase our ability to compare in time and space within and between populations in the future. Such a review of methods would also be instructive with regard to ensuring the generation of best quality data for tracking trends in overall population size.

The majority of goose populations in the northern hemisphere seem to be showing increasing or stable trends over the last 10 years, but our ability to truly judge these trends is highly variable among populations. The situation is best in North America, where estimates of population sizes are good and the associated trends generally of the best quality, with the highest levels of confidence in the rate of change. The situation is very much worse in Eurasia and particularly in Central and Eastern Asia where we lack good population estimates as well as count data series over sufficiently long time horizons to offer a robust basis for generating trends, although data from Korea and Japan are excellent. The situation is improving very rapidly for instance in China where count networks are being established and coordination with flyway partners throughout the range of key species is well advanced. In Europe, several species lack effective coordination of the existing highly organised count networks to generate annual assessments of total population size and therefore the ability to generate time series to effectively assess population trajectories. In these cases there is a very clear need for an organising structure than combines national count totals to generate flyway population estimates.

For many goose populations, we still lack a good understanding of linkages between breeding, moulting, staging and wintering areas, knowledge that is fundamental to the effective identification of discrete units for management purposes. The advances in specialist marking of individuals for both field (i.e. hunter killed returns of marked birds and

Ross's Goose. Photo Jason Caswell

reading of codes on collars and leg rings) and remote (e.g. through the attachment of telemetry devices to individual geese) observations of individual movement make it easier than ever before to follow such individuals. The application of such techniques is especially relevant in East Asia, where our knowledge of population definition and flyways, as well as population size and trends, are most rudimentary.

These areas remain the most urgent priorities for the future – improvements in our knowledge of migration routes to better inform our definitions of discrete flyway populations; implementation of effective mechanisms for delivery of annual population size estimates for many of the northern hemisphere goose populations, and periodic assessments of trends over time. Once these mechanisms are in place, we shall be better able to establish the immediate priorities for action. At present, we are fortunate that most of the goose populations of the northern hemisphere are showing apparent stable or increasing trends. However, it continues to be of great concern that many of the populations for which we have the poorest population information (such as the Greylag Goose populations of Central and Eastern Asia) are those that we suspect are showing the greatest declines. To be able to adequately address these declines, we need to understand not only the rate of change in population size but also the drivers of such change – are these declines due to shifts in range, limits to reproductive success or excessive mortality? For many populations in North America, there exist long runs of annual data relating to the ratios of first winter geese to adults amongst shot samples in the population, while in Europe field age ratios are regularly undertaken based on plumage characteristics. These annual assessments of production of young provide a unique perspective on reproductive success and, in concert with capture-mark-recapture or band recovery assessment of age specific annual survival, provide the basis for hypothesis testing and generating with regard to the causes of observed changes in population size. In North America in particular, this forms the basis of a massive continent wide framework for the management of populations through hunting regulation, for example, which is conspicuous by its absence in Europe, but see Madsen et al. (2017) for an outstanding example in the case of Svalbard Pink-footed Geese and see Stroud et al. (2017) for proposals for the wider development of such mechanisms. Elsewhere in Eurasia there are few such mechanisms in place or in prospect. It is therefore increasingly important that we not only track annual changes in population size but initiate demographic monitoring of these populations to inform the necessary conservation measures for these populations in the future.

Finally, and perhaps most importantly, we see a need for developing some framework for the regular reporting of annual population size estimation to make such information available for policy development and decision makers, as well as the very many stakeholders for whom such information is vital. North America has been exemplary in producing a digest of this information for geese (as well as other hunted waterbirds) over many years (e.g., Canadian Wildlife Service 2015, US Fish and Wildlife Service 2015). Such an annual presentation of updated status and abundance data is an essential and recognised source of information to a variety of interests. It also enshrines a framework, timescale and discipline for reporting which is highly desirable. We would encourage such a development to embrace all the goose populations of the northern hemisphere in a regular reporting round that ensured an annual updating of information. This might include periodic assessments of changing distributions that may affect the efficacy of methods to estimate population size and the updating of annual assessments of reproductive success and survival where these are available.

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Canada Geese. Photo Shannon Badzinski

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White-fronted Geese. Photo Andrea Mott

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