Defining flyways, discerning population trends and assessing conservation challenges of key Far East Asian Anatidae species: an introduction

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Abstract

Long-distance migratory waterbirds contribute many ecosystem functions and services, not least as important huntable quarry species, as well as posing challenges to human societies, through agricultural crop damage, threats to flight safety and pathogen transmission. As a result, throughout much of the Northern Hemisphere, they have received considerable research attention to identify discrete population flyways upon which to build monitoring programmes, a basis for their effective internationally coordinated conservation management, especially in North America and Europe. However, until recently, we lacked comparable information about migratory Anatidae populations in Far East Asia, despite long-term monitoring programmes and some knowledge of migration routes based on Japanese satellite tracking. In this article, we set the scene for the presentation of the species accounts for 10 large-bodied Anatidae species, which follow in this Special Issue of *Wildfowl*, and which attempt to fill some of the gaps in knowledge about these important species in Far East Asia. Papers in the Special Issue combine new telemetry data, winter counts and expert knowledge on the 10 species, to update maps of the extent of breeding and wintering areas, and to define the flyways that connect them. Critical stopover sites and the remotely-sensed habitats that these waterbird populations exploit along the way are also described, to provide a basis for their more effective future conservation.

Key words *Anser*, *Branta*, *Cygnus*, distribution range, geese, *Mareca falcata*, migration routes, swans.

As autumn temperatures fall to below zero, and the wetlands of the north begin to freeze following the summer pulse of production in the Northern Hemisphere, the arctic, taiga and steppe biomes become silent as these areas are enveloped in ice and snow. With the approach of winter, these northern wetlands empty of the estimated

146 million Anatidae of 56 species (over 1 million swans, 39 million geese and some 95 million freshwater duck species; Rees *et al.* 2019; Fox & Leafloor 2018; Wetlands International 2020). These huge numbers of waterbirds exploit the surge of summer biological productivity to reproduce there, but fly elsewhere to survive the winter (Dalby *et al.* 2014). This massive movement of avian biomass is of considerable consequence to humans and natural ecosystems around the globe. Waterbirds contribute to the functioning of ecosystems as a source of mobilised nutrients, vectors of plant parts (including seeds) and invertebrates, as well as being herbivores, browsers and predators, with the potential to control pests (Green & Elmberg 2013), to the point where they are recognised as valuable indicators of environmental change (Amat & Green 2010). They have developed particular societal value to human communities, because they have long provided provisioning (*e.g.* through hunting for meat, for eggs and down) and cultural ecosystem services to westernised (Brown & Hammack 1972) and indigenous societies alike (*e.g.* Krcmar *et al.* 2010). Even the sense of awe that attracts folk to view and experience their numbers can carry considerable economic and cultural significance (Cooper & Loomis 1991).

Waterbirds: a shared resource requiring coordinated protection

This value, particularly because of their importance as huntable quarry species, was reflected in the early and wide proliferation of protective legislation and agreements to protect waterbird species as a common resource for the good of all. Safeguarding this common interest was enshrined in The Migratory Bird Treaty Act of 1918 between the United States of America and the UK (on behalf of Canada), one of the first major pieces of international wildlife protection legislation (Dorsey 1998). Subsequent international legislation (*e.g.* the Ramsar Convention of 1971, the European Union Directive 79/409/EEC on the conservation of wild birds in 1979, and the 1996 African-Eurasian Waterbirds Agreement established under the Convention on the Conservation of Migratory Species of Wild Animals adopted in 1979) bear witness to the economic and cultural importance of these shared resources and the shared inter-governmental recognition of the need to protect them at all stages of their migratory annual life cycles. In the last 60 years, modern agriculture has provided Anatidae with food resources of superior quality and quantity to that provided by natural habitats (Fox & Abraham 2017), contributing to population increases and, in some cases, conflicts with sectoral interests through crop damage (Fox *et al.* 2017a), ecosystem function (Buij *et al.* 2017) and flight safety (Bradbeer *et al.* 2017). Finally, the movements of waterbirds across the planet have the potential to transmit pathogenic diseases, which present a threat to our domestic animals or to us, as well as acting as sentinels for such outbreaks (Elmberg *et al.* 2017). This is especially the case concerning the spread of highly pathogenic avian influenza, generated within domestic poultry, that has the potential to create substantial economic loss to poultry interests as well as posing a threat to public health (*e.g.* Tian *et al.* 2015).

Fundamental to our ability to manage and protect these populations for future generations, as well to dealing with some of the challenges that their movements pose to sectoral interests in society, is a basic understanding of population abundance and their rate of change. Most waterbirds are highly site faithful (within and between years) to pockets of habitat that provide them with the energy, nutrients and safety from predation needed to sustain them through the annual cycle as they transit between their breeding and non-breeding habitats. Because such suitable habitats are often geographically isolated by intervening "deserts" of dry habitat unsuitable for the birds, the areas used by these waterbirds may be highly restricted and the numbers of individuals using them can be large. Anatidae are site-loyal to wintering sites (Roberston & Cooke 1999), to staging and breeding areas (Anderson *et al.* 1992), and to the migration corridors that connect them, all of which may be reinforced by the cultural reinforcement of long-term parent-offspring bonds in some species (Weegman *et al.* 2016). Such structuring of populations inevitably begins to create barriers to gene flow between all elements of an otherwise contiguous distribution, historically shaped and reinforced by geological processes, in response to the evolution of oceans, river catchments, mountain chains and glacial refugia. The cumulative use of linked breeding, moulting, staging and wintering areas confirm the separate nature of flyways used by different individuals of the same population, which can form the basis for population flyway structuring, ultimately resulting in genetic isolation of the elements involved.

It should be noted that throughout this Special Issue, we use the term flyway to describe the linkages throughout the annual cycle exploited by a single individual, or a group of individuals, that appear to be discrete from others, based on the results from telemetry studies of many different individuals of the same species. This differs from the Ramsar Convention definition which consists of "…many overlapping migration systems of individual waterbird populations and species, each of which has different habitat preferences and migration strategies" (Boere & Stroud 2006; Ramsar Secretariat 2018). Although we acknowledge that overlaps with the definition of a "biogeographical population" defined by Scott & Rose (1996) and subsequently adopted by the Ramsar Convention (Ramsar Secretariat 2018), we retain the term "flyway" here because we feel our knowledge has not advanced beyond our plotting of the relatively short-term trajectories of a relatively limited number of individual birds to the point where we can speak confidently about biogeographical flyways. We fully accept that these data form the basis for making such distinctions, but consider this requires more information and the actions of statutory bodies in consultation with conservation agencies to make informed decisions about such distinctions based on the available information. So it is the case that information accumulated over many decades in western Europe has led to the definition of such discrete biogeographical flyways.

One such case is the Pink-footed Goose *Anser brachyrhynchus*, which breeds in Greenland, Iceland and Svalbard and winters in the UK, Belgium, the Netherlands and Denmark. Long-term marking has shown that the Iceland/Greenland breeding birds winter exclusively in the UK, while those on continental Europe originate only from Svalbard (Madsen *et al.* 2014), despite any lack of morphological or major genetic differentiation. Such an understanding of flyway structure clearly is essential if management interventions are required for particular populations, as there is no point in restricting the harvest in the UK if hunting mortality was considered to be causing declines amongst the Svalbard-breeding Pink-footed Geese. Since these two flyways are constituted of the same species, there is likewise every need to undertake monitoring of their abundance and demographic rates in isolation to understand fully their population development and factors affecting observed changes in annual abundance.

Traditional methods for describing populations and flyways

In North America and Europe, over 70 years of dedicated research and results from marking with metal leg rings and other unique markers has accumulated considerable knowledge about the flyway structure of waterbirds on those continents. This has enabled the logical division of species into "flyway populations", linked by the common use of individuals moving annually between the non-breeding and breeding elements of their lifecycles (see for instance the pioneering work of Boyd 1961). Such definitions establish a biological and/or political basis upon which to build monitoring systems to track the status and trends in abundance of most native waterbird populations across these two continents. Alas, this has not been the case throughout much of Asia (for example, see the data summaries for the geese in Fox & Leafloor 2018). In Far East Asia, mid-winter waterbirds counts have been a regular feature in South Korea and Japan for the last 50 years, providing an invaluable perspective on long-term changes in abundance in those countries (*e.g.* Kasahara & Koyama 2010; Kim *et al.* 2016; Jia *et al.* 2016). Since the mid-2000s, monitoring of the more than 1 million waterbirds that winter in freshwater wetlands along the Yangtze River floodplain has rapidly developed and improved (see below), with resultant data indicating that numbers at these most vital Anatidae wintering areas are in decline (Jia *et al.* 2018). On the Russian arctic breeding grounds, it was very evident that there have been serious declines in a number of goose populations (*e.g.* Syroechkovskiy 2006). However, in the previous absence of historical metal ringing-recovery data and only rudimentary telemetry tracking data from pioneering studies, it has not been possible to construct a framework for defining flyway populations of waterbirds to underpin the development of rational coordinated waterbird monitoring networks across Far East Asia. So, while early survey results suggested that increasing wintering numbers of Greater White-fronted Geese *Anser albifrons* in Japan and Korea coincided with declines in China, it was not possible to know if this was because of different trajectories amongst separate wintering populations, or if declines in China merely reflected birds shifting their wintering distribution to Japan and Korea (Jia *et al.* 2016).

Applications of new technologies

There has been an increase in the use of biochemical markers to help to define discrete flyway populations of waterbirds, for instance in the use of stable isotopes (Fox *et al.* 2017b) and genetic markers (Wilson *et al.* 2018). These techniques are increasingly being applied in Far East Asia, for example to show the high degree of relatedness between Japanese- and Korean-wintering Greater White-fronted Geese based on microsatellite DNA (Moriguchi 2010) and, together with telemetry techniques, migratory connectivity of Swan Geese *Anser cygnoides* from different breeding areas (Zhu *et al.* 2020; Q. Zhu, unpubl. data). However, in the absence of many years of metal ringing recovery data, the region lacks clear information on how the movements of individual birds linking breeding, moulting, staging and wintering areas combine to provide an impression of what constitutes flyway structure and how best to monitor, manage and conserve these identifiable units ("conservation management units" *sensu* Ramsar Secretariat 2018). To the rescue, in the last ten years, has come affordable lightweight telemetry devices that record highly accurate GPS latitude and longitude positions with a time and date stamp that can be fitted to waterbird species. Suddenly, the multiple deployment of such devices has revolutionised our ability to examine in detail the movements and habitat use of a variety of different species (*e.g.* Yu *et al.* 2017; Aharon-Rotman *et al.* 2017; Meng *et al.* 2019) and to compare migration strategies within and between species (*e.g.* Wang *et al.* 2018, 2019; Deng *et al.* 2019). Telemetry devices have also enabled us to contrast individuals of the same species that are sympatric in winter, but breed in different areas and hence face different environmental challenges along their separate flyways, which affect migration phenology and potentially annual survival and reproductive output (Li *et al.* 2020). Most important of all, with the benefit of collaboration with colleagues in Russia, Japan, Korea and Mongolia, as well as elsewhere, there is now the possibility of deploying these devices in different areas throughout the breeding and wintering ranges of the key waterbird species, to begin to describe their flyway structure and connectivity across Far East Asia. After the deployment of 2,397 devices on individuals of 75 species since 2013, we are beginning to gain a basic but vital and solid understanding of these populations, how they segregate between breeding and non-breeding areas and how we might begin to recognise their flyway population structure. Such information is fundamental for monitoring these flyway populations effectively and for assessing their respective conservation management, not least in the face of climate change.

Scope of the Special Issue

Given this increase in available data, this Special Issue aims bring together information for the first time on ten key Far Eastern Asian migratory Anatidae species, namely Whooper Swan *Cygnus cygnus*, Bewick's Swan *C. columbianus bewickii*, Mute Swan *C. olor*, Brent Goose *Branta bernicla*, Greater White-fronted Goose, Lesser White-fronted Goose *Anser erythropus*, Greylag Goose *A. anser*, Swan Goose, Bean Goose *A. fabalis* and Falcated Duck *Mareca falcata*. Three international meetings were convened to facilitate this process, gathering experts, sharing data and developing an understanding of these species. The first meeting took place under the auspices of the IUCN-SSC/Wetlands International Goose Specialist Group's 16th International Conference, which was held in Beijing during 22–25 November 2014, where the idea was discussed and the process initiated (by 125 experts from 13 countries). This was followed by two international symposia to develop effective coordinated monitoring of East Asian waterbirds, held in Hulunbuir, China during 6–10 April 2017 (59 experts from 9 countries) and in Beijing during 14–18 October 2019 (66 experts from 10 countries). There was a major effort at this last meeting to gather all the key waterbird experts from all the range states, where status reports from all countries were presented. At these symposia, workshops were convened for each of the species, to establish the framework and content of the species reviews presented here. There were many significant advantages in gathering the very best experts physically together in order to brainstorm the state of current knowledge and the priorities for future investigations. It enabled the assembled teams to draw directly onto maps the currently known breeding, staging and wintering distributions, based on expert knowledge and the results of the telemetry studies, and relate these to those previously published (*e.g.* those of BirdLife International and Handbook of the Birds of the World 2019). More than that, it established a lasting relationship and an ownership of the process of bringing forward the assembled data and information into some form of published resumé of our current knowledge.

A second major objective has been to use the telemetry data to isolate discrete flyways, where the aggregated movement tracks of individuals identify groups of birds commonly using separate breeding and wintering areas, as a basis for considering their definition for monitoring and conservation interventions, as well as the degree of connectivity between them. This is the case, for instance, for the Greater White-fronted Goose (Deng *et al.* 2020), where telemetry data confirmed the existence of two more or less discrete groups of birds moving between allopatric breeding and wintering areas. The first consisted of birds breeding on the tundra from the Khatanga River to the east of Svyatoy Nos Cape, which winter in China; the second of birds breeding from just east of Svyatoy Nos Cape eastwards to the Anadyr River, which winter in Japan and South Korea (Deng *et al.* 2020). Single examples of tracked birds exchanging between these flyways suggested some permeability, but the separation of these two groups of birds was clearly illustrated, providing a solid basis for treating them as separate entities. This is important as Deng *et al.* (2020) showed that the Chinese-wintering birds (now almost totally confined to the Yangtze River floodplain) numbered only 30,000–55,000 individuals during the last 15 years, compared to 140,000 in the 1990s. In contrast, geese wintering in Japan and Korea had increased to 224,000 and 146,000, respectively compared to 28,000 and 61,000, respectively in the late 1990s (Deng *et al.* 2020). This constitutes the first evidence that the declines in China are unlikely to be simply the result of birds redistributing from there to Japan and Korea, but rather implies that differential conservation challenges to the two separate flyways are the reason for the contrasting population trajectories in the two wintering areas. This knowledge has also provided the basis for tentatively naming these new groupings as potential "biogeographical populations", as we attempt to do for each of the species treated in this Special Issue of *Wildfowl*.

A third major objective of these species presentations has been to produce an update of the status, distribution and abundance of each of the species in China as far as possible and in the Yangtze River floodplain in particular, based on winter surveys carried out over the last 15 years. The progressive improvement in waterbird count coverage in China over this period must be taken into account when comparing these counts with historical surveys, on combining the results with surveys from other wintering range states for the species, and (where data are available) on considering trends in numbers in relation to those recorded in the breeding and staging areas. Before 2004, due to the limited number of experienced waterbird observers and restrictions on travel, counts of waterbirds in the Yangtze River floodplain were largely limited to a restricted number of sites where the birds were concentrated, typically the large wetland nature reserves surveyed by local reserve staff. In January–February 2004, the World Wildlife Fund invited Mark Barter from Australia, as the chief consultant, to organise the first simultaneous coordinated survey of waterbirds overwintering on the Yangtze River, coordinating the main reserve staff, university researchers and volunteers to carry out counts on the ground (Barter *et al.* 2004). Encouraged by the success of the first survey and by the wealth of waterbirds they encountered, Mark Barter, assisted by Lei Cao, decided to invest in training observers in the autumn of 2004, to create a team of motivated and capable surveyors who could continue the monitoring programme. These training courses included teaching observers about aspects of waterbird ecology, as well as species identification, counting and analysis methods necessary to enhance the quality of the surveys. In January–February 2005, the second successful synchronous survey of overwintering waterbirds on the Yangtze River floodplain was carried out (Barter *et al.* 2006). Increasingly concerned at the problems facing overwintering waterbirds throughout the floodplain, it was decided to concentrate attention on individual lakes to provide a better understanding of how environmental pressures were affecting specific species at the site level. As a result, in February 2008, they developed a systematic survey method for monitoring overwintering waterbirds in Shengjin Lake, Anhui Province, within and between years, based on counting the entire lake by surveying discrete, defined areas ("sites") from regular fixed viewing locations (Cheng *et al.* 2009). In the surveys carried out during winters 2008/09–2015/16, this site survey method was applied to all the lakes covered in the Anhui Lake complex. Following this, during winters 2015/16–2019/20, new information was forthcoming about sites used by waterbirds tracked with telemetry devices that were not known before, adding some additional survey sites even within previously well-covered lakes. Currently, the number of lakes surveyed annually stands at 87, comprising 1,079 survey sites covering a total area of 16,000 km^2.

The newly-defined flyways enable an estimation of the numbers of birds using the discrete networks of sites along their separate routes and, in the context of these, to identify key sites (amongst those for which count data exist), which have regularly supported more than 1% of the population at a given point in the annual cycle. We do this both for comparison with the historical perspective and also to guide potential site safeguard and management requirements for the immediate future. Note that because we present new information on potential flyway definitions, which has yet to achieve formal and widespread recognition, we have chosen to identify what we call "key sites" for each species in terms of national and their new-found "population" status (Cao *et al.* 2020). For all species we have attempted to determine the degree to which key wintering sites enjoy site protection of one form or another in each of the range states. For selected species we have also begun this process for important staging areas along the flyway (as recently undertaken for Bar-headed Geese *Anser indicus* by Zhang *et al.* 2020).

As well as linking sites used by individual birds, the telemetry data has also provided considerable fine-scale spatial and temporal data on their use of habitats at all stages of the annual cycle. For some species, we have started to investigate this by overlaying individual bird positions on land-use cover (from remote-sensing data) mapped within GIS layers, to try and investigate habitat use and roost site selection. Where possible, we have incorporated the results of these analyses into the species accounts.

Finally, as far as possible, we have attempted to draw all these threads together to outline the conservation implications of these results and suggest ways forward to achieve the aim of safeguarding these species.

We feel extraordinarily privileged to have worked with so many outstanding and knowledgeable experts, who have freely shared their knowledge for the common benefit in compiling these species accounts, and thank all those who have selflessly contributed to the process, whether or not they are co-authors of these Special Issue publications. This work has been the result of a massive combined effort and we heartily thank all those taking part for their contributions, hoping that they are satisfied with this Special Issue as a fitting tribute to their work.

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Photograph: Counting Lesser White-fronted Geese at Daxiaoxi Lake, in the East Donting Lake National Nature Reserve in 2008, by Eileen Rees.

