Swan research and conservation: a synthesis of information presented at the 7th International Swan Symposium

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Abstract

Detailed studies of swans *Cygnus* sp. have been undertaken since the mid-20th century, with results of research programmes presented periodically at international symposia since the 1st International Swan Symposium was held in the UK in 1971. Here, we introduce the proceedings of the 7th International Swan Symposium (7th ISS) of the IUCN SSC Swan Specialist Group, held at Jackson, Wyoming in October 2022, by providing an overview of the latest information on swan populations presented at the meeting, published as papers in this issue and in other journals. The symposium was held in conjunction with the 26th Conference of the Trumpeter Swan Society and was hosted and co-organised by the Ricketts Conservation Foundation. Presentations covered a range of topics including population monitoring, movements and flyway delineation, habitat use, demographic rates, climate change, threats and conservation management of the species. As for the 6th ISS, held in Estonia in 2018, Southern Hemisphere swans were under-represented at the 7th ISS, but greater efforts will be made to cover these species more effectively, along with continued monitoring and assessment of swan populations in the Northern Hemisphere, ahead of the next International Swan Symposium in *c.* 2–3 years' time.

Key words: conference proceedings, conservation initiatives, *Cygnus* sp., monitoring, population change, research updates.

The world's swan species and populations, have long received the attention of researchers, conservationists and the wider public for their beauty, social behaviour, the worrying decline in numbers during the early–mid 20th century, and in the case of the Northern Hemisphere species the mystery of their migrations. Moreover, their large size and gregarious nature has facilitated catching and marking individuals for subsequent identification, mainly by fitting them with leg rings or neck collars inscribed with unique codes readable in the field, which together with behavioural observations has provided much insight into their life cycles over the decades. The earliest known reason for marking individuals was probably to denote ownership of Mute Swans *Cygnus olor* in England, when the British Crown claimed ownership of all unmarked Mute Swans in open water, but occasionally ceded its rights to landowners whose swans historically were marked usually with notches on their bills, although marks may have been made on the wings and feet. Earliest records of ownership come from the 10th century, when King Edgar gave the Abbots of Croyland rights over stray swans in their area, and the first record of a swan mark is from 1230 although they may have occurred earlier (Ticehurst 1957; Birkhead & Perrins 1986). The only bodies still to exercise ownership rights are the Abbotsbury Swannery in Dorset and two livery companies of the City of London (the Dyers' Company and the Vintners' Company), with the birds now being fitted with leg-rings. Most notably during the annual swan-upping ceremony on the River Thames, which dates back at least to the 14th century (Birkhead & Perrins 1986).

Monitoring and research has been extended to other swan species more recently, with the development of count programmes for North American's waterbirds (including the Trumpeter *Swan Cygnus buccinator* and Tundra (previously Whistling) Swan *Cygnus columbianus columbianus* populations), with the initiation of the Mid-Winter Waterfowl Survey (MWS) in the 1930s (Crissey 1984; Vrtiska *et al.* 2024). Systematic counts of Europe's swan population – *i.e.* the Bewick's Swan *Cygnus c. bewickii*, Whooper Swan *Cygnus cygnus* and Mute Swan – commenced with the development of the International Waterbird Census (IWC) from 1967 onwards by the International Waterfowl and Wetlands Research Bureau (IWRB; now reconstituted as Wetlands International; Stroud *et al.* 2022). Species-specific population censuses were subsequently initiated, first with the establishment of the North American Trumpeter Swan Survey (NATSS) in 1968 (review in Vrtiska *et al.* 2024), then through the comprehensive and coordinated counts made of Europe's migratory Bewick's and Whooper Swan populations from the 1980s onwards (*e.g.* Salmon & Black 1986; Beekman *et al.* 1985, 2019; Laubek *et al.* 2019). The ability of trained researchers to identify individual Bewick's Swans by their natural black-and-yellow bill markings, famously noted by Sir Peter Scott and his family at Slimbridge, UK during winter 1963/64, formed the basis of a long-term study of the swans wintering at the site which continues to this day (Scott 1966; Moore & Rees 2022). Colour-marking programmes, using leg rings, wing tags, or neck collars, were also initiated during the mid-late 20th century, now being augmented by GPS-tracking of individual birds, and these resulted in a wealth of data being developed on the swans' movements, family associations, longevity and use of key sites over the decades.

In 1971, the IWRB convened the first meeting of swan researchers and conservationists for a two-day symposium, held at Slimbridge immediately following the IWRB Board meeting (also being held at Slimbridge that year; Stroud *et al.* 2022), the proceedings of which were published in *Wildfowl* 24 in 1973. This saw the formation of the Swan Research Group, which over time evolved into the Wetlands International Swan Specialist Group and is now the Swan Specialist Group (Swan SG) of the International Union for the Conservation of Nature Species Survival Commission (IUCN SSC). The Swan SG comprises an international network of swan specialists who undertake monitoring, research, conservation and management of swan populations. Its mission is: "*to facilitate effective communication between members and others with an interest in swan management and conservation worldwide, in order to improve national and international links for cooperative research, identify gaps in knowledge and provide a forum for addressing swan conservation issues*". All eight of the world's swan species and subspecies fall within the remit of the group: five in the Northern Hemisphere (the Trumpeter and Tundra Swans native to North America, and the Mute, Bewick's and Whooper Swans of Eurasia), and three from the Southern Hemisphere. The latter include two "true" swan species – the Black Swan *Cygnus atratus* of Australia/New Zealand and the Black-necked Swan *Cygnus melancoryphus* of South America, with the Coscoroba Swan *Coscoroba coscoroba*, although not truly a swan, also embraced by the Swan SG.

Following the success of the first symposium, international swan symposia (ISS) were organised at intervals thereafter, initially *c.* 10 years apart, with the second ISS held in Sapporo, Japan in 1979, the third in Oxford, UK in 1989, the fourth in Airlie, Virginia, USA in 2001, and the fifth in Easton, Maryland, USA in 2014. During the 5th ISS, however, it was felt that the meetings should be held more frequently, ideally at 4–5 year cycles, resulting in the 6th ISS being held at the Estonian University of Life Sciences in Tartu, Estonia in October 2018. From the outset, meetings held in North America have been held in conjunction with conferences of The Trumpeter Swan Society (TTSS), and papers presented at all symposia subsequently published as proceedings of the meeting. Either as stand-alone volumes (see Matthews & Smart 1980 for the 2nd ISS; Sears & Bacon 1991, the 3rd ISS; Rees *et al.* 2002, the 4th ISS; Wood & Rees 2019, the 6th ISS) or, for the 1st and 5th ISS, as a group of papers within the *Wildfowl* journal (*Wildfowl* 24 in 1973 and *Wildfowl* 64 in 2014). These have provided an invaluable source of information on the work undertaken on swan species over the decades. Papers in the proceedings of the 6th ISS included a comprehensive synthesis of the presentations given at the meeting combined with an overview of current trends and future directions in swan research (Wood *et al.* 2019a), and also summarised the conservation status of the world's swan populations (Rees *et al.* 2019). With the benefit of new work presented at the 7th ISS, published in this volume and in other journals, we aim here to provide an update on the work undertaken and knowledge gained on swans globally in recent years, since the meeting held in Estonia in 2018.

The 7th International Swan Symposium

The 7th International Swan Symposium (7th ISS) of the IUCN SSC Swan Specialist Group (Swan SG) was held in conjunction with the 26th Conference of the Trumpeter Swan Society (TTSS) in Jackson, Wyoming,

Photograph: Participants of the 7th International Swan Symposium, Jackson, Wyoming, USA, by Leho Luigujõe.

USA from 23–27 October 2022 (Fig. 1). It was hosted and co-organised by the Ricketts Conservation Foundation (RCF), which was also a major sponsor of the meeting. Given that the RCF and TTSS were the main organisers and contributors to fund-raising, and with the meeting being held in the USA, members of the TTSS from the host country formed the lion's share of the 108 delegates, but the talks/poster presentations ranged geographically from Canada and the USA via Eurasia to Australia. For the first time, the symposium provided a virtual conferencing facility which enabled 29 attendees unable to be there in person to join the meeting remotely. This ability to attend and/or present online – a first for a swan symposium – was invaluable for broadening the scope of the meeting, greatly enhancing the international component and discussions more widely. Eleven of the 50 presentations were given as virtual online contributions, resulting in excellent updates on work undertaken in recent years. There was representation from 14 countries (Australia, Belgium, Canada, China, Denmark, Estonia, Germany, Iceland, Latvia, the Netherlands, Poland, Russia, UK, and USA), from 4 of the 5 continents where breeding and/or wintering swans are native (rather than introduced), excepting only South America. A more dedicated account of the meeting, including the organisation, presentations, workshops and excursions, is given by Rees *et al.* (2022).

Fifty oral presentations were given at the meeting, and all were recorded by the team from the Ricketts Conservation Foundation, either live during the symposium or pre-recorded if presented virtually. These were subsequently made available online via the Swan SG website in early 2024 (Ricketts Conservation Foundation 2024). Fourteen papers resulting from these presentations are published in this Special Issue, comparable to the Special Issues published for the 6th ISS (11 papers) and 5th ISS (7 papers). A further 10 papers published previously are also incorporated into this synthesis of information presented at the meeting.

Population size and trends

The review of the population size and trends in numbers for the world's swan populations, described by Rees *et al.* (2019) in the proceedings of the 6th International Swan Symposium, puts the total number of swans globally in the region of 1.5–1.6 million individuals, with a further > 110,000 swans (*c.* 60,000 Mute Swans; 50,000 Black Swans) considered to be non-native invasives where they have been introduced outside their traditional range. Of 20 populations described (3 Trumpeter Swan, 2 Tundra Swan, 3 Bewick's Swan, 5 Whooper Swan and 7 Mute Swan populations), the 10-year trends for most (16 populations) were found to be stable or increasing but with two – the Caspian/West Siberian Whooper Swan and the Eastern Bewick's Swan populations – classed as fluctuating and the NE/NW European Bewick's Swan population in decline. Additionally, the status of the Central Asian and East Asian Mute Swan populations remained unclear, as they were based on assessments dating back to the 1990s, and trends for Black Swans, Black-necked Swans and Coscoroba Swans were also uncertain due to very limited monitoring of these species (Wetlands International 2019).

Since then, the most recent of the internationally coordinated censuses of Europe's migratory Bewick's and Whooper Swan populations, organised by the Swan SG and key collaborative organisations at *c.* 5-year intervals since the 1980s (*e.g.* Beekman *et al.* 1985, 2019; Salmon & Black 1986; Laubek *et al.* 2019), was conducted in January 2020. Moreover, noting the decline in the NE/NW European Bewick's Swan population, and considering that assessing population interchange was an action listed within International Single Species Action Plan adopted by the African-Eurasian Migratory Waterbird Agreement (AEWA) to address the decline (Nagy *et al.* 2012), the census was extended to cover swan wintering areas from the East Mediterranean to Central Asia. The main aim was to improve estimates of total numbers in the Northwestern Siberia/Caspian population Bewick's Swans (previously known as the Caspian population), which had been put at just 3,000 birds in 2015 (Rees *et al.* 2019), but also included winter areas used by the Black Sea/East Mediterranean and the Caspian/West Siberian Whooper Swan populations. Additionally, more extensive and systematic monitoring of swans in eastern Eurasia – particularly in China, Japan and Korea – was providing valuable updates on the status of migratory swan populations on the East Asian flyway, in a region where (excepting Japan) counts were relatively patchy and uncoordinated during the 20th century.

Results of the recent censuses and population estimates were presented at the 7th ISS and are summarised in Table 1.

Table 1. Population size updates for migratory swans in Eurasia.

Species	Population	2015 Estimate	2020 Estimate	10-year trend	Sources
Whooper Swan	Icelandic	34,004	43,255	INC	1, 2
	NW Mainland Europe	138,448	> 140,000	INC	3, 4
	Black Sea/East Med	14,000	14,000	INC	5, 6
	Caspian/W & C Siberian	20,000	20,000	UNC	5, 6
	East Asian	42,000[a]	57,690	STA?	7, 8
Bewick's Swan	NE/NW European	20,148	*c.* 12,900	DEC	4, 9
	NW Siberia/Caspian	3,000	*c.* 6,000–13,000	INC	5, 10
	East Asian	90,000[b]	105,000	DEC/ STA	5, 11

Sources: 1 = Hall *et al.* 2016, 2 = Brides *et al.* 2021, 3 = Laubek *et al.* 2019, 4 = IUCN SSC Swan Specialist Group unpubl. data; 5 = Wetlands International 2019; 6 = Wetlands International 2024?; 7 = Jia *et al.* 2016 (cited in Rees *et al.* 2019); 8 = Ao *et al.* 2020; 9 = Beekman *et al.* 2019; 10 = Rees *et al.* 2024; 11 = Fang *et al.* 2020. Notes: [a] = 2011 estimate; [b] = 2017 estimate.

Numbers in the Icelandic Whooper Swan population continue to increase to a total of 43,255, a 27.2% increase in numbers since the previous census in 2015 (Brides *et al.* 2021). Breeding success was not associated with temperatures on either the breeding or wintering grounds, and showed no clear trend over time, suggesting that increased survival might be the demographic driver of the population growth (see also Soriano-Redondo *et al.* 2023 in the demography section below). Numbers in the NW Mainland European Whooper Swan population had more than doubled in the 20 years from 1995 to 2015, but preliminary results presented during the 7th ISS suggest stability over the last 5-year period from 2015 to 2020 (Table 1). These data as well as additional counts for Whooper Swans wintering from the East Mediterranean to the Caspian Sea have been compiled for analysis and publication in 2025. Further east, the Eastern Whooper Swan population is now estimated at 57,690 birds and numbers are currently thought to be stable although they have declined in Japan since the turn of the century (Ao *et al.* 2020). Few counts of the species were made in China prior to 2000, however, and it's possible that key Chinese wintering areas are still being missed.

Of the three Bewick's Swan populations, the NE/NW European population continues to be in marked decline, which is of conservation concern. The provisional estimate of *c.* 12,900 swans counted in January 2020 (pending verification and formal publication of the data) is the lowest recorded since the international Bewick's Swan censuses commenced in the mid-1980s, when the population was put at *c.* 16,000 birds (Beekman *et al.* 1985, 2019). In contrast, the first full census of the Northwestern Siberia/Caspian population published in this issue put numbers at 6,000–13,000 birds, the wide range of the estimate reflecting uncertainty over the proportion of the *c.* 13,000 swans wintering on the Evros/Meriç Delta that migrates along the NW European flyway (and thus arguably NE/NW European population swans) and the variation in earlier count data (Rees *et al.* 2024). It seems very likely, however, given the marked rise in numbers wintering on the Evros/Meriç Delta (Litvin & Vangeluwe 2016; Vangeluwe *et al.* 2016), that this population has increased substantially during the 20th century. For the East Asia population there was also variable trends, with an apparent decrease in Bewick's Swan numbers wintering in China between 2004/05 and 2019/20 (although coverage was inconsistent), and also in the small numbers wintering in South Korea, whereas counts from Japan were more stable (Fang *et al.* 2020). The estimate of 105,000 in the Eastern Population in winter 2019/20 therefore was not a significant change in comparison with the 110,000 estimated 10 years earlier in 1999/2000 and the 90,000 of winter 2014/15 (Fang *et al.* 2020).

For the other species – notably the Southern Hemisphere swans – population estimates have not been updated since the summary provided by Rees *et al.* (2019), although sporadic counts made of the Far East Asian Mute Swan population during the 21st century suggested that it was more likely to be in the order of 1,000 individuals rather than the previous estimate of 1,000–3,000 birds (Meng *et al.* 2020). Better monitoring of Mute Swans is required in this part of its range for providing a more robust population estimate, noting also that the species is considered to be naturalised (*i.e.* introduced) but not invasive in Japan (Gayet *et al.* 2019).

In North America, total population estimates used to be produced for Trumpeter Swans at 5-year intervals from 1968 through to 2015 through the North American Trumpeter Swan Survey (NATSS), with the species listed for federal conservation following its near-extinction during the early 20th century. A paper presented at the 7th ISS and published here (Vrtiska *et al.* 2024) describes how the NATSS has been suspended because of financial and logistical constraints, pending a review by the International North American Trumpeter Swan Survey Steering Committee of the objectives and the future direction of the survey. Planning the NATSS proposed for 2020 was made difficult by the spread of Covid-19 and other issues, and the NATSS Steering Committee recommended in January 2020 that the survey be suspended indefinitely at that time. Vrtiska and his co-authors provide a careful review not only of the strengths and weaknesses of the NATSS but of other continuing monitoring programmes in North America (*e.g.* the Waterfowl Breeding Population and Habitat Survey, the Mid-Winter Waterfowl Survey, the Breeding Bird Survey, the Christmas

Bird Count, and eBird) which have been suggested as possible alternatives to the NATSS for assessing the status of Trumpeter Swan populations, which should help to inform the relevant agencies and encourage them to reinstate a comprehensive monitoring programme for this iconic species. Meanwhile, in the absence of more recent total population estimates for the Pacific Coast Population (PCP), the Rocky Mountain Population (RMP) and the Interior Population (IP) of Trumpeter Swans, there has been no update on its global population estimate of *c*. 76,000 individuals recorded by the NATSS in 2015 (Groves 2017; Rees *et al.* 2019). In a second paper presented in this issue, results of annual autumn surveys of the U.S. Breeding Segment of the RMP (the "Fall Trumpeter Swan Survey") found that, whilst the count of 940 swans 2022 was 1.8% higher than the 923 counted the previous year, there was no evidence for a trend in total numbers from 2015–2021. Moreover, there was a decrease in the proportion of cygnets recorded during this period, suggesting some inward movement of swans from elsewhere (Olson 2024). In the absence of data from elsewhere, however, or indeed for the RMP as a whole, recent trends for Trumpeter Swan populations remain unknown. This is in contrast to the Tundra Swans of North America, which is a quarry species following increases in numbers during the mid-20th century, and for which desired population levels and distributions have been described in management plans. A 10% harvest rate of the three-year average winter population index was initially established until more definitive data became available, and if the three-year average winter population index for the Eastern Population (EP) and Western Population (WP) fell below 60,000 and 40,000 swans, respectively, season closures were to be considered (Serie & Bartonek 1991; Rees *et al.* 2019). The most recent report found a significant decrease in both the EP (to 64,000 birds in 2024) and the WP (74,000 birds; U.S. Fish & Wildlife Service 2024) though the EP count may be an underestimate, and numbers remain above the population threshold levels that would result in season closures.

Population interchange

In addition to updates on the abundance of swan populations, there has been increasing interest in population delineation and population interchange in recent years. For instance, the extent to which the decrease in size of the NE/NW European Bewick's Swan population and the increasing estimates being made for the Northwestern Siberia/Caspian population (see above) reflect a change in the migration routes taken by some individuals, rather than variation in productivity and survival rates for swans breeding in different parts of the Russian Arctic combined with a shift in winter distribution and improved coverage for the Northwestern Siberia/Caspian population, remains an open question. GPS-tracking studies have thrown much light on the routes and staging sites used by Bewick's Swans migrating to apparently discrete wintering areas and confirmed an overlap on the breeding grounds of those that follow different migratory flyways (Vangeluwe *et al.* 2016, 2018; Rozenfeld *et al.*

2019), and earlier ringing programmes have also shown that individuals may occasionally change flyways (review in Rees 2006). Further research is however required to determine not only the level of population interchange between the NE/NW European and the Northwestern Siberia/Caspian Bewick's Swan populations, but to assess whether those wintering in central Asia (Vangeluwe *et al.* 2018) should be treated as a separate population.

Meanwhile, in contrast to the potential for population interchange for Bewick's Swans breeding in the Arctic reaches of European Russia and central Siberia, results of GPS-tracking of migratory swans in east Asia presented at the 7th ISS suggested that two distinctive flyways were used by Bewick's Swans in the East Asia population. Previous studies had described the Yamal to China and the Lena Delta to China migration routes (Huang *et al.* 2018; Vangeluwe *et al.* 2018), but more extensive deployment of GPS-tags fitted to Bewick's Swans breeding in different areas of the northeast Russian Arctic reinforced the view that Bewick's Swans wintering in Japan bred between the mouth of the Indigirka River and the Chaun Delta, whereas those wintering in China bred between the Yamal Peninsula and Svyatoy Nos Cape (Fang *et al.* 2020). The evidence for the existence of two distinctive flyways (and thus potentially separate subpopulations) therefore was proposed as the basis for designating the East Asian Continental flyway and the West Pacific flyway as separate entities for the East Asian Bewick's Swans (Fang *et al.* 2020). GPS-tracking of Whooper Swans and Mute Swans, combined with survey data, has also provided valuable new information on their distribution and movements in East Asia in recent years (Ao *et al.* 2020; Meng *et al.* 2020), but further studies are required to confirm their population delineation and migration routes within the region.

Whilst GPS-tracking has undoubtedly made a huge contribution towards describing migration routes and the birds' use of relatively inaccessible staging areas, resightings of colour-marked birds continue to remain crucial for understanding site use and changes in the distribution of individuals within populations. Monitoring of two of Europe's Whooper Swan populations – the Icelandic and the Northwest Mainland European (NWME) populations – has been undertaken at 5-year intervals since the 1990s, but the level of movement of individuals between the populations and thus the extent to which any interchange influenced the total population estimates remained unresolved. They follow geographically separate flyways (the former breeding in Iceland and migrating to winter in Britain and Ireland; the latter breeding primarily in Fennoscandia, European Russia and the Baltic States and wintering further south in continental Europe), but occasional "out of range" sightings have long indicated some level of population interchange (*e.g.* Gardarsson 1991; Laubek *et al.* 1998). Given that population size estimates are used to determine sites of international importance for the species (measured as those which regularly support ≥ 1% of the individuals in a population), the extent to which these may be influenced by a net movement of birds from continental Europe to the Icelandic population's wintering areas or *vice versa* therefore needed to be determined, resulting in Brides *et al.* (2022) compiling and analysing ringing and resightings data from colour-marking schemes across Europe and presenting the results at the 7th ISS. Of > 18,000 Whooper Swans ringed in 17 European countries since the late 1970s, only 172 individuals (0.94%) were later found outside the nominal range of their assigned biogeographical population, and there was no evidence for a directional bias in population interchange. With both the Icelandic and the NWME populations also having increased substantially since the early 1990s (see above), this low level of population interchange was thought unlikely to have caused major inaccuracies or biases in the population size estimates over the decades (Brides *et al.* 2022).

Whilst the mobility of swan populations is receiving increased attention in Eurasia (see also the climate change section below), in North America GPS tracking is being used to investigate the more sedentary nature of reintroduced Trumpeter Swan populations. In Ohio, where Trumpeter Swans were first reintroduced in 1996 and their movements outside the breeding season were unclear, tracking data from GPS/GSM transmitters fitted to adult birds during the 2020–2022 breeding seasons revealed that most (85%) dispersed locally, remaining in Ohio, but three made longer distance movements with two travelling > 1,500 km into Canada (Kearns *et al.* 2024). Whilst the long-distance movements are encouraging, because they imply a migratory tendency, the generally more sedentary patterns are similar to those recorded for other reintroduced Trumpeter Swans within the range of Interior Population birds (Handrigan *et al.* 2016; Groves 2017), suggesting that most are not integrated with migratory populations and that Ohio therefore would need to provide suitable non-breeding habitat as well as breeding habitat if the species is to continue to thrive in the state (Kearns *et al.* 2024).

Demographic studies

The past 5 years have seen further advances in our understanding of the demographic drivers of population trends for swan species, with reasons underling the decline in the Northwest European Bewick's Swan population continuing to receive particular attention. Previous studies found that, despite some years with very low breeding success (*i.e.* < 5% cygnets in flocks across the wintering range), there was no significant long-term decline in breeding success over the period 1988–2013 (Wood *et al.* 2016; Beekman *et al.* 2019), with fewer young observed on the wintering grounds in years following a cold breeding season in the Russian Arctic was colder and when predator (Arctic Fox *Vulpes lagopus*) abundance was higher. Density-dependent effects and duration of the pair-bond also influenced breeding success (Wood *et al.* 2016). Additionally, analysis of ringing and ring resightings data recorded for winters 1970/71–2014/2015 inclusive found that, although apparent survival rates fluctuated broadly in line with trends in population size, the drivers of variation in survival rates were unclear (Wood *et al.* 2018). More recently, an integrated population model (IPM) used to analyse three demographic datasets in combination (population counts, capture–mark–resightings (CMR) and the proportion of juveniles recorded in winter) over a *c.* 50-year period, found higher apparent breeding success in years of population growth, with apparent breeding success and adult survival contributing most to the variation in population trend (Nuijten *et al.* 2020a). There was no consistent trend in adult and yearling survival, but an increasing trend in juvenile survival associated with colder summer temperatures and with water levels at autumn staging areas (notably at Lake Peipsi) which affects the accessibility of food (macrophytes) at such sites. Further studies are however required to determine why apparent breeding success may have declined over time, and to confirm the environmental variables affecting the different demographic rates recorded for the species, including further assessment of the food resources available at for the swans at key sites used during both autumn and spring migration.

Meanwhile, a different set of reasons was found to be underlying population change for another swan population – this time the increases in the Icelandic Whooper Swan population during the late 20th and early 21st century. Soriano-Redondo *et al.* (2021) analysed 30 years of movement and demographic data recorded for colour-marked individuals, to assess the value of nature reserves for birds using protected sites on their wintering grounds in the UK and the Republic of Ireland. The swans were found to have a lower breeding probability when wintering inside than outside the reserves but there was better survival for swans of all age classes wintering on the sites protected and managed for the species. Interestingly, there was a net movement of individuals from the reserve to non-reserve sites, but population projection models which combined the demographic rates with movement estimates (*i.e.* into and out of the reserves) predicted that the reserves should help to double the numbers of Icelandic population Whooper Swans wintering in the UK by 2030 (Soriano-Redondo *et al.* 2021).

The Trumpeter Swans which breed and winter in Yellowstone National Park (YNP) have an important historic role in North American ornithology, as they formed the remnant population of < 70 individuals when the species neared extinction in 1930s (Banko 1960). Subsequent conservation efforts, including reintroduction programmes, saw all three populations (*i.e.* the PCP, RMP and IP) increase markedly in abundance during the second half of the 20th century and into the 21st century, but within the YNP resident numbers declined from 1960–2010, when they were supplemented by captive-bred birds released into the YNP (Shields *et al.* 2024). Long-term historical data and existing covariate data therefore were used to explore, using Bayesian modelling, the various competing hypotheses for the temporal and spatial variation in swan abundance in the YNP. The main hypothesis considered were: (1) human disturbance at nest sites, (2) predation, (3) habitat change, and (4) movement of swans into/out of the YNP. Strong correlations of some covariates (*e.g.* visitor numbers; Grizzly Bear *Ursus arctos* abundance) with time made it difficult to distinguish between underlying causes of temporal change, but the location and conditions at the main sites used by the swans for breeding should help to inform management actions and more detailed monitoring of potential impacts on breeding success into the future (Shields *et al.* 2024).

In addition to the population modelling, several authors presented work on variation in productivity during the 7th ISS. There have been relatively few studies of individual Black Swans in its native Australia in recent years, where the bird is relatively abundant so not considered a priority species for research and conservation (review in Rees *et al.* 2019) but a colour-marking programme and year-round monitoring of both breeding and non-breeding birds, initiated in coastal southeast Queensland in 2007 (Coleman 2014) has developed into a valuable long-term study. This now includes an evaluation of the environmental variables influencing breeding attempts, which found that the extent of the breeding season (measured as the number of months in which eggs were hatched) was correlated both with the number of breeding attempts made by paired birds that year and also the number of territorial pairs recorded, the latter thought to reflect adjustment in the onset of breeding by pairs with a view to reduce competition for sites favoured breeding and feeding (Coleman & Coleman 2024). With the number of breeding attempts also influenced by summer rainfall and the Southern Oscillation Index (SOI), the authors suggested that the increase in the numbers of pairs and breeding attempts associated with more favourable weather conditions may have led to the longer breeding seasons recorded for Black Swans in southeast Queensland in recent years (Coleman & Coleman 2024). Elsewhere, increases in numbers and distribution across breeding habitats were reported for Whooper Swans in the Baltic countries (Boiko & Luigujoe 2024), and in southwest Russia (Kouzov *et al.* 2024a), which serve to underline the continued importance of maintaining long-term monitoring programmes for describing and understanding population change. Kouzov *et al.* (2024b) also studied the influence of winter temperature and ice melt on the breeding performance of Mute Swans nesting on offshore islands in the Russian part of the Gulf of Finland and demonstrated that the marked annual variation recorded in the number of breeding pairs was influenced by the timing of ice melt in this northern part of the species' breeding range.

Consequences of climate change

Environmental change associated with anthropogenic climate warming is affecting ecosystems globally (Walther *et al.* 2002) and is of particular concern for migratory species that use geographically discrete areas during to breed and overwinter each year, often relying on being able to rest and feed at sites known to have favourable conditions during their long-distance journeys (Robinson *et al.* 2009). Understanding how animals adapt to new conditions (if indeed they can do so) and identifying sites likely to emerge as important for migratory species in a changing world, therefore is crucial for determining future conservation priorities. Two papers on how climate change is affecting swan populations have been published in recent years – both for the

NE/NW Bewick's Swan population, which is undergoing both a major population decline and a change in its distribution. The first of these, by Nuijten *et al.* (2020b) analysed *c.* 50 years of resighting data (1970–2017) and found that the swans shifted eastwards ("short-stopping") on their wintering grounds at a rate of *c.* 13 km/year, whilst concurrently reducing the time spent at the wintering grounds has reduced ("short-staying") by *c.* 38 days since 1989. Individuals were generally consistent in their timing of migration in winter (*i.e.* indicating a generational shift in the proportion of individuals with different migratory schedules), but in contrast, for short-stopping, both individual plasticity (with individuals decreasing their migration distances over their lifetime) and a generational shift were evident (Nuijten *et al.* 2020b). The eastward shift in distribution appeared to be linked to air temperature, with the swans frequenting areas where winter temperatures were at *c.* 5.5°C.

In a follow-up study, Linssen *et al.* (2023) using multi-year GPS tracking data found that the timing of the Bewick's Swans' autumn migration is influenced by temperature on a day-to-day basis, with individuals moving long distances only when temperatures drop below freezing during late autumn, resulting in quite large flexibility in the overall distance flown during autumn migration and proximity to the breeding grounds of sites used by the swans in mid-winter. This provided further insight into the range shift described by Nuijten *et al.* (2020b), with the swans' redistribution largely driven by individual responses to a warming climate, and has implications in identifying areas likely to be used as wintering sites by the swans in future years, assuming that other conditions are favourable, in the event that temperatures continue to rise.

A third paper presented at the 7th ISS, whilst not yet showing a definite change in the swans' behaviour attributable to climate change, has clear implications for future warming. In an investigation of how incubating swans accommodate thermal flux in their environment, Miller & Delehanty (2024) used digital video imaging, environmental monitoring devices and thermal recording devices places within clutches and also on nest mound material to study the incubation behaviour of swans nesting at the Red Rocks Lake National Wildlife Refuge in southwest Montana. The swans were found to maintain a mean (± s.e.) egg temperature of 35.7 ± 0.27°C during active incubation, and there was an interactive association between nest attendance and: (1) deviation of ambient environmental temperature from average egg incubation temperature, (2) solar radiation and (3) vapour density. Nest mound temperature was positively associated with ambient temperature, solar radiation and vapour density, and the nest material acted as a thermal mass, moderating thermal flux. Nesting success depended on swans shielding their eggs from excessive daytime warming and desiccation, and on contact incubation when ambient temperature was below the average egg incubation temperature, leading the authors to make several recommendations for wildlife managers visiting Trumpeter Swan nests and, noting the swans may encounter increasingly warmer during future breeding seasons, emphasising the need to maintain and renew attention paid to the thermal conditions during the swans' breeding season (Miller & Delehanty 2024).

Habitat and resource use

Historically the swan species mainly used aquatic habitats for foraging, as well as for roosting and breeding, but with the intensification of agriculture during the mid-20th century birds from many populations and in many countries moved increasingly onto terrestrial habitats to feed on pasture and arable crops during the winter (*e.g.* Limpert & Earnst 1994; Mitchell 1994; Laubek 1995; Rees *et al.* 1997; review in Wood et al. 2019a), although *e.g.* Mute Swans in the Baltic Sea to a large extent still use natural habitats and feed on submerged vegetation in shallow estuaries, coastal lagoons and bays (Kieckbusch 2010; Nilsson & Haas 2016; Heldbjerg *et al.* 2024; Nielsen *et al.* 2024). The relative accessibility of migratory swans during the winter months, in comparison with their remote Arctic breeding grounds, resulted in a number of papers relating to the swans' feeding behaviour, which addressed a range of topics such as conflict with agriculture (Colhoun & Day 2002; Crawley & Bolen 2002), habitat selection (Chisholm & Spray 2002), switching feeding areas to maximise energy gain (Nolet *et al.* 2002; Wood *et al.* 2019b) and potential interspecific competition for resources on the feeding grounds (Wood *et al.* 2021). The last of these studies notably found no evidence for the net energy gain for Bewick's Swan wintering in southeast England being affected by sharing agricultural feeding habitat with the larger Whooper and Mute Swans during winter, despite aggression having some influence on the Bewick's Swans' foraging and vigilance behaviours, especially among cygnets. The authors however advised that research is needed to test for competition in other parts of the flyway, including migratory stopover sites and on the breeding grounds. A recent paper in which the foraging locations of Bewick's Swans (fitted with GPS/GSM neck collars, including an accelerometer and water sensor) were monitored during spring migration likewise emphasised the importance of considering staging areas, on finding that the birds foraged mainly in protected zones along the Estonian coast and in the Gulf of Finland, but on reaching Dvina Bay they also foraged extensively in unprotected areas, and there were no protected areas at the fourth staging area, in Cheskaya Bay on the Barents Sea (Nuitjen & Nolet 2020). At all of these sites the swans were feeding on macrophyte vegetation, which is threatened by ongoing or planned construction works in the Gulf of Finland and Dvina Bay, and by future oil and gas exploitation in Cheskaya Bay, emphasising the importance of protection measures for maintaining a chain of suitable stopover sites to enable the swans to complete their migration (Nuitjen & Nolet 2020). Swans may of course use non-protected sites for various reasons, with a recent study finding that the proportion of time that Bewick's Swans wintering in southeast England spent at alternative, unprotected roost site was associated with river levels and temperature, with a combination of competition, freezing of waterbodies and foraging flight distances thought to drive these relationships (Wilson *et al.* 2024). Understanding of the environmental conditions under which swans vary their use of sites is therefore important in developing conservation programmes for these species.

Conditions in the Gulf of Finland were also presented in two other papers during the 7th ISS. The timing of the ice melt in the eastern part of the gulf was found to affect the migration patterns for both Bewick's and Whooper Swans with a late ice melt reducing both the duration of the stopover period and peak abundance for both species, but the date on which the staging period ended varied little from year to year, perhaps reflecting the importance of the swans reaching the breeding grounds to occupy territories and lay a clutch at the optimal time (Kouzov *et al.* 2024c). Interestingly, use of alternative stopover sites was recorded in recent early springs, when the birds were recorded feeding on agricultural land (Kouzov *et al.* 2024c). In a separate study, counts made of three swan species (Bewick's, Whooper and Mute Swans) during the spring migration period on the Gulf of Finland, comparing their use of "traditional" (*i.e.* natural shallow coastal waters with low levels of disturbance) and "reclaimed" (*i.e.* shallow waters created behind artificial sand embankments associated with construction work) parts of the gulf, found that the swans returned to reclaimed sites following completion of the reclamation work (Mikhailov *et al.* 2024) leading the authors to suggest that with the continued gradual colonisation by aquatic vegetation there is potential for the number of swans feeding in these areas to increase, assuming that the sites are protected from disturbance and continue to provide suitable habitats for the swans.

That waterbirds can exploit artificially created waterbodies and habitats if conditions are favourable is well known – *e.g.* the recreation of a lake at Martin Mere, UK saw it becoming a site of international importance for migratory swans (Rees & Bowler 1996) and the restoration of Lake Hornborgasjön in southern Sweden reinstated it as a major moulting site for Greylag Geese *Anser anser* (Nilsson & Hermansson 2019). Even in suburban areas the creation of wetlands, combined with protection from human disturbance, can provide important sites for waterbirds including swans. Most recently the development of an artificial Danish suburban lake (Egå Engsø) in 2006, primarily for nutrient retention and flood control, resulted in submerged macrophyte cover which now attracts moulting concentrations of 600 Mute Swans along with other species, and the site is considered to be a model of how appropriate planning can accommodate multiple objectives for humans and wildlife (Clausen *et al.* 2024). The benefits of reducing disturbance levels for wildlife are also described here in a paper by Włodarczyk (2024), who found that restrictions to human movements because of the Covid-19 pandemic resulted in a significant increase in spring 2020 in the number of breeding Mute Swans pairs at a reservoir open to visitors in non-Covid years, but not at fishponds which were private and generally closed to visitors.

Threats and conservation

The review by Wood *et al.* (2019a) of the threats to swan populations illustrated the many and varied issues that face the species globally, mostly attributable to human activity, including habitat loss and degradation, disturbance at feeding and roosting sites, collisions with infrastructure, poisoning (especially lead poisoning through the birds ingesting shotgun pellets and anglers' weights), disease (*e.g.* pathogenic avian influenza), persecution (notably illegal hunting) and climate change. Several of these issues, including potential interspecific competition for food resources and nest sites, were discussed during the 7th ISS and new information presented. In North America, where increasing numbers of the non-native Mute Swan are thought to be affecting efforts to restore Trumpeter Swans to some areas, a control of Mute Swan numbers may have contributed to improved Trumpeter Swan breeding success and growth of the non-migratory population in Ohio during the 21st century (Kearns *et al.* 2024). Elsewhere, the presence of Mute Swans does not seem to be inhibiting the expansion or consolidation of the Whooper Swans' breeding distribution in Europe (*e.g.* Kouzov *et al.* 2024a; Boiko & Luigujõe 2024); indeed, recent research has suggested the opposite pattern, with some evidence that Whooper Swans may be displacing Mute Swans from breeding sites in eastern Europe (Szewczuk & Kasprzykowski 2024). However, whilst earlier reviews of publications on inter- and intra-specific competition involving swan species provided by Wood *et al.* (2017, 2019a) also generally show a lack of evidence for displacement, the level of concern suggests that more detailed studies focussing on this issue are still warranted for describing scenarios (*e.g.* at breeding territories in North America, and in relation to food resources at staging sites in Europe) where competition may occur.

Lead poisoning, from ingesting spent lead shot or lead fishing sinkers, has long been known to be a cause of mortality for wildfowl including swans (Wetmore 1919) and there were several papers on the issue presented at the 3rd ISS in 1989, both from North America (Degernes & Frank 1991; Bartonek *et al.* 1991) and Eurasia (Sears & Hunt 1991; O'Halloran *et al.* 1991). Ingestion by swans of anglers' lead weights was found to be a major source of mortality Mute Swans in the UK, implicated in local population declines during the 1970s and 1980s, and a ban in on the import and supply of 0.06–28.35 g lead weights (sizes considered likely to be ingested by swans as grit), therefore was introduced across Great Britain in January 1987. Additionally, use of these sizes of lead weights was prohibited from 1987 via the Fisheries Byelaw amendment to the 1975 Salmon and Freshwater Fisheries Act (Sears & Hunt 1991), effectively reducing (though not eliminating) the Mute Swans' exposure to lead. Some 30 years later, a population-level study found that the subsequent increase in the numbers of Mute Swans in Great Britain was best explained by the regulation of lead fishing weights, rather than by changes in food supplies, habitat quality, or winter temperature, and that the proportion of individuals dying of lead poisoning had dropped following regulation (from 0.34 before regulation to 0.06 thereafter), suggesting a decline in lead-induced mortality (Wood *et al.* 2019c). A review at the 7th ISS of the information currently available on the impacts of lead fishing weights of swans in other parts of Europe, presented in this issue, however found that statutory regulations on lead anglers weights currently exist only in the United Kingdom and Denmark, although there have been some voluntary initiatives to reduce and phase-out the use of lead for fishing in Belgium, the Netherlands and Sweden (Wood & Newth 2024). Anglers' weights are of course not the only source of lead ingested by swans, with lead poisoning from ingested gunshot having not only lethal but also sub-lethal impacts on individual birds, for instance through physiological effects such as reduced body condition (Newth *et al.* 2016). Currently, two countries have total bans on the use, trade and possession of lead shot: the Netherlands since 1993 (Avery & Watson 2009) and Denmark since 1996 (Kanstrup 2006), but the European Commission requested in 2019 that the European Chemicals Agency (ECHA) should assess the risks posed by the use of lead in ammunition and in fishing, and to propose any necessary restrictions across the European Union (see Wood & Newth 2024). Following a 2-year consultation period, a ban on using lead shot within 100 m of wetlands was finally introduced for all 27 EU countries on 15 February 2023, as well as for Iceland, Norway and Lichtenstein. The ECHA is now working towards a second recommendation within the EU REACH process, with a view to addressing the risks of lead shot, bullets and fishing weights to human and wildlife health, wherever they are used. The progress in Europe towards the complete phase-out of all lead ammunition (for shotguns and rifles) contrasts with the situation in the United States, where bans on the use of lead are on a piecemeal, state-by-state basis, and in some instances on a site-by-site basis within individual states (review in Ellis & Miller 2023).

Since the previous swan symposium proceedings, which provided a summary of the illegal hunting of swans and measures being used to address it (Newth *et al.* 2019; Wood *et al.* 2019a) there have been no major updates on the extent to which swans are being shot on different flyways, but an established socio-psychological model – the theory of planned behaviour (which assesses societal reasons for the illegal killing of wildlife) – has been used to explore reasons for hunting Bewick's Swans in the European Russian Arctic (Newth *et al.* 2022). Responses from hunters to the questionnaire survey was illuminating: of 236 who participated overall, 14% expressed an intention to hunt the swans, and this intention was predicted by all components of the theory of planned behaviour, specifically: the hunters' attitude towards the behaviour, perceived behavioural control (*i.e.* perceived capability of being able to perform the behaviour) and their subjective norms (*i.e.* perception of social expectations). The inclusion of attitudes towards protective laws and perception of whether other people perform the behaviour increased the predictive power of the model. This suggests that understanding attitudes towards protective laws can help guide the design of conservation measures that reduce non-compliance. It was therefore concluded that conservation interventions should incorporate measures to address the sociopsychological conditions that influence hunters' attitudes, social norms and perceived behavioural control, such as activities that build trust, encourage support for conservation, generate social pressure against poaching, and use motivations to prompt behavioural change (Newth *et al.* 2022).

Recreational human activity continues to be an issue for swan populations, through the disturbance caused at feeding and roosing areas used by the birds. For instance, coastal waters of northwest Europe have been subject to growing recreational human activity, including recreational kayaking which was found to displace Mute Swans at on average 297 m, with the swans covering an average distance (displacement distance) of 376 m (Clausen *et al.* 2020). In the Curonian Lagoon in the southeastern Baltic Sea, moulting Mute Swans were found to exploit only half of the suitable habitat available to them, with their use of the site apparently influenced by kitesurfing and boating on the lagoon (Morkūnė *et al.* 2023).

Whilst the swans continue to face numerous threats in different parts of their range and different stages of their life cycle, the ability of conservation initiatives to protect and restore swan populations continue to be evident. Whilst reintroduced Trumpeter Swan populations in North America may not have regained a full migratory tradition, they continue to be stable or increasing in most areas where management actions for the species are being maintained (Kearns *et al.* 2024; Olson 2024). In Europe, where Whooper Swans have received widespread protection since the mid-1950s (Brazil 2003), they are continuing to occupy their former breeding grounds (Boiko & Luigujõe 2024; Kouzov *et al.* 2024a), and both the Icelandic and the Northwest Mainland European populations are increasing (Brides *et al.* 2021; IUCN SSC Swan Specialist Group unpubl. data). The benefits of habitat creation, combined with limiting the disturbance caused by human activity at wetland sites, continues to be evident (*e.g.* Clausen *et al.* 2024; Włodarczyk 2024), which provides optimism for the success of future conservation initiatives for swan species.

The future for swan research and conservation

Since the 6th ISS held in Estonia in 2018, there has been a marked increase in the number and intensity of major threats to people and wildlife in our world, with wars underway in Ukraine and the Middle East, the risk of global conflict rising, and environmental change associated with global warming ever more evident, making the research and conservation of wildlife, including swan species, particularly challenging in the coming years. Similarly, the Covid-19 pandemic caused major disruption to wildlife research and monitoring efforts across the globe (Primack *et al.* 2021), as well as highlighting the impacts that human pressures can have on swan populations (*e.g.* Włodarczyk 2024). It remains to be seen if lessons can be learned to prevent similar disruption during future pandemics. A key component of successful conservation of migratory species is good communication and understanding between researchers and conservationists along flyways, and we are aiming to maintain this in the IUCN SSC Swan SG, including through the publication of these proceedings. This remains crucial not only for continuing to understand how the rapidly changing conditions are affecting swans and other species, and for addressing conservation issues as they arise whenever possible, but for ensuring that the network required for successful conservation remains in place for future initiatives.

One encouraging message, however, that emerged from presentations at the 7th ISS, is the extent to which technology continues to improve both communication between researchers and our understanding of swan species. Refinement and reduction in the size of devices fitted to swans has provided valuable insight into their movements and behaviour throughout the year, so that we now have a much better idea about the reasons underlying their selection and use of particular sites, and also their activities during key stages of their annual cycle, particularly in remote or less well-known areas (*e.g.* Nuijten & Nolet 2020; Fang *et al.* 2020; Ao *et al.* 2020; Meng *et al.* 2020; Linssen *et al.* 2023). At the same time, advancements in population modelling combine data on different demographic rates with explanatory variables to provide better insight into the drivers of population change (*e.g.* Nuijten *et al.* 2020a; Soriano-Redondo *et al.* 2023; Shields *et al.* 2024). Further development of analytical techniques should be beneficial, whilst of course remembering the importance of rigorous monitoring programmes to provide the sound and comprehensive data needed to ensure that the analyses are meaningful.

From the communications perspective, for the first time, the ISS provided a virtual conferencing facility, which enabled delegates to attend and/or present online, and virtual meetings continue to facilitate discussions between researchers more widely. Development of the Swan SG website (https://swansg.org/), and the production of newsletters such as *Swan News* (*i.e.* the annual newsletter of the IUCN SSC Swan SG) and *Trumpetings* (the TTSS's newsletter published three times a year) has also improved dissemination of information on swan research and conservation, not only among swan researchers and conservationists but to a wider audience. Information on the Southern Hemisphere swans – the Black-necked Swans and Coscoroba Swans of South America and the Black Swans in Australia – remain a gap in knowledge, both regarding the research being undertaken and their population trends. Greater efforts will be made to cover these species more effectively (*e.g.* by approaching researchers active in these regions, known from their publications or *via* the IUCN SSC network to be studying waterbirds), in addition to continued monitoring and assessment of swan populations in the Northern Hemisphere, ahead of the next International Swan Symposium in *c.* 2–3 years' time.

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