International census and population trends for Bewick's Swans *Cygnus columbianus bewickii* wintering from the East Mediterranean to Central Asia

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Abstract

Trends in abundance and changes in the distribution of the Northeast Europe/Northwest Europe Bewick's Swan *Cygnus columbianus bewickii* population have been studied in detail since the second half of the 20th century, but much less is known about the Northwestern Siberia/Caspian population which was estimated at 1,000–1,500 individuals at the turn of the century. Here, we describe the results of the first species-specific mid-winter International Bewick's Swan Census (IBSC) covering the East Mediterranean to Central Asia, made in January 2020. We also use longer-term data collated by Wetlands International through the annual International Waterbird Census (IWC) programme to construct trends in wintering numbers in the region. Results from the IBSC and IWC both showed a marked increase in population size for the Northwestern Siberia/Caspian Bewick's Swans over the past two decades. A total of 6,819 was recorded during the IBSC and there was a five-year mean of 9,111 ± 4,300 swans reported to the IWC (for the years 2018–2022) with a peak count of 13,775 in 2019. An aerial survey of the Volga Delta in the northern Caspian Sea in 2020, rarely covered because of the logistical difficulties of carrying out mid-winter counts in the region, found an estimated 551 Bewick's Swans wintering at the site. There was marked annual variation in the IWC counts recorded from 2017 onwards, although the reasons for these fluctuations remain unknown. Trends analysis suggested a slow increase over time from 2000–2015, followed by a period of rapid increase during 2015–2017, then a weak decline in 2017–2022. Given that the IBSC and the IWC have provided totals of > 6,000 Bewick's Swans in five of the last six years, however, we propose that the new population estimate should be increased to 6,000–13,000 birds, pending further comprehensive surveys of the whole region.

Key words: central Asia, distribution, population trends, southeast Europe, swans.

The Bewick's Swan *Cygnus columbianus bewickii* breeds across the Russian arctic tundra, from the Kanin Peninsula in the Arkhangelsk Oblast to Eastern Chukotka (GSDSG 2023), and is currently held to consist of three populations which follow very different migration routes (Rees 2006). The first, formerly the "Northwest European population" (Delany & Scott 2002; Nagy *et al.* 2012), now described as the Northeast Europe/Northwest Europe population (hereafter NE/NWE), migrates from European Russia (west of the Urals) west to the White Sea then southwest to the Baltic and wintering sites in Northwest Europe. The second, the Northwestern Siberia/Caspian population (previously the "Caspian population"; Delany & Scott 2002), heads south along the River Ob, east of the Ural Mountains, towards what was traditionally thought to be its winter quarters: mainly along Caspian Sea coasts, although the precise distribution and status of that population is less well known. The third, and largest, of the three populations, the Eastern population, migrates east from the Yamal Peninsula to winter primarily in China, Japan and South Korea, with notably some population overlap of swans moulting on the southern Yamal Peninsula (Vangeluwe *et al.* 2018; Rozenfeld *et al.* 2019, see below). Thirteen swans tagged on the Pyasina Delta of the Taymyr Peninsula in far northern Russia in 2022 all migrated to Chinese wintering sites, showing that these were Eastern population birds (S. Rozenfeld, unpubl. data). GPS tracking of individual swans tagged east of the Ural Mountains additionally indicates that there may be at least two sub-populations of the Eastern population: the East Asian Continental population which winters in China and the West Pacific population which winters in Japan (Fang *et al.* 2020).

Whilst these three swan populations follow different flyways from the breeding grounds to distinct wintering sites, the boundaries of their summer distribution, and particularly whether the populations overlap in the breeding range, has generally been less well defined. Tracking data from 23 swans fitted with GPS-loggers in the southern part of the Yamal Peninsula east of the Urals (on Baydaratskaya Bay, 68.50°N, 68.00°E) between 2015–2017 found that these individuals took very different migration routes; all headed south along the eastern side of the Ural Mountains, with three birds continuing through northern Kazakhstan and the Caspian region to the Evros/Meriç Delta whilst others wintered on the Caspian Sea, in Central Asia and in southeastern China (Vangeluwe *et al.* 2018). Ten swans tracked from Khaypudyrskaya Bay (68.50°N, 59.50°E) on the eastern Pechora Sea just west of the Urals in 2019 all followed the same route easterly to Greece/Turkey (S. Rozenfeld & D. Vangeluwe, unpubl. data), indicating that a significant proportion of the Bewick's Swans which winter in the East Mediterranean region follow a very different flyway to that of the NE/NWE Bewick's Swan population, which heads west from the breeding grounds to the White Sea and across Karelia to the Baltic and to wintering grounds in northwest Europe. Re-sightings in Greece of a few (< 10) individuals ringed in western Europe (Rees 2006; Hellenic Rarities Committee

2007; Nagy *et al.* 2012) was indicative of population interchange, but the route taken by at least some of the swans to Greece was previously unknown.

Whilst the NE/NWE population has been studied in some detail since the mid-20th century (*e.g.* review in Rees 2006), internationally coordinated monitoring of the Eastern population across key wintering sites in China, Japan and South Korea has been undertaken only in the past two decades (Fang *et al.* 2020), and the conservation status of the Northwestern Siberia/Caspian population remains poorly understood (Rees *et al.* 2019). During the mid–late 20th century, the Northwestern Siberia/Caspian population was put at just 500 individuals by Wetlands International, with the main wintering sites located in Armenia and on the Caspian Sea coast of Azerbaijan, Turkmenistan and particularly Iran (Delany & Scott 2002; Rees 2006). Although 843 birds were counted in Iran alone in 1969, total counts submitted to Wetlands International for the mid-January International Waterbird Censuses (IWC) did not again exceed 400 until the early 2000s (Delany *et al.* 1999; Wetlands International, unpubl. data). Variable coverage and the small number of birds involved made it difficult to ascertain population changes convincingly, although counts tentatively suggested a population increase based on trends during the early 1990s followed by a decline towards the end of the 20th century (Delany *et al.* 1999). Syroechkovski (2002), however, emphasised that the size of this population was probably underestimated during the 20th century, through a combination of the misidentification of birds at stopover and wintering sites, the irregularity of wetland censuses in the region, difficulty in surveying swans in the north Caspian Sea during winter and the lack of dedicated Bewick's Swan surveys. Consequently, given the count of 843 swans in Iran and sightings elsewhere, he considered the Northwestern Siberia/Caspian population to be in excess of 1,000 and put it at 1,500 birds.

The NE/NWE Bewick's Swan population increased steadily during the second half of the 20th century to reach peak numbers in 1995, but numbers then declined markedly, resulting in the development of an International Single Species Action Plan (ISSAP) for the population, within the framework of the African-Eurasian Migratory Waterbird Agreement (AEWA) in May 2012 (Nagy *et al.* 2012). The reasons for the decline were unclear, and the situation was confounded by numbers wintering on the Evros/Meriç Delta on the Greek-Turkish border increasing from just a handful of birds present up to the mid-1990s (Handrinos 1996; Handrinos *et al.* 2015) to 8,400 counted in February 2016 (Litvin & Vangeluwe 2016; Vangeluwe *et al.* 2016), and 13,000 in 2024 (D. Vangeluwe, unpubl. data). Determining the extent to which Bewick's Swans in the East Mediterranean region represented a redistribution of swans from traditional NW European wintering sites, or a shift in distribution and concurrent increase in the Northwestern Siberia/Caspian population, therefore was included as an action for investigation within the ISSAP. In addition to the tracking studies described above, survival analyses of re-sightings data from colour-marked birds

in the NE/NWE population reported in winters 1970/1971–2014/2015 included numbers at the Evros/Meriç Delta as an explanatory variable. There was little support, however, for the population decline in northwest Europe being attributable to the growth in numbers of swans migrating to Greece and Turkey (Wood *et al.* 2018).

Nonetheless, during the preparation for the January 2020 international censuses of migratory swans across northwest Europe, it was decided to extend the census to include the wintering grounds of the Northwestern Siberia/Caspian population. The IWC had shown a marked upward trend in numbers during the early 21st century, with a particularly high estimate (and high confidence intervals) in 2017, resulting in the population being put at *c.* 1,000–8,400 birds (Wetlands International 2018). A coordinated international census of Bewick's Swans for wintering grounds ranging from the East Mediterranean to Central Asia in January 2020, timed to coincide with that of the NE/NWE population, therefore was undertaken in order to provide a more comprehensive near-simultaneous census of both populations. The overall aim was to improve our estimates of total numbers in the Northwestern Siberia/Caspian population, to provide a better description of the main wintering areas and internationally important sites for Bewick's Swans in the region for conservation purposes. The results of the census are also considered in relation to the longer-term IWC data (particularly those from 2000 onwards) for informing any changes needed to the monitoring of Bewick's Swans wintering between the East Mediterranean and Central Asia, for future assessment of population size and distribution.

Methods

The International Bewick's Swan Census (IBSC) has been undertaken across northwest Europe at 5-year intervals from 1990 onwards. This first species-specific census of the Northwestern Siberia/Caspian Bewick's Swan population was timed to coincide with the January 2020 census of the Northwest European Bewick's Swan population, so that the results could be directly compared. For each of the NE/NWE Bewick's Swan population censuses, the IBSC has been undertaken by a network of volunteer and professional ornithologists involved in national waterbird count programmes across the core wintering range, who submit their records to national count coordinators following the process put in place for the IWC, but extended to include non-IWC sites (*e.g.* where birds are feeding in arable areas) in an attempt to obtain complete coverage (see Beekman *et al.* 2019 for further details). The IBSC dates have been timed to coincide with the dates of the national waterbird monitoring schemes contributing to the IWC, to avoid asking the counters to make two surveys in January of census years. For January 2020, this was the weekend of 11–12 January, although counts made up to two weeks either side of the census dates were also included for sites not surveyed on the census weekend, if the national coordinator considered that the risk of duplicate counts was low.

In addition to the mid-January ground counts, an aerial survey was made of the

northern Caspian Sea (Volga Delta) by one of us (Sonia Rozenfeld) from 9–11 February 2020, to assess the number of swans in this part of their wintering range (Rozenfeld *et al.* 2020a, see details below). Given that Syroechkovski (2002) considered it likely that the area was used by Bewick's Swans in winter, an aerial survey was thought particularly important for improving coverage for the census. February dates were chosen because they provided a slightly longer daylength with better light conditions, and (as for aerial surveys made in Iceland for the 5-yearly Whooper Swan *Cygnus cygnus* censuses; Brides *et al.* 2021), the swans were also considered to be relatively settled in the mid-winter (non-migratory) season.

Whilst the January 2020 IBSC was the first species-specific simultaneous census of Bewick's Swans in the region, IWC data provide longer-term information on their numbers and distribution. The IWC data for 2000–2022 collated by Wetlands International are therefore also described, to illustrate changes in numbers and distribution over time.

Ground counts

For the January 2020 IBSC, in addition to contacting national count coordinators across northwest Europe, we contacted the national count coordinators of countries identified as being in the wintering range of the Northwestern Siberia/Caspian Bewick's Swan population, and also areas used by two Whooper Swan populations (the Black Sea/East Mediterranean Whooper Swan population, and the Caspian/West Siberian Whooper Swan population), requesting that they participate in the census. These were for countries extending from the East Mediterranean region through the Black Sea and Caspian Sea region to Central Asia; specifically, coordinators in Armenia, Azerbaijan, Bosnia & Herzegovina, Bulgaria, Croatia, Georgia, Greece, Iran, Iraq, Italy, Kazakhstan, Kyrgyzstan, Macedonia, Malta, Moldova, Montenegro, Romania, Russia, Serbia, Slovakia, Slovenia, Turkey, Turkmenistan, Ukraine and Uzbekistan were invited to advise their count network about the data request (*i.e.* to obtain comprehensive counts of both species) for the IBSC.

Each regional coordinator was provided with a formatted Microsoft Excel spreadsheet for geographic consistency in data collection. Data requested on the spreadsheet included: country, site name/location and coordinates, count date, species, the total number of birds counted, the number of adults and cygnets in the flocks, family sizes (*i.e.* number of cygnets associating with their parents), and the habitat on which the swans were located.

Aerial survey of the Volga Delta

The shallow waters of the Volga Delta provide important staging and wintering areas for swans, and the mild 2019/2020 winter (characterised by a lack of ice) is thought to have resulted in a higher number of swans being present during mid-winter, in comparison with more usual years (Astrakhansky State Nature Reserve, pers. comm.). The northern Caspian region has only twice been included in the IWCs (winter ice conditions restricts access by boat), but *c.* 22,800 swans were counted (most not identified to species level, but

including 6,585 Whooper Swans and 1,901 Mute Swans *Cygnus olor*) from the air and by boat in mild conditions in January 2005, compared with very few (47 and 944, respectively, during a boat survey) in 2006, when the Volga Delta was mostly frozen (counts by Dr. German Rusanov of the Astrakhan Biosphere Reserve; A. Solokha, pers. comm.). The sea did not freeze until November in 2019 and in February, after the aerial survey, it melted quite quickly (further details in Rozenfeld *et al.* 2020a). The aerial survey of swans on the Volga Delta was made a few weeks later than the ground counts, during 9–11 February. On 9 February, temperatures fell to –16°C, it snowed, and shallow marine areas (the most important wintering areas for the swans) froze completely. Consequently, the swans congregated at the water's edge in the avandelta (*i.e.* the subaqueous part of the delta) which undoubtedly contributed to the ability of making a comprehensive survey of most of the swans present at that time. Counts were undertaken from a high-wing ultralight aircraft SP-30 (Rozenfeld *et al.* 2020a), with a two-seater (side-by-side) cockpit that had a forward view of 180°, a maximum speed of 120 km/h and a small (200–250 m) turning radius, which facilitated counting birds from the air. Counts were carried out at 80–120 km/h, at an altitude of 30–80 m, and the flight tracks were recorded by GPS (Garmin). All swans encountered during the flight were photographed, from both sides of the plane, using a DSLR camera with 100–400 mm lens and built-in GPS locator. The total route flown during the aerial survey was 1,509 km, of which 1,269 km was along the Volga Delta and 240 km through the lakes area (*i.e.* the northwestern part of the survey area), and the area surveyed was estimated at 726 km^2 (Fig. 1).

Swarovski 10 × 42 binoculars were used to search for flocks during the survey, whereupon the aircraft flew lower (by 10–20 m) to permit identification of the swans and assess the proportion of each species in a flock. Individual birds and groups of < 10 birds were mapped, counted and photographed. The flight trajectory therefore was not in a straight line (transect) but resulted from the actual flight path flown from group to group. The area covered by the aerial survey was calculated by describing an 800 m buffer on either side of the flight lines within a GIS. Numbers of Bewick's Swans, Whooper Swans, Mute Swans and unidentified swan species encountered were recorded relative to the actual GPS-determined position of the aircraft during the flight and subsequently from the photographs taken during the survey. The 13,706 photographs were compiled into a photobank, with georeferencing (uploaded to https://yadi.sk/d/ew8KivDc2tvK3Q), and numbers of each species were then counted manually and age ratios determined from plumage characteristics from the images. Unidentified swans were ascribed to one of the three swan species in the region on a proportionate basis, based on overall relative encounter rates of identified swans.

Statistical analyses

The temporal trends in Bewick's Swan total numbers were assessed by fitting regression models in R version 4.2.2 (R Core Team

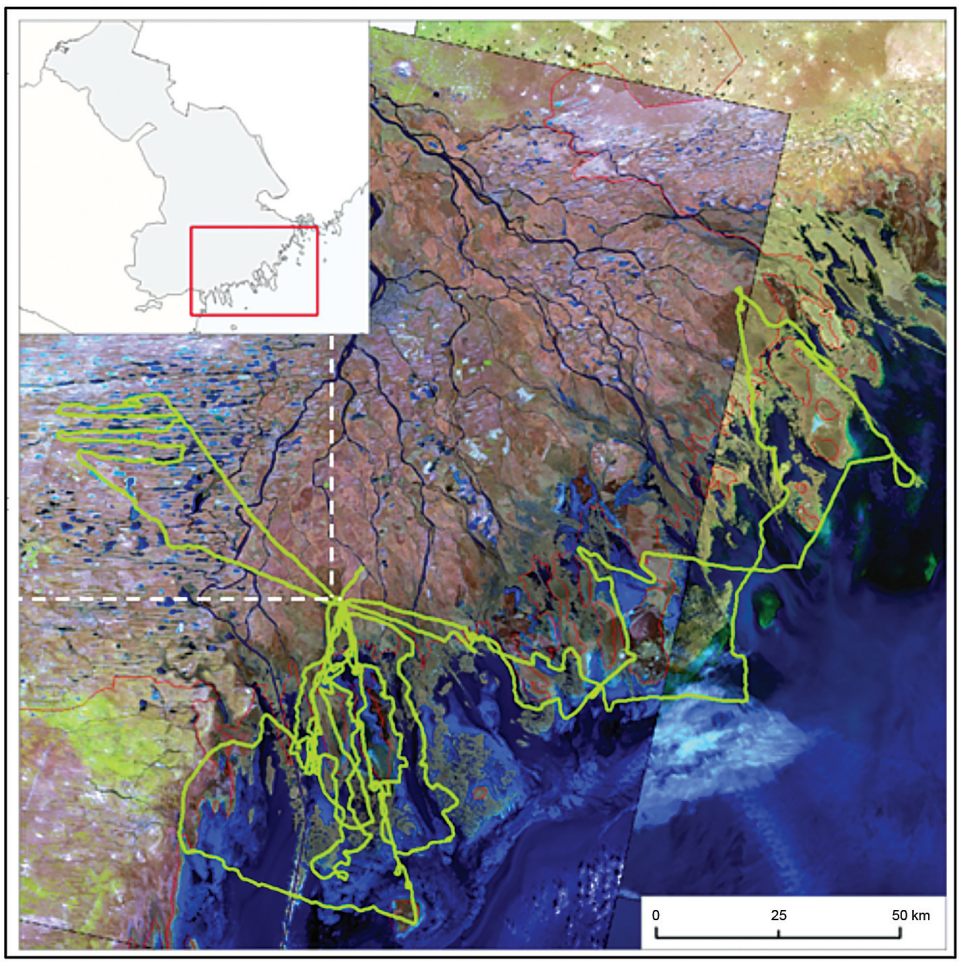

Figure 1. Route of the aerial survey of the Volga Delta region, in the north Caspian Sea: 8–11 February 2020. The dashed white line indicates the "lakes area" part of the survey.

2022), with model assumptions assessed using the performance package (Lüdecke *et al.* 2021). Time-series data for swans can show temporal autocorrelation over successive years, which must be accounted for in regression models (Wood *et al.* 2019). To test for the presence of temporal autocorrelation we fitted a linear regression of Bewick's Swan total annual counts against count year, using the nlme package (Pinheiro *et al.* 2023). An assessment of the model residuals revealed no statistically significant temporal autocorrelation ($P > 0.05$ for all time lags) and hence no autocorrelation structure was required in subsequent models.

Four competing models of temporal trends in Bewick's Swan total annual

numbers were fitted: (i) a null model (*i.e.* no temporal trend), (ii) a linear model, (iii) a piecewise regression model with one break point and (iv) a piecewise regression model with two-break points. Break points in the time-series were estimated using the segmented package (Muggeo *et al.* 2008). Models with three or more break points could not be fitted given the available data. The relative performance of each of the four models was compared using Akaike information criterion (AIC), with the model with the lowest AIC value judged to be the best-supported model. The adjusted R^2 value was also calculated to indicate the proportion of the variance in the data explained by each model.

Results

Aerial survey of the Volga Delta

A total of 225,532 swans was counted, of which 95,186 (42%) were identified to species level: 19,944 (20.95%) Mute Swans, 75,018 (78.81%) Whooper Swans and 224 (0.24%) Bewick's Swans. Applying this ratio to the unidentified swans gave extrapolated totals of 47,255 Mute Swans, 177,746 Whooper Swans and 531 Bewick's Swans in the Volga Delta. Only one Bewick's Swan cygnet was recorded during the survey (0.5% among 224 birds, compared with 17.9% among the Whooper Swans and 24% for Mute Swans). It was not possible to relate swan distribution to habitat and food availability in the delta, but whereas Mute Swans (in particular), and to a lesser extent Whooper Swans were found in the lakes area as well as in the delta (Fig. 2a,b), the Bewick's Swans were recorded only in the delta area, where the Volga River joins the Caspian Sea (Fig. 2c). For full details see Rozenfeld *et al.* (2020b) and for the positions of swans detected see GSDSG (2023).

Census of the Northwestern Siberia/Caspian Bewick's Swan population in 2020

In addition to the aerial survey, ground-based counts of Bewick's Swans were reported for an additional 40 sites in 14 countries, ranging from Italy (2 birds) in the west to Uzbekistan (55 birds) in the east (Fig. 3a, Table 1, Supporting Materials Table S1). A total of 6,512 Bewick's Swans was counted during the census, increasing to a population estimate of 6,819 on including extrapolation of unidentified swans on the Volga Delta. Most of the birds were found in the Evros/Meriç Delta region of Greece (3,320) and Turkey (1,302) on 12 January 2020, with 359 at other sites in Greece (notably Lake Kerkini) and a further 693 in the Black Sea region (Supporting Materials Table S1).

In addition to the 14 countries where Bewick's Swans were observed, a further six countries (Armenia, Bosnia & Herzegovina, Croatia, Georgia, Kyrgyzstan and Slovakia) reported zero counts, although Whooper Swans were recorded in Armenia and Kyrgyzstan. Data were missing for some countries where Bewick's Swans have been seen in other winters, but generally where they have only occasionally been recorded.

Longer-term trends in the IWC data (2000–2022)

Prior to 2000, only small numbers of Bewick's Swans at wintering sites between

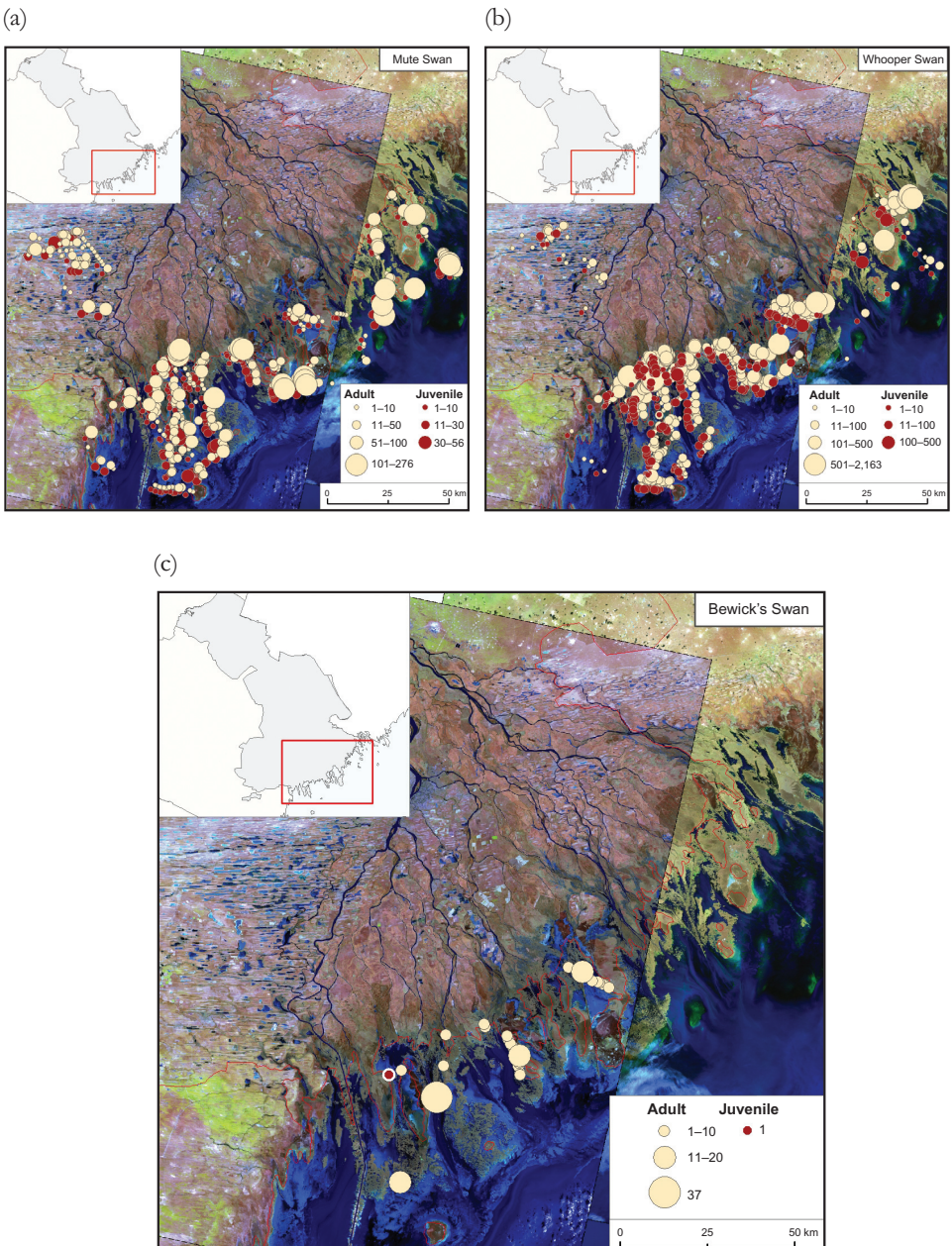

Figure 2. Location of swans recorded during the aerial survey of the Volga Delta region, February 2020: (a) Mute Swans, (b) Whooper Swans, and (c) Bewick's Swans.

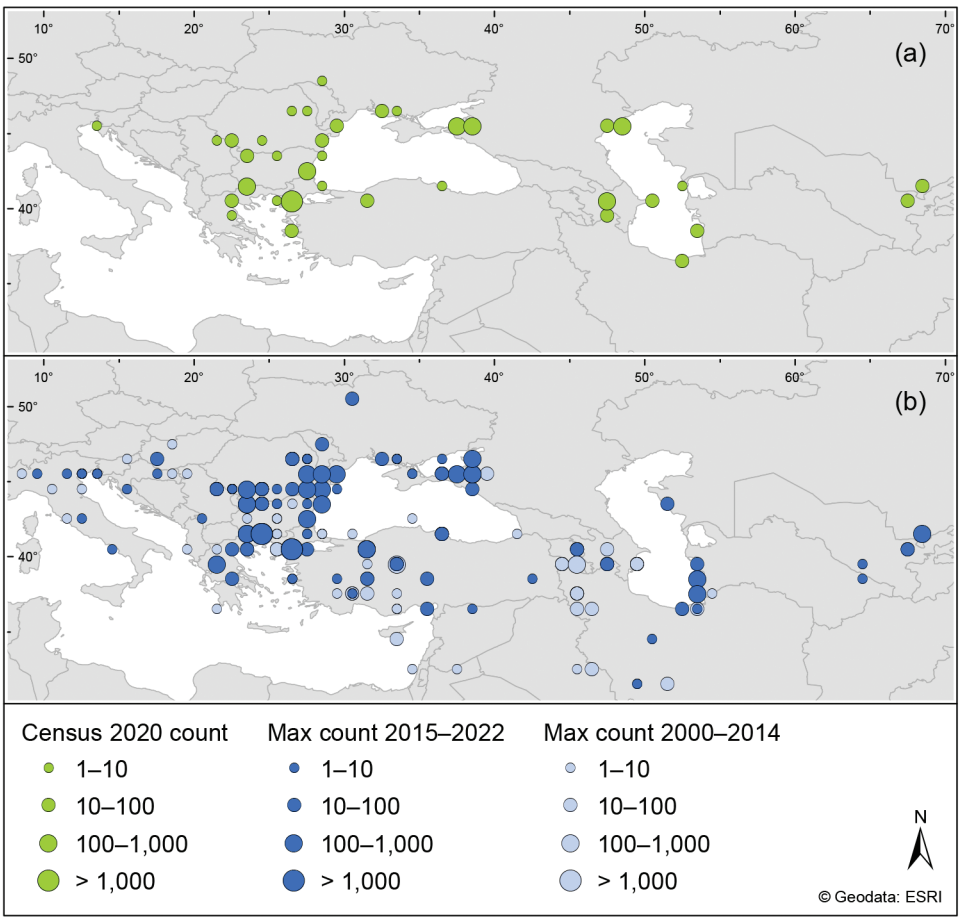

Figure 3. Location of Bewick's Swans counted in the wintering range of the Northwestern Siberia/Caspian population: (a) during the International Bewick's Swan Census (IBSC) in January–February 2020 and (b) reported to the International Waterbird Census (IWC), 2015–2022 and additional grids 2000–2014 (from Nagy 2023) (aggregated into 1° × 1° grid squares)

the East Mediterranean and Central Asia were counted during the annual IWC. The number of countries in this area reporting Bewick's Swans to the IWC ranged from zero to five each year during 1969–1999 inclusive, and the peak count of 849 swans in 1969 was mostly a result of 843 birds being reported from Iran. The other six birds were sighted in Greece (Wetlands International unpubl. data).

Numbers remained low in the early part of the 21st century, with < 700 individuals reported annually from three to ten countries up to 2010, including 761 in 2005 (n = 9 countries) and 348 in 2008 (n = 8 countries) when coverage was relatively

Table 1. Total number of Bewick's Swans counted in the wintering range of the Northwestern Siberia/Caspian population during the international swan census 2020. In addition to 14 countries where Bewick's Swans were recorded, zero counts were reported from a further five countries participating in the census: Armenia, Bosnia & Herzegovina, Croatia, Georgia, Kyrgyzstan, Slovakia.

Country	Total Bewick's Swans counted	No. sites with Bewick's Swans	Total aged	No. cygnets (%)	Habitat
Azerbaijan	269	2	14	0 (0%)	Artificial lake (*n* = 14 birds)
Bulgaria	157	4			
Greece	3,679	6			
Iran	68	2			
Italy	2	1	2	0 (0%)	Non-tidal river (*n* = 2 birds)
Kazakhstan	14	1	14	4 (28.6%)	
Moldova (Republic of)	1	1	1	1 (100%)	
Romania	44	7			
Russian Federation (Black Sea)	472	2			Artificial lake (*n* = 138 birds); Brackish lake (*n* = 334 birds)
Russian Federation (north Caspian)	224†	1			Avandelta
Serbia	23	2	8	3 (37.5%)	Non-tidal river (*n* = 15 birds)
Turkey	1,374*	5			
Turkmenistan	57	2	57	19 (33.3%)	Open coast (*n* = 53 birds)
Ukraine	73	4			
Uzbekistan	55	1			
TOTAL	**6,512‡**	**41**	**96**	**27 (28.1%)**	

*Including 1,302 on the Turkish side of the Evros/Meriç Delta

†Increases to 531 on adding 307 birds from the 130,346 swans not identified to species level during the aerial survey, on a proportionate basis.

‡Total population estimate = 6,819 Bewick's Swans on including the 307 birds mentioned above.

good (Supporting Materials Table S2), but there was a significant increase thereafter to a peak count of 13,775 reported to the IWC in January 2019 (linear regression for years 2000–2022: $F_{1,21} = 31.44$, $P < 0.001$; Fig. 4). Most were recorded in Turkey and Greece in mid-winter (Fig. 3b, Fig. 4), notably on the Evros/Meriç Delta, where the swans roosting on the Greek side of the delta fly out to feed on Rice *Oryza sativa* crops in fields on the Turkish side during the day. Of the peak counts of 9,934, 8,712 and 9,705 recorded in Turkey in 2017, 2019 and 2022, respectively (Fig. 4, Supporting Materials Table S2), 9,523 (95.7%), 8,645 (99.2%) and 9,610 (99.0%) were found in the Evros/Meriç Delta region. Following the initial build-up to 4,556 in 2016, numbers more than doubled to 11,083 in 2017, largely attributable to the particularly high counts in Turkey. There was marked annual variation in the annual totals thereafter, ranging from 3,855 in 2021 to 13,309 in 2019, with the IBSC total of 6,819 in 2020, when 18 countries reported Bewick's Swan counts (including six with zero Bewick's Swans) either to the IBSC or to the IWC, which fell midway between these extreme values.

Based on IWC data from the other countries, there was some evidence for increasing numbers in the western Black Sea region where Bewick's Swan counts in Romania and Bulgaria rose to a maximum count to date of 800 and 266 birds respectively, in 2022 (Supporting Materials Table S2). Mid-winter counts were more

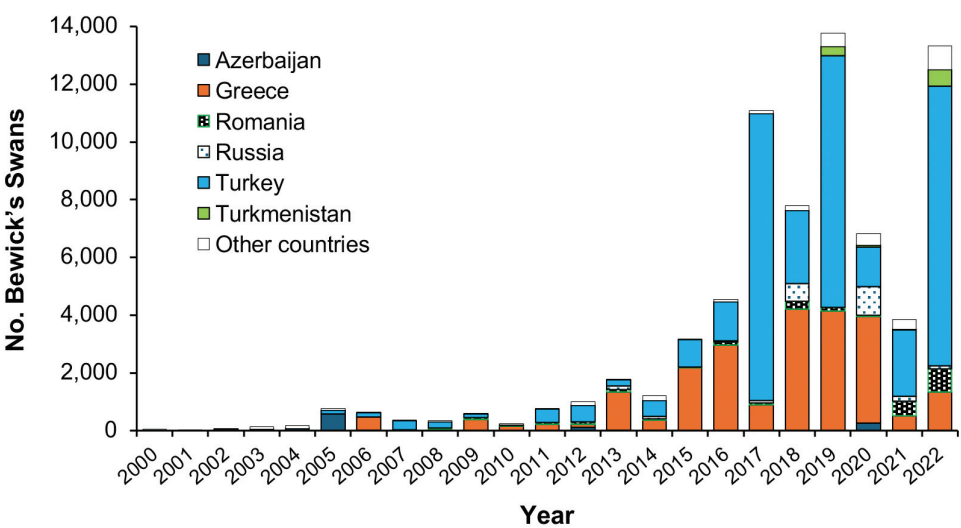

Figure 4. Number of Bewick's Swans in the wintering range of the Northwestern Siberia/Caspian population reported to the International Waterbird Census, showing the contribution of all (named) countries with counts of > 500 swans in any one year during 2000–2022 and the contribution from other countries (Other). Data for 2020 include counts from the International Bewick's Swan Census in January–February of that year.

variable further east, ranging from zero to 76 birds in Armenia (n = 7 years' data between 2000–2022), 3–583 in Azerbaijan (n = 8), 8–123 in Kazakhstan (n = 8), 1–115 in the Republic of Moldova (n = 4), 2–1,003 in the Russian Federation (n = 9), 1–71 in Serbia (n = 23), 57–553 in Turkmenistan (n = 4), 1–73 in Ukraine (n = 8) and 9–55 in Uzbekistan (n = 3; Supporting Materials Table S2). Italy receives small numbers on a regular basis (n = 11 years with Bewick's Swan sightings in 23 years of monitoring between 2000–2022), usually of < 5 individuals but with 15 recorded in 2019, possibly originating from the birds regularly wintering in the Camargue, France (Nagy *et al.* 2012). Elsewhere, Bewick's Swans were recorded only occasionally, apparently as vagrants: in Albania (six and four birds in 2005 and 2022, respectively), Croatia (three and one in 2005 and 2017), Cyprus (11 birds in 2002), Georgia (two birds on the eastern coast of the Black Sea in 2014), Hungary (two, 21 and one in 2010, 2018 and 2019), Israel (two birds in 2005), Iraq (20 and three in 2008 and 2010), Jordan (one in 2005), Kyrgyzstan (one and two in 2004 and 2019) and Slovenia (two birds in 2013). Five were recorded in Oman in 1989 and two in the United Arab Emirates in 1994, but there have been no records of Bewick's Swans in these countries in more recent years (Wetlands International, unpubl. data).

The distribution of Bewick's Swans recorded by the IBSC and the IWCs were generally consistent, extending from Italy, Romania, Bulgaria and Greece in the west to Turkmenistan and Uzbekistan in the east in both cases, except that those wintering in the northern part of the Caspian Sea (in the Volga Delta region) were missing because the area was not covered by the IWCs. The species has regularly been seen on the southern shores of the Caspian Sea since the early days of the IWCs, with a mean (± s.d.) of 25.8 ± 23.8 birds recorded in Iran for the 15 years between 2000 and 2017, increasing to 122.2 ± 142.8 in 2018–2022. Numbers further east, in Uzbekistan, were rather low with nine birds counted across two sites (Lakes Tudakul & Kuymaza and at Sechankul) in 2018, 55 at one site (Tuzkan Lake) in 2020 and 12 again at Tuzkan Lake in 2021.

The temporal trends in Bewick's Swan total annual counts were best-explained by a model featuring two break points in the relationship between count and year, which had the lowest AIC value of any of the four models tested and accounted for 75% of the variance in the data (Table 2). The relationship between Bewick's Swan total count and year showed a slow increase over time between 2000 and 2015, followed by a period of rapid increase (2015–2017), with a weak decline in the final years (2017–2022) (Table 3).

Discussion

Population delineation

An initial objective for attempting to determine the abundance and status of the Northwestern Siberia/Caspian population of Bewick's Swans was to determine its winter distribution in relation to the NE/NWE and the Eastern populations, particularly for swans wintering in southeast Europe in the east Mediterranean and Black Sea regions. The small numbers of Bewick's Swans recorded in Greece, Turkey and

Table 2. A comparison of four competing models of changing Bewick's Swan numbers in the wintering range of the Northwestern Siberia/Caspian population in 2000–2022.

Model	AIC	ΔAIC	Adjusted R^2
Segmented (2 break points)	426.3	0.0	0.752
Segmented (1 break point)	429.4	3.4	0.694
Linear	434.9	8.9	0.581
Null	454.0	28.0	0.000

Table 3. The parameter estimates associated with our best-supported model of the changes in Bewick's Swan numbers over time (see Table 2).

Parameter	Estimate	Standard error
Intercept	–214022.20	261675.60
Year (2000–2015)	106.90	130.40
Year (2015–2017)	3760.40	3088.10
Year (2017–2022)	–4002.00	3129.10

around Black Sea coasts up to the 1990s initially resulted in these birds being treated as vagrants, so they were not ascribed to either of the two western Palearctic populations in earlier editions of the Waterbird Population Estimates, published by the International Waterfowl Research Bureau and more recently by Wetlands International (Scott & Rose 1996).

The source of the increasing numbers wintering on the Evros/Meriç Delta during the 21st century was (and to some extent remains) unclear. GPS-tracking of swans tagged in the Russian arctic have shown that a proportion of those summering between Khaypudyrskaya Bay and the Yamal Peninsula in northcentral Siberia consistently head south along the eastern side of the Ural Mountains, through northern Kazakhstan and the Caspian region, to the Evros/Meriç Delta (Vangeluwe *et al*. 2018; S. Rozenfeld & D. Vangeluwe, unpubl. data), indicating that Bewick's Swans wintering in the East Mediterranean region follow the flyway of the Northwestern Siberia/Caspian population. The study in fact described four main wintering areas for the 23 swans tracked from northcentral Siberia between 2015–2017: the Evros/Meriç Delta (southeast Europe), the north Caspian Sea (including

the Volga Delta), central Asia (Uzbekistan, Turkmenistan) and Poyang Lake (China; Vangeluwe *et al.* 2018). Whilst those migrating to the north Caspian Sea and southeast Europe can be ascribed to the Northwestern Siberia/Caspian population, and those heading to Poyang Lake are of the Eastern population, whether Bewick's Swans wintering in central Asia should be grouped separately from the Northwestern Siberia/Caspian population required further consideration. It was, however, noted that (expecting the Poyang Lake birds, which took a more eastwardly route) swans with these different wintering destinations tended to follow the same flyway at the start of their migration, in that they all generally head south along the River Ob to the agricultural areas of Northern Kazakhstan, where they also use the numerous lakes in the region (N. Rogova, pers. comm.), before some continue further south and east into central Asia, whilst others head along the north Caspian, Black Sea and Evros Delta corridor (Vangeluwe *et al.* 2018). Moreover, the migration routes for swans wintering in other parts of the range such as the southern Caspian Sea, Azerbaijan and Turkey remain unknown, so it is unclear whether the swans fan out on a broad-front migration from Kazakhstan, or have a smaller number of distinct migration routes to their wintering destinations. Even with counts of *c.* 100–600 in Azerbaijan in some years (Supporting Materials Table S2), the small numbers in Uzbekistan, Turkmenistan and Kazakhstan means that the eastern part of the range currently does not fulfil some of the AEWA guidelines for separating them as a separate population. For instance, thresholds for describing sites of international importance for the species (1% of the total population size) are very low where the population size is small, which could put undue emphasis on sites with relatively few birds on considering the species in a global context (Atkinson-Willes *et al.* 1982).

Overall, it was therefore considered that Bewick's Swans wintering from southeastern Europe through to Uzbekistan should be treated as a single flyway population, pending further information on the numbers and migration routes for swans in different parts of the wintering range. We recommend the investment of particular effort to study swans in the more easterly regions, however, to confirm the numbers of Bewick's Swans wintering in central Asia, identify key sites and provide a better description of their migration routes, with the overall aim of improving measures to protect them in this part of the range, where we currently lack information on their abundance and distribution.

Population size and trends

The longer-term IWC data, combined with the results of the IBSC in 2020, confirm a marked increase in population size for the Northwestern Siberia/Caspian Bewick's Swans over the past two decades. A total of 6,819 swans was recorded during the coordinated species-specific census (the IBSC) and there was a 5-year mean of 9,111 ± 4,300 swans reported to the IWC (for years 2018–2022; peak count = 13,775 in 2019), compared with population estimates of *c.* 1,000–1,500 individuals up to the end of the 20th century (Delany *et al.* 1999; Syroechkovski 2002). Our regression

analyses highlighted the mid-2010s as a period of particularly rapid increase in swan numbers. High variability in the total numbers recorded by the IWC each year from 2017 onwards resulted in wide confidence intervals for the most recent population trends analysis undertaken by Wetlands International, which provided a population estimate of *c.* 1,000–8,400 birds (Wetlands International 2018). The overall increase reported by Wetlands International and in this paper is however significant and, whilst it is possible that some double-counting has occurred through surveys being made on the Greek and Turkish sides of the Evros/Meriç Delta, coordination between the counters in 2020 aimed to keep this to a minimum. Moreover, several hundred Bewick's Swans were found wintering in the northern Caspian Sea during the aerial survey of the Volga Delta in February 2020 (Rozenfeld *et al.* 2020b) and, although longer-term data are needed to determine the extent to which this varies between years, it seems likely that IWC will usually have missed swans wintering in this area. Meanwhile, given that the IBSC and the IWC have provided totals of > 6,000 Bewick's Swans in five of the last six years, we propose that the new population estimate be increased to 6,000–13,000 birds.

The onset of the population growth appears visually to have commenced in about 2010 but given some variation in coverage may have started earlier, *e.g.* from about 2006 when 473 birds on the Evros Delta in mid-January was a record for the species in Greece (Hellenic Rarities Committee 2007). Our regression analysis indicated that the period of the most rapid increase in population size began in 2015. Numbers wintering at the site increased steadily to 8,400 in February 2016 (Litvin & Vangeluwe 2016), although the high February count contrasted with a combined report from Greece and Turkey of 4,325 Bewick's Swans on the Evros/Meriç Delta during the mid-January IWC in the same year. This gave rise to the question of whether the late-winter peak count reflected variation in coverage between counts (with more rigorous counts being made in February, *e.g.* as described by Litvin & Vangeluwe 2016), a seasonal westward shift of Northwestern Siberia/Caspian Bewick's Swans during the winter (in response to environmental conditions such as the availability of food resources in different parts of the wintering range), or a combination of these factors. In 2017, however, the swans appeared to arrive earlier, with over 9,000 swans in Turkey and 899 in Greece during the IWC January mid-winter count (Wetlands International, unpubl. data; P. Ioannidis, unpubl. data), illustrating that the variables which affect the timing of migration of swans to the East Mediterranean region and their use of the Evros/Meriç Delta site warrant further investigation.

Reasons underlying the population increase

In addition to determining the origins of the swans wintering on the Evros/Meriç Delta (also considered above), the reasons underlying the increase in population size are of great interest, particularly when compared to the marked decrease in the NE/NWE Bewick's Swan population since the mid-1990s (Nagy *et al.* 2012). Three main hypotheses have emerged, which are

not necessarily mutually exclusive: (1) that the increase, particularly in Greece and Turkey, is at least partly attributable to a redistribution of swans, either from the NE/NWE Bewick's Swan population or the East population (described as fluctuating or possibly declining; Fang *et al.* 2020; Rees *et al.* 2019; Rees & Clausen 2024), (2) that the Northwestern Siberia/Caspian population has previously been underestimated, with the increase reflecting a westwards shift in distribution from areas such as the north Caspian region which have not previously been covered by waterbird surveys, and (3) that the increase is a consequence of relatively high productivity and/or low mortality rates in recent decades.

The first of these hypotheses has received particular attention because of the NE/NWE Bewick's Swan population decline, and it was noted that, even if all the swans wintering on the Evros/Meriç Delta were from northern Europe, the population would still be below the levels recorded in the mid-1990s (Beekman *et al.* 2019). Some movement of birds between the two flyways undoubtedly occurs, with three swans ringed in the UK subsequently recovered near Perm (on the western side of the Ural Mountains; one individual) and in Astrakhan (north of the Caspian Sea; two individuals) during the 1980s (Rees 1991). More recently, only a handful of Bewick's Swans colour-marked on the NE/NWE flyway have been identified in Greece (< 10 individuals; Rees 2006; Vangeluwe *et al.* 2016), despite extensive searches made for neck-banded Bewick's Swans on the Evros Delta during 1997–2024, with 5 more marked further east (on the eastern Pechora and Yamal Peninsula) also sighted in the region (D. Vangeluwe, pers. obs.). That the number of NE/NWE Bewick's Swans reported in Greece is very low in comparison with the number of colour-marked birds in the NE/NWE Bewick's Swan population suggests that relocation of swans which traditionally winter in northwest Europe is likewise low. Additionally, annual changes in the peak numbers counted in Greece were not found to be an important explanatory variable on analysing the swans' apparent survival rates, which also includes permanent emigration (Wood *et al.* 2018). There is some evidence from our study for an increase in Bewick's Swans on the western Black Sea coast in Romania and Bulgaria (where the combined total amounted to 1,066 in 2022), but numbers recorded in these key countries between wintering grounds in northwest and southeast Europe are relatively low and 6,000–13,000 birds taking this route are unlikely to be missed. It should be remembered, however, that a shift in distribution is perhaps more likely to occur in summer than in winter, potentially in response to differential warming effects on the breeding areas, and that individuals extending further east in the breeding range may join flocks migrating along the River Ob rather than returning west during autumn migration. Observations made in east European Russia found that swans from the eastern part of the Nenetsky Autonomous Okrug congregate in the Baydaratskaya Bay, from where they migrate through the Ural Mountains along the Ob River to other wintering areas (including the Evros Delta) but not towards northwest Europe (Rozenfeld *et al.* 2019).

Whether the increase in numbers is a consequence of a westward shift in distribution by the Northwestern Siberia/Caspian population making it easier to count the birds and thus improve estimates of total population size is of course difficult to assess, but the tracking data and also the relatively few sightings from Greece of swans colour-marked whilst wintering in northwest Europe, is indicative of a redistribution by the population from sites further east. Such redistributions have been noted for other waterbird species at different times; for instance, several tens of thousands of Red-breasted Geese *Branta ruficollis* wintered in the Caspian Sea region during the mid-1950s, but since 1968 only 1,000–2,000 remain there with the birds now wintering primarily in the Black Sea region (Carboneras *et al.* 2020). Pink-footed Geese *Anser brachyrhynchus* likewise have been shown to follow new migration routes (Madsen *et al.* 2023), and to change their migration strategies in order to track food resources in response to rapid land use change (Clausen *et al.* 2018). Since the 1970s, the wintering range of the NE/NWE Bewick's Swan population has shifted northeast in response to climate warming (Nuijten *et al.* 2020; Linssen *et al.* 2023). For the Northwestern Siberia/Caspian population, conditions on the rice fields used by the swans for feeding (*e.g.* the biomass available and whether there have been dry periods or flooding) are likely to be an important influence on the swans' movements to and within the region (D. Vangeluwe & P. Ioannidis, pers. comm.).

An earlier study has shown that Bewick's Swans in the Eastern population had consistently higher breeding success than those in the NE/NWE population in the early years of the 21st century (Cong *et al.* 2011), so it is certainly possible that the different population trajectories of the NE/NWE and the Northwestern Siberia/Caspian Bewick's Swans are at least partly attributable to differences in productivity, though annual survival rates for swans migrating through western Siberia remain unknown. Whether it is biologically possible for the steep increase in numbers to be explained only by demographic parameters, or if some redistribution of birds either from the NWE/NEE or the Eastern populations is necessarily involved, is also hard to assess in the absence of consistent and extensive historic data on Bewick's Swan numbers in Central Asia. Aerial surveys made of waterbirds on the Taymyr Peninsula in 2019–2021 found that Bewick's Swan numbers there have increased markedly to 14,800–26,300 individuals since estimates of 4,000 birds made during the 1990s (Syroechkovski 2002; GSDSG 2023; S. Rozenfeld, *in litt.*), indicating population increases in the central part of the breeding range, although it should be noted that all Bewick's Swans GPS-tagged on the Taymyr Peninsula to date have migrated to East Asia (S. Rozenfeld unpubl. data). Sample sizes of birds aged during the IBSC were quite small, and also rather variable. Of 27 birds age-checked in Azerbaijan, Kazakhstan, Moldova, Serbia and Turkmenistan, 28.1% were cygnets (Table 1; compared with 6.6% in 9,269 Bewick's Swans aged in the NE/NWE population in the same winter, in December 2019; Tijsen & Koffijberg 2021), but only one juvenile was found in 224

Bewick's Swans during the aerial survey of the Volga Delta, in contrast to 17.9% juveniles among Whooper Swans and 24% for Mute Swans at the site (Rozenfeld *et al.* 2020). Nonetheless, whilst noting the lack of long-term productivity data currently available for Bewick's Swans wintering from the East Mediterranean to Central Asia, the increase in population size for the Northwestern Siberia/Caspian Bewick's Swan population may at least to some extent be associated with relatively high breeding success by the swans breeding between the east Pechora and the Yamal Peninsula. Meanwhile, aerial surveys made between 2014–2017 to estimate the numbers and productivity of Bewick's Swans in European arctic Russia, and also on the Yamal and Gydan Peninsulas, found an increase in numbers of nesting birds compared with the 1980s, indicative of a movement of birds from the Eastern population to breeding areas further west (Rozenfeld *et al.* 2019).

The increase in the Northwestern Siberia/Caspian population therefore may be attributable to one or a combination of factors, and it will be difficult to confirm all of the reasons underlying the change in distribution and population trajectory. It is clear, however, that this population is currently in a state of flux and that it warrants much more extensive monitoring and research in order to determine the drivers of population change.

Data availability

The R code and data associated with the analyses reported in our study can be accessed via the following DOI: https://doi.org/10.6084/m9.figshare.25216058

Acknowledgements

The insight into Northwestern Siberia/Caspian Bewick's Swan population presented in this paper would not have been possible without the data provided by the dedicated network of volunteer counters and professional ornithologists who spent time observing the swans and reporting their data in countries ranging from the East Mediterranean and western Black Sea areas through the Caspian region to central Asia. We are immensely grateful to them all. We also wish to thank Goran Topic (Bosnia and Herzegovina), Tibor Mikuska (Croatia) and Jimsher Mamuchadze (Georgia) who advised that there were no Bewick's Swans in their countries during the 2020 International Bewick's Swan Census. This provides valuable baseline information for future IBSCs! The aerial survey of the Volga Delta, a major undertaking, would not have been possible without the management of the Astrakhansky State Nature Reserve, K.V. Litvinov, Maxim Perkovsky and A.V. Nikitin who organised the logistics, pilots S.V. Kuznetsov and G.A. Pliguzov, and technician N.V. Zapaschenko. Wetlands International and the Wildfowl & Wetlands Trust kindly provided financial support of the survey. Finally, we are indebted to the national count coordinators for their important ongoing work in providing waterbird count data to the IWCs, and to Craig Ely (Guest Editor) and two referees for helpful comments on an earlier draft of the manuscript. The international swan censuses are a collaborative initiative, coordinated by members of the IUCN SSC Swan Specialist Group.

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