Year-round movements of female Common Scoter *Melanitta nigra* nesting in Scotland; birds of a feather don't flock together

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Abstract

Numbers of breeding Common Scoter *Melanitta nigra* have declined in Britain and Ireland since the mid-1990s. To investigate little-known aspects of their annual cycle, nine nesting females at four of the main breeding sites in Scotland (in Inverness-shire, Perth and on Islay) were fitted with unique coloured leg rings and global location sensing (GLS) daylight loggers to track their year-round migrations and wintering areas. Unsuccessful breeders (failing at eggs or duckling stage) left the nesting areas and arrived on the sea from 22 July to 7 August (n = 10) with successful breeders (young reared to > 10 days) arriving between 18 and 20 August (n = 2). In December to February, when movements were at a minimum, the birds were widely dispersed at locations including the Moray Firth, (northeastern Scotland), the west and east coast of Ireland, Liverpool Bay (mid-western England) and the west coast of Morocco. The results from GLS deployed on female Common Scoter are the first to link breeding, staging and wintering areas in this species in time and space, showing Scottish-breeding birds wintered at sites from the north to the southerly extent of their known winter distribution. One of the birds wintering off Morocco staged off the Netherlands before returning to Scotland. All birds arrived back on the breeding sites between 13 and 30 April (n = 10). The apparent high survival rate and strong philopatry of female Common Scoters suggest that low reproductive output and/or low first-year survival contribute to the observed decline in breeding numbers, supporting the need for current conservation actions at the Inverness-shire breeding sites to protect the species.

Key words: annual cycle, geolocator, GLS, migration, winter dispersal, winter site fidelity.

The Common Scoter *Melanitta nigra* is a Palearctic migrant sea duck that breeds in freshwater habitats from Iceland, east to northern and central Russia (Collinson *et al.* 2006). It winters in the Baltic Sea, off the Atlantic coast of Europe and North

Africa, south to Mauritania, and is highly gregarious when not breeding (Kear 2005). The population size (*c.* 687,000–815,000 birds, Wetlands International 2021) and range are large and the species is evaluated as Least Concern (Birdlife International 2023). An analysis of the population trend in the Baltic Sea suggested a 47% decline between 1988–1993 and 2007–2009 (Skov *et al.* 2011), although declines have not been noted in other areas (Birdlife International 2023). Small numbers nest in Scotland, where it is one of the rarest breeding waterbird species, and in Ireland, forming the most southwesterly nesting birds in the Western Palearctic. Numbers breeding in Ireland and Scotland have declined since 1970, with < 50 pairs now thought to nest in Scotland (Stanbury *et al.* 2021). This species is strongly migratory (del Hoyo *et al.* 1992) and almost wholly marine outside the breeding season, but can migrate considerable distances over land making brief stop-overs on inland waters (Madge & Burn 1988).

Larger point-source pollution events can threaten this species in the moulting and winter period where large and highly vulnerable concentrations of the birds occur, as for example with oil spills (*e.g.* Larsen *et al.* 2007), while development associated with oil drilling sites can cause additional, low-level impacts through human disturbance and the degradation of food resources (Nikolaeva *et al.* 2006).

Despite two studies of adult female survival and breeding site fidelity (Fox *et al.* 2003; Petersen *et al.* 2020), there have been few studies of Common Scoter on the breeding grounds, although the winter distribution and ecology is slightly better known (see Kear 2005 for a review). However, understanding the routes and timing of migration, as well as the connectivity between breeding and wintering areas, is critical for the effective conservation of the species and a more complete knowledge of range and habitat use throughout the annual cycle is still lacking for this species.

Ring recoveries offer glimpses into these large-scale patterns of movement throughout the annual cycle. However, up to 2013, all the Common Scoters ringed in Britain and Ireland (n = 67, British Trust for Ornithology (BTO) data) had been caught during the winter months and provided no information on the movements of the small breeding population in Scotland. In recent decades, bird-borne archival data-loggers and real-time satellite-tracking devices have revolutionised this field of research by offering the ability to track daily movements within and between years. The technology continues to advance rapidly and global location sensing (GLS) loggers (hereafter geolocators) are now small enough to be fitted safely on small and medium-sized birds. However, limitations of geolocators include the need to retrieve the device for downloading and the relative imprecision of the location data.

To inform conservation measures and investigate little-known aspects of their annual cycle, a study was initiated in 2014 across four of the main nesting sites for Common Scoter in Scotland. The main aim of the study was to determine the location of the Scottish-breeding females during the non-breeding season, and in particular to establish whether females nesting on the

same loch, or across the complex of four different lochs studied, all wintered at one location and might therefore be sensitive to point-source mortality events. Additional aims were to investigate between-winter site fidelity and migration patterns.

Methods

The study areas comprised four breeding sites in west Inverness-shire (57°5'N, 4°59'W), north Perthshire (56°46'N, 4°07'W) and Islay, Argyll & Bute (55°48'N, 6°25'W). Nests were located by watching females return to their nest sites after recesses. Adult female Common Scoters were caught using an 18 m mist net attached to two bamboo poles, placed *c.* 3–5m from the nest. A field worker approached the nest from the opposite direction and flushed the incubating female into the mist net. Data from temperature loggers (see below) confirmed that none of the birds abandoned incubation within the 24 h period post-catch. Each bird was fitted with a BTO metal ring on one leg and a coloured plastic leg ring to the other. A geolocator was fitted to the plastic leg ring (Lisovski *et al.* 2020). The geolocators used were model MK4093 by Biotrack, measured 15 × 10 × 6 mm and weighed 2 g which was < 1% of female body weight for those birds caught (range = 740–1,110 g). In a subsequent year, if the bird returned and it was re-trapped, the geolocator was removed and the data were downloaded using *BASTrack* software (British Antarctic Survey 2010). Prior to deployment, the geolocators were calibrated for approximately seven days against a known position near Kingussie, Inverness-shire (57°4'N, 4°03'W).

Geolocator data provided estimates of location at twilight (dusk and dawn) based on the threshold method (Lisovski *et al.* 2012). Individual twilights were excluded if the pattern of change in light levels during transitions between light and dark were erratic one hour either side of the twilight. This could happen due to scoters diving underwater (darkness), the geolocator being obscured by body feathers, or cloud cover. Based on the calibrated geolocator data for Inverness-shire, for the post-deployment analysis, the threshold was set at 32 and the angle of the sun was set at –3 (see Lisovski *et al.* 2012; BAS 2010). Geolocator data were then processed in Excel. Smoothing of daily location data were achieved by calculating the running means every five days. Maps were produced using QGIS.

The geolocation estimates were approximately 12 h apart; therefore, it was not possible to determine the actual time of departure or arrival at locations during movements (although time of arrival on/departure from seawater was possible to determine – see below).

Measures of conductivity between the external battery contacts were recorded and stored at 10 min intervals. These showed levels of zero when the birds were on freshwater (or flying), and values up to 200 when in brackish or saltwater. These data were analysed to determine the dates on which the ducks arrived on saltwater after the breeding season and also the dates when the birds left saltwater and either flew to, or arrived on, freshwater habitats.

Given the suspicion that females and broods were subject to relatively high levels of predation at Scottish breeding sites, and

in preparation for a planned future survival analysis, records of individually colour-marked birds (nine females) were recorded each summer, either through recapture or visual observation with field telescope or nest cameras. Re-sighting effort was high with near-daily checks in 2015–2019, and at least weekly checks in other years, apart from 2020 when access restrictions due to the Covid pandemic limited observation effort. In addition, the fate of each nest was recorded through the deployment of temperature loggers and trail cameras (see Sullivan *et al.* 2020) and the fate of broods was recorded through regular observations, when weather conditions were favourable, allowing a picture of seasonal mortality to be built.

Results

Nine female Common Scoters (referred to by their metal ring numbers below) were fitted with geolocators; seven in west Inverness-shire, one in Perthshire and one on Islay. Eight of the geolocators were retrieved (Table 1 and see below). Upon recapture, three females were fitted with a new geolocator to track further years of movements and all three were retrieved. The conductivity data suggested that, once the female scoters had arrived on the breeding quarters, none of them flew back to the sea during the breeding season, even though one nest (on Islay) was only 1.5 km from the sea. The geolocators provided data for 14 southward autumn migrations, but only 12 winter locations, and 11 northward spring migrations because four geolocators failed during the non-breeding season (Table 1). One geolocator was not recovered due to predation of the female (GN61202) on the nest in the year after deployment (see "Observations of predation events" below).

Southward migration

The date of departure of the Common Scoters from breeding areas and arrival on the sea differed significantly between those that had apparently successfully bred and raised a brood of ducklings to > 10 days (mean = 19 August, range = 18–20 August, $n = 2$) and those that failed to breed due to either eggs or ducklings being predated (mean = 1–2 August, range = 22 July–11 August, $n = 10$, Welch two sample test: $t = 6.55$, $P < 0.001$, d.f. = 9.78, Table 2).

Once on the sea, the scoters showed different patterns for moving to their winter quarters. GH05397 staged off north Ireland before moving south to its winter quarters in southwest Ireland in November 2014 and in late August 2015. GH05400 flew directly to its winter quarters in Liverpool Bay in all three years (2014–2016). GN61203 wintered on the Moray Firth (2014) but moved to the east coast of north Ireland in February 2015. In late August 2015, it flew directly to the east coast of north Ireland to winter. In 2014, GN61204 spent a month in the north Irish Sea before heading south, arriving off Morocco by early September 2014. In autumn 2015, it probably flew to the west coast of Portugal where the geolocator tag failed and its ultimate winter destination is not known. GN61209 moved to the Moray Firth after the breeding season in 2015 but, after the equinox period, it was off the Moroccan coast. In 2016, it had flown to Morocco before October. GN61207, GN61210 and GN61211 all flew

Table 1. Dates of geolocator deployment and retrieval for eight geolocators fitted to Common Scoter in Scotland. Nest areas are shown in Fig. 2. Migrations for which data available: a = autumn, w = winter, s = spring. * denotes date of battery failure, but geolocator was subsequently retrieved from live bird.

Bird ring number	Nest area	Date deployed	Retrieval or * battery failure date	Duration of deployment (days) and migrations where data available	Second deployment	Second retrieval or * battery failure date	Deployment duration (days) and migration periods covered
GH05400	A	17/06/2014	22/06/2015	370 (a,w,s)	23/06/2015	30/11/2016*	526 (2a,w,s)
GH05397	A	18/06/2014	30/06/2015	377 (a,w,s)	30/06/2015	12/07/2016	378 (a,w,s)
GN61203	A	25/06/2014	23/06/2015	363 (a,w,s)	23/06/2015	17/06/2016	360 (a,w,s)
GN61204	B	03/07/2014	23/06/2015	355 (a,w,s)	23/06/2015	27/10/2015*	126 (a)
GN61207	B	23/06/2015	01/06/2016	344 (a,w,s)	–	–	–
GN61209	B	15/07/2015	24/06/2017	710 (2a,2w,2s)	–	–	–
GN61210	C	25/06/2016	10/04/2017*	289 (a,w,s)	–	–	–
GN61211	D	15/07/2016	15/01/2017*	184 (a,w)	–	–	–

Table 2. Date of (a) arrival to, and (b) departure from, seawater of Common Scoter fitted with geolocators deduced from conductivity data.

(a) Arrival on sea	**Mean date**	**Date (range)**	**Sample size (*n*)**
Brood survive to > 10 days	19 August	18–20 August	2
Unsuccessful at egg stage	1 August	22 July–11 August	5
Unsuccessful at brood rearing stage	2 August	23 July–7 August	5
(b) Departure from sea	**Mean date**	**Date (range)**	**Sample size (*n*)**
All birds	20 April	13–30 April	10

directly from the breeding grounds to their winter quarters in the north Irish Sea.

Winter quarters

The mean two-week latitude and longitude locations for each geolocator indicated that there was reduced movement during late November (week 48) to late February (week 9) and we used this period to define the winter locations (Fig. 1). The exception to this pattern was GN61204, which arrived off Morocco in mid-October but appeared to move north from there from mid-December. The distance from the breeding area to the wintering area ranged from *c.* 100km (Moray Firth) to *c.* 3,200 km (Morocco) (Figs. 1 & 2).

Northward migration and arrival back in Scotland

The geolocator data suggest that some of the tagged birds wintering in UK and Irish waters appeared to fly directly to their breeding grounds, while others used intermediate staging areas. The birds arrived back on freshwater (assumed to be the nesting areas) in mid-April (mean = 20 April, range = 13–30 April, *n* = 10) (Table 2). GN61203 had wintered on the Moray Firth, but appeared to move to a sea area off northeast Ireland in late February. Unfortunately, interpretation of the geolocator data for the two birds that wintered off Morocco was hampered by the lack of data during the spring equinox. During northward spring migration from Morocco in 2016, GN61209 appeared to be off the coast of the Netherlands in late March/early April (Fig. 3). In 2017, however, the same bird appeared to move directly to the north Irish Sea from Morocco.

Observations of predation events

One bird (GN61202) was predated by a Red Fox *Vulpes vulpes* on the nest (confirmed by trail camera). Predation was strongly suspected for two further individuals: GN61203 – a Red Fox was recorded by a trail camera on the nesting island when the bird was last recorded at its nest; and GN61203 – this female hatched seven eggs of which four ducklings were observed

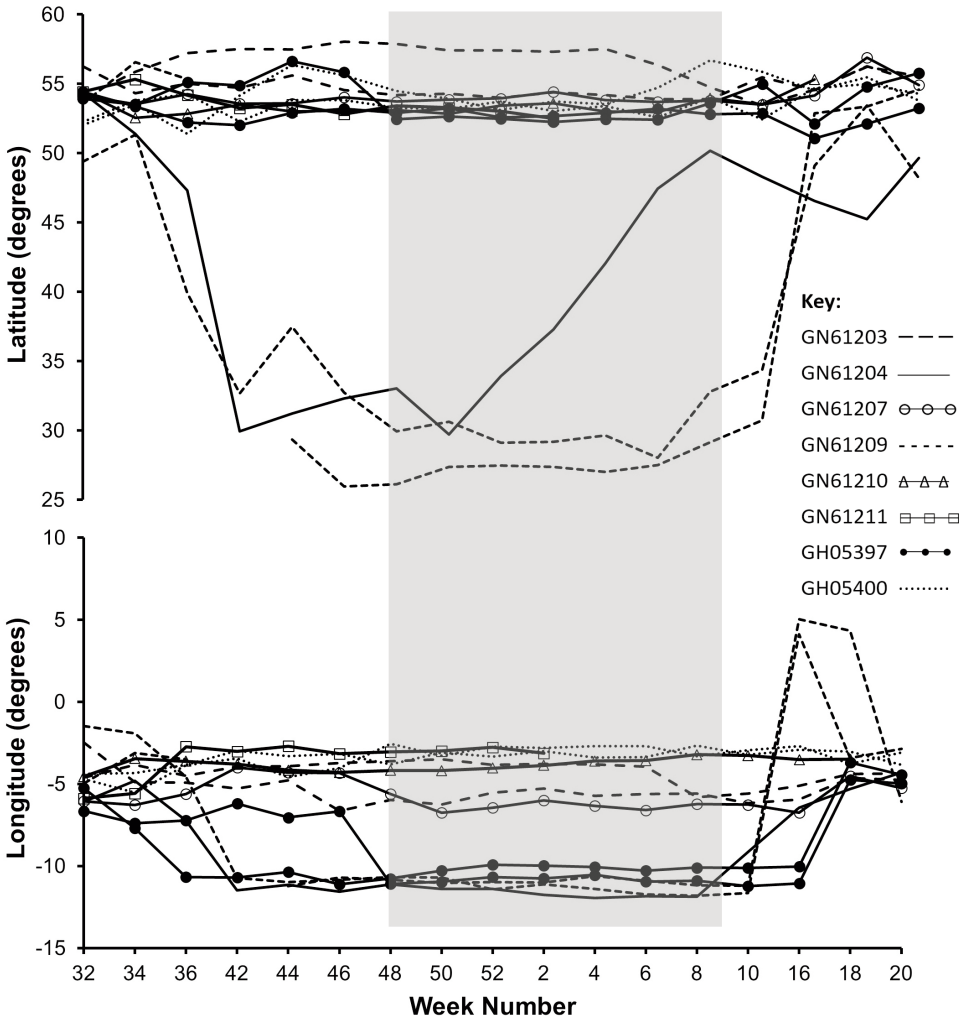

Figure 1. Mean two-week latitude and longitude values for Common Scoter caught in Scotland. Grey shaded box indicates period of reduced movement during winter (week 48 ~ end November, to week 9 ~ end February). Note that the graph excludes data from weeks 38–40 and 12–14, the time around the equinox. GN61204 arrived off Morocco in mid-October but appeared to move north from there from mid-December.

three days later near the nest location without an adult female present, the only known nest hatched on the loch at that time. Two other unringed adult female Common Scoters were known to have been predated whilst incubating, with plucked scoter carcasses being found next to their nests in 2014 suggesting an aerial predator may have been involved (with Common Buzzard *Buteo buteo*, Golden Eagle *Aquila chrysaetos* and

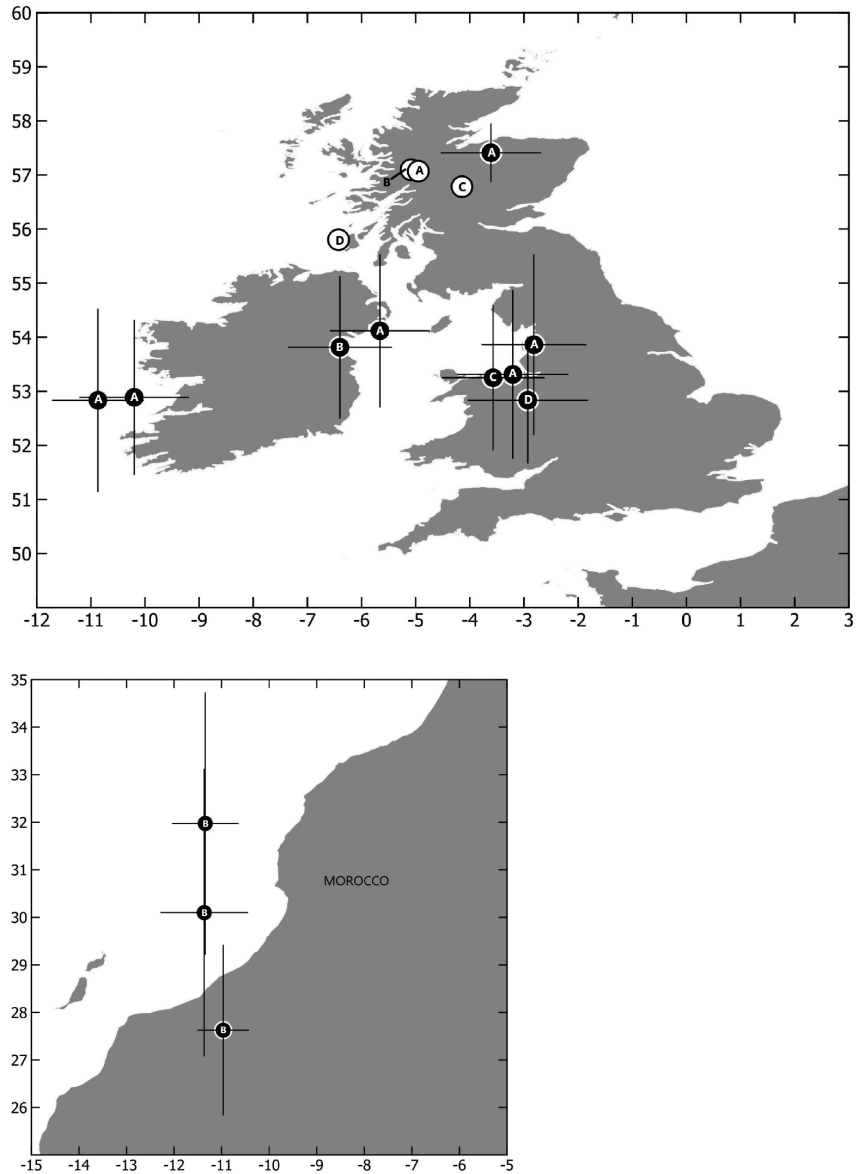

Figure 2. Wintering (December–February) locations of eight female Common Scoter caught on nests in north and west Scotland (black symbols). Black lines = mean wintering location with ± 1 s.d. given as bars. White symbols = ringing location (A and B = West Inverness-shire; C = North Perthshire; D = Islay, Argyll). White letters within black wintering locations refer to ringing location. Upper map shows distribution in Ireland and Britain, lower map off Morocco. Only the first autumn and first spring dates are shown for repeat migrations.

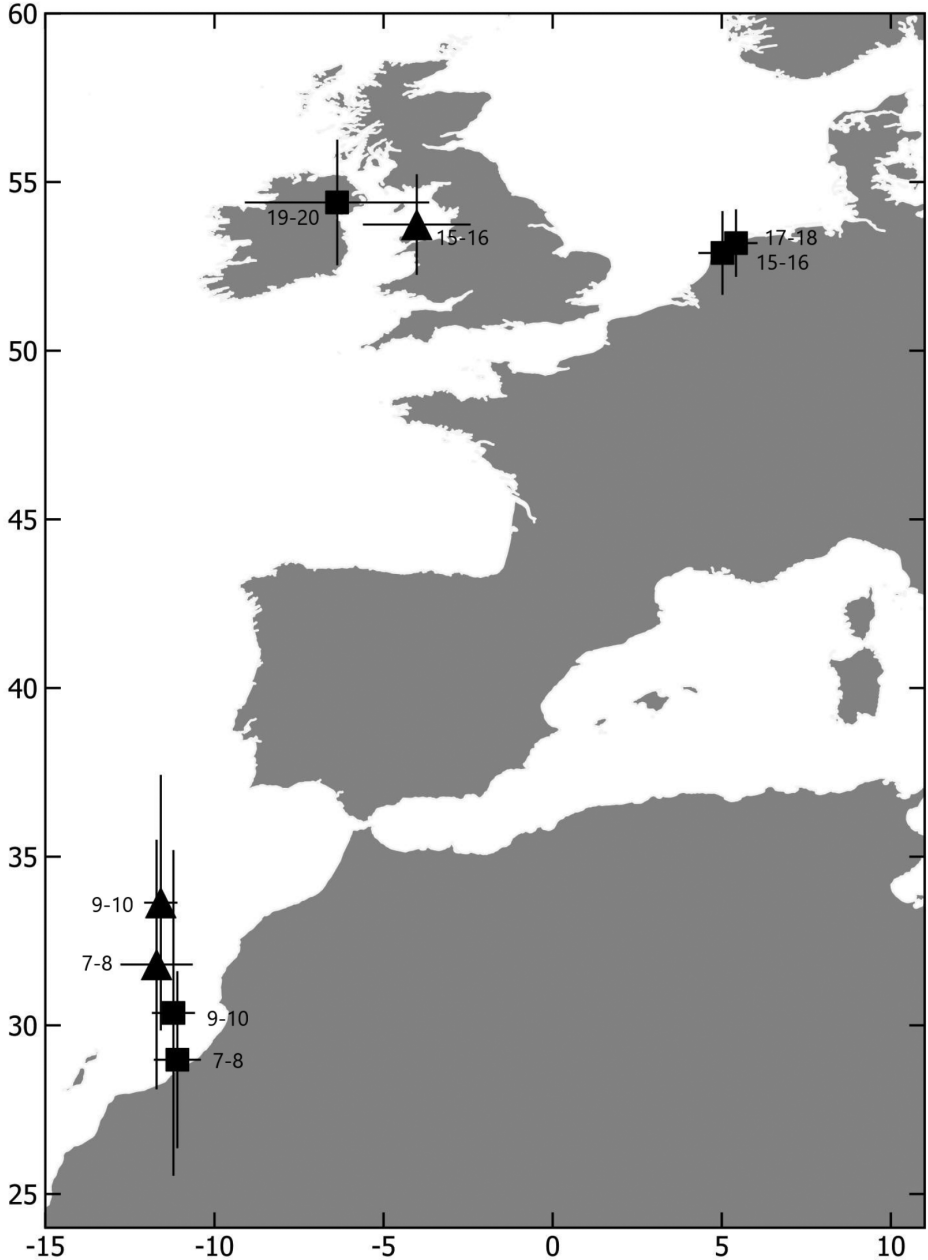

Figure 3. Spring movements of a Common Scoter (GN61209) ringed on the breeding grounds in Scotland that had wintered off the coast of Morocco. Note: no latitude data could be determined during the Equinox period (British Antarctic Survey 2010). ■ = 2016, ▲ = 2017 (week numbers shown).

White-tailed Eagle *Haliaeetus albicilla* all present in the area). In addition, in 2021, the likely predation of a prospecting female scoter that had landed on a traditional nesting heath, by a Common Buzzard that dropped on it, was prevented by the fortuitous intervention of a nearby fieldworker in woodland within 50m of the prospecting site (this study) able to scare the raptor into releasing its talons from the duck's back.

Discussion

This is the first study of the small numbers of Scottish breeding Common Scoter to demonstrate their formerly unknown wintering distribution. Our results show their distribution during the non-breeding season was widely dispersed across the Moray Firth (Scotland), the Irish Sea, the west coast of Ireland and Morocco, *i.e.* from the northerly to the very southernmost parts of the known winter distribution of the species (Birdlife International 2023). Female ducks often show a high degree of natal philopatry (Anderson *et al.* 1992, including Common Scoter *e.g.* Fox *et al.* 2003) and most waterbirds are faithful to winter areas between years (Robertson & Cooke 1999). Such wide winter dispersal amongst the Scottish Common Scoters was unexpected, given that these remaining small populations of two to four known breeding females at each site might be related and thus might be expected to show signs of having linkages with the same wintering sites; the results of the current study suggest such linkages to a single wintering site was not the case.

The four Common Scoters with location data from successive winters showed high between-year site fidelity: GH05400 wintered in the Irish Sea for two winters; GH05397 wintered off southwest Ireland in two winters; GN61203 wintered on the Moray Firth up to early February 2015, then moved to the northeast coast of Ireland, where it wintered in 2015/16; GN61204 wintered in Morocco in one winter and appeared to be off the Portuguese coast by late October 2015 when the geolocator stopped working and so was perhaps heading to Morocco.

We acknowledge that the location data from geolocators is relatively imprecise (see Lisovski *et al.* 2012 for a review) so the exact distribution of the Common Scoters during the non-breeding season could not be determined. The geolocators were fitted to the birds' legs and so were underwater for virtually all of the non-breeding season and occasionally covered by body feathers – both can affect the amount of light reaching the geolocator, which in turn can affect the calculation of the twilight times. However, despite these limitations, a reduction in movement at the winter locations provided evidence of a geographically dispersed range of sites. Thus, the use of different wintering sites by females from the same breeding site greatly reduces the threat of a catastrophic point-source mortality event affecting a large proportion of these Scottish-breeding birds. The mechanism for Common Scoters that nest relatively close together wintering in such widely dispersed sites is unknown

Despite our observations of predation events on the nesting areas, no birds out of the nine followed over a 2–7-year period were lost to the study during the non-

breeding stage of their life-cycles (noting that all were caught as adult females of 2+ years old). Although the sample size is not sufficient to generate robust annual survival estimates, simple Cormack-Jolly-Seber model (MARK 9.0; White & Burnham 1999) estimates based on re-encounters of nine females over seven seasons (Appendix 1) suggested an annual survival of well over 80% (WWT unpubl. data). This high apparent annual survival, and our observation of predation events during the breeding season, suggest that nesting is the period of greatest risk to females and may also contribute to the highly skewed sex ratio that characterizes this species in Britain and Ireland (Underhill *et al.* 1998; unpubl. data for the breeding sites in the current study). A review by Donald (2007) found that biases in sex ratios were more skewed in populations of threatened species than in non-threatened species. Highly male-biased sex ratios can therefore be a cause for concern to conservationists and wildlife managers.

The number of Common Scoters nesting in Scotland is low and declining. The apparent high survival rate and strong philopatry of female Common Scoters suggest that low reproductive output and/or low first-year survival are driving the decline. This supports and vindicates the conservation actions already conducted through the partnership of conservation actors working at the Inverness-shire sites to protect the species (Hancock *et al.* 2020).

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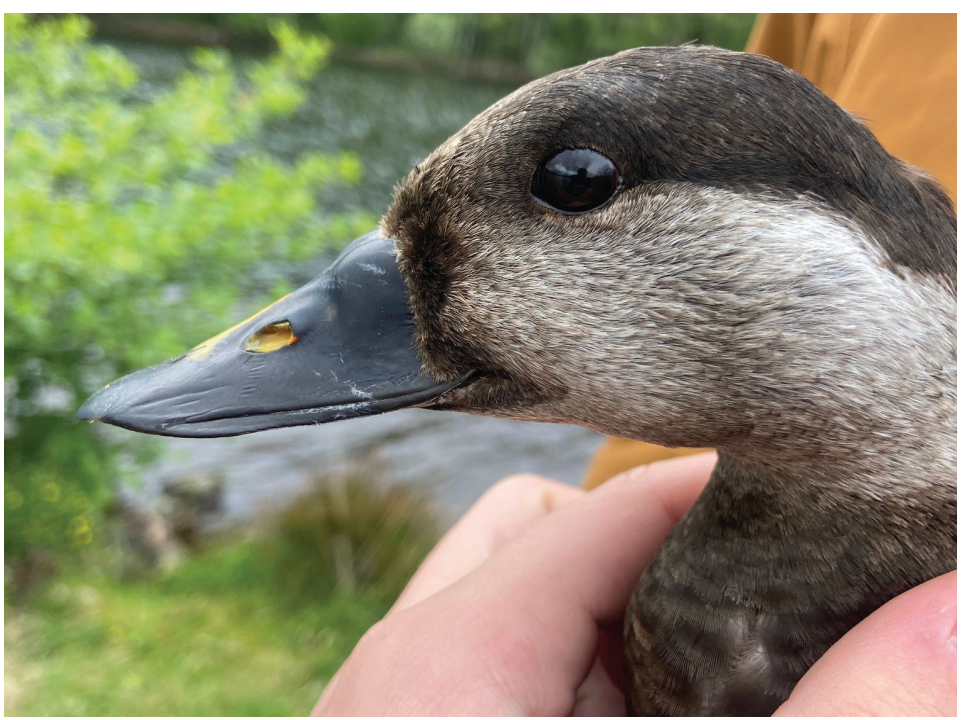
Appendix 1. Encounter histories (live capture or resightings) for nine Common Scoter at breeding sites in Scotland (2014–2021, see Fig. 2 for nest areas). The Covid pandemic precluded fieldwork in 2020. 0 = not seen. P = probably predated.

Nest area	Bird ring number	2014	2015	2016	2017	2018	2019	2021
A	GH05397	1	1	1	1	1	1	1
A	GH05400	1	1	1	1	1	1	1
A	GN61203	1	1	1	1	1	P	
A	GN61202	1	P					
B	GN61207	1	1	1	1	0	0	0
B	GN61204	1	1	P				
B	GN61209		1	0	1	0	0	0
C	GN61210			1	1	1	1	
D	GN61211			1	1	1	1	1



Photograph: Female Common Scoter in hand, by Jack Griffin.