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RESEARCH

Long-term demographic changes in harvested Eurasian teal (*Anas crecca*) and Eurasian Wigeon (*Mareca penelope*) in the UK

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Abstract
Long-term surveys for monitoring the demographics of a population can shed light on reproductive success and survival, as well as identify when changes may have occurred. For many species, collecting this data can be time consuming and labour intensive but for harvestable species we are able to collect this data more easily and use demographic patterns in the harvested population as a proxy for demographic changes in the overall population. Here, we use a 37-year dataset of harvested wildfowl wings to explore the demographic changes in two popular quarry species, Eurasian teal *Anas crecca* and Eurasian wigeon *Mareca penelope*. Generalised linear models revealed a significant decline in the reproductive index (juveniles per adult female) of Eurasian teal, which has halved over the study period alongside a decline in the proportion of females within the adult population. These declines are somewhat at odds with the long-term increasing wintering population trend within the northwest European flyway. Similarly, for Eurasian wigeon we found a significant decline in the proportion of adult females and reproductive index, the latter of which has dropped by a third. After notable wintering population declines across the northwest European flyway over the past decade, this population is now increasing and beginning to recover. Our results demonstrate that demographic changes observed in national datasets may not always align with flyway-level population trends and express the need for collaborative, long-term monitoring of our migratory species across their flyway to better inform sustainable harvest.

Keywords Wing survey · Demography · Population dynamics · Hunting · Monitoring

Introduction

The demographic structure of a population reveals how different age classes and sexes respond to ecological and anthropogenic pressures, including differential mortality and survival (Promislow 1992; Holand et al. 2003; Liker and Székely 2005). Such information provides valuable insight into population dynamics, identifying vulnerable groups and potential conservation concerns (Manel et al. 2003; Hindrikson et al. 2013). While migration allows species to persist, it can expose them to threats such as over-exploitation and habitat change across their migratory range (Horns and Sekercioglu 2018), therefore, assessing demographics across this range can highlight where different pressures may be acting on particular age groups or sexes (Francis and Cooke 1992; Tamate and Maekawa 2004). When monitored over a longer-term, demographic information can provide focus for local conservation initiatives as well as migration route level action plans, as demonstrated for the North Atlantic right whale *Eubalaena glacialis* (Borggaard et al. 2020), cinereous vulture *Aegypius monachus* and barnacle goose *Branta leucopsis* (Andevski et al. 2017; Jensen et al. 2018).

Recording the age and sex ratios of birds in field surveys is challenging, often requiring targeted and time-consuming approaches such as trapping for ringing, or networks of trained fieldworkers. However, wildfowl are a globally popular group of harvestable species (Mooij 2005), therefore an alternative means of collecting data is with the assistance of the hunting community who harvest an estimated 5.5 million wildfowl annually across 24 countries in Europe (Guillemain et al. 2016). The UK supports a large proportion of the wintering duck populations within the northwest European flyway and

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so is well placed to collect such data (Méndez et al. 2015). Yet, there remains a lack of co-ordinated, long-term monitoring programmes for many wildfowl species, limiting the understanding of flyway population dynamics (Wood et al. 2021).

Wing surveys are hunter-dependent and subject to several known biases, which can influence both participation (Ellis 2020) and how representative harvested birds are of the broader population (Olson 1965; Conroy et al. 1989; Fox et al. 2015, 2016a). However, when such survey methods are used to generate trends and indices they can act as vital sources of long-term data on the age and sex composition of harvestable species (Fox et al. 2015, 2016a). The importance of these trends continues to be highlighted in literature (Clausen et al. 2013; Guillemain et al. 2013; Christensen and Fox 2014; Fox et al. 2015; Christensen 2017), underscoring the need for increased understanding of wildfowl population dynamics and how hunting pressures interact with them, which is vital for informing discussions on sustainable harvest management.

Using wing submissions from 1987 to 2002 and 2017–2025, we investigate age and sex ratios of the two most commonly and consistently submitted species in the wing survey, namely the Eurasian teal *Anas crecca* and the Eurasian wigeon *Mareca penelope*. Both species are amongst the most popular wildfowl species harvested in the UK with the most recent bag sizes estimated to be between 93,000 and 200,000 for teal and 21,000–89,000 for wigeon (based on data from 2016; Aebischer 2019). In Europe, their breeding populations are considered to have a poor conservation status (European Environment Agency 2025) as well as an unsustainable harvest at a flyway level (Carboneras et al. 2024), making both species of particular interest to the hunting and conservation community. In this study, we assess how the age and sex composition of wing submissions has changed over the study period. This provides demographic data to enhance our interpretation of long-term population trends for both species. To examine any changes in within-season migratory behaviour, we also investigate the change in monthly proportions of different sex and age categories within the bag, comparing historic (i.e. the first five hunting seasons of the study; 1987/88–1991/92) and contemporary (i.e. the last five hunting seasons of the study; 2020/21–2024/25) wing submissions. The findings are interpreted alongside long-term population trends and discussed in relation to pressures facing these quarry species across the flyway.

Methods

Data collection

The UK wing survey, historically named the 'Duck Production Survey', began as a collaborative project between the Wildfowlers Association of Great Britain and Ireland (WAGBI), now the British Association for Shooting and Conservation (BASC) and the Wildfowl Trust, now Wildfowl and Wetlands Trust (WWT), in 1965. Although the wing survey was established in the 1960 s, due to incomplete records we only report results for teal and wigeon from 1987/88 to 2024/25 in this study. This dataset includes a gap of 14 years between 2002/03 and 2016/17 during which time the survey was stopped due to lack of funding.

Between 1987/88 and 2024/25, wildfowl hunters in the UK were asked to voluntarily submit a single wing of each duck they harvested, along with the date and county to BASC for analysis. The specific species requested by BASC varied over time subject to surveyor interests. As a result, wings from 19 species of ducks, geese and waders have been collected over a 37-year period. The species, age and sex of harvested ducks were determined through assessment of the feather colour, characteristics and structure using standardised criteria described in Boyd et al. (1975) between 1987 and 2002, and in Baker (2016) and Mouronval (2016) between 2017 and 2025. Use of these identification guides facilitated consistent approaches to wing assessment, thus minimising inter-observer variation. Since 2017, all wing assessments have been conducted by the authors. Age was categorised as either adult (EURING codes 4 or 6; British Trust for Ornithology 1979) or juvenile (EURING codes 3 or 5; British Trust for Ornithology 1979), with juveniles being birds that hatched during the most recent breeding season. Since the survey commenced, members have been encouraged to participate in the survey through (i) articles in BASC's members' magazine, (ii) the sporting press, (iii) face-to-face membership engagement and (iv) bespoke training days. More recently, there has been a focus on encouraging participation through social media and developing alternative ways to submit data through digital photographs (Ellis et al. 2021).

Data analysis

The wings of each species were grouped into three categories: adult males, adult females and juveniles. For each month and UK hunting season (September to February) for both species the proportion of adult females was calculated as a proportion of the adult sample, and the proportion of juveniles was calculated as a proportion of the entire sample. The number of juveniles per adult female was also used to provide a metric of 'reproductive success' for each season (Fox et al. 2016b).

To assess annual changes in population composition for both species, the proportion of adult females among adults and the proportion of juveniles in the bag each season were separately modelled against season using generalised linear models (GLMs) with a quasibinomial structure. These models were fitted using a 'weights' function, where weight was sample size per season, to account for the large variability in wing numbers submitted between seasons. Analysis of reproductive success over time was modelled using a GLM with a gaussian family structure and the models were again weighted by sample size to account for the large variation in the number of wings submitted between seasons.

To assess if the within-season population composition had changed over time, we grouped the dataset into a 'historic' subset of the data (i.e. the first five hunting seasons of the study; 1987/88–1991/92) and a 'contemporary' subset of the data (i.e. the last five hunting seasons of the study; 2020/21–2024/25). We then ran a generalised additive model (GAM) with a quasibinomial structure and a logit link function to investigate if the proportion of adult females among adults and the proportion of juveniles in the bag changed between months within and between each time period.

All analyses were undertaken in RStudio version 2025.5.1.513 (Posit Team 2025).

Results

Wings collected

Between 1987/88 and 2024/25, a total of 18,483 teal and 23,612 wigeon wings were submitted by hunters (Table 1). 2025The mean number of teal and wigeon wings collected per year was 804 (range: 33−2,764) and 1,027 (range: 72−3,034) respectively. Due to missing data (i.e. no date or sex or age class given), 119 teal wings and 27 wigeon wings were excluded from all analyses.

Teal

The proportion of female teal among adults in the harvested sample significantly declined over the study period (β_1−0.009, SE=0.003, t = −2.730, $p<0.01$, Fig. 1a). Modelled estimates indicate a reduction from 49.3% in 1987/88 (95% CI: 46.5–52.1%) to 40.3% in 2024/25 (95% CI: 35.7–44.8%). The proportion of juvenile teal harvested declined significantly (β_1−0.023, SE=0.003, t = −7.008, $p<0.001$, Fig. 1c), from 63.9% in 1987/88 (95% CI: 61.7–66.1%) to 42.7% in 2024/25 (95% CI: 38.4–47.1%). The reproductive success index for harvested teal also showed a significant decline in the number of juveniles per adult female (β_1−0.048, SE=0.013, t = −3.622, $p<0.001$, Fig. 1e) from 3.53 (95% CI: 3.14–3.92) in 1987/88 to 1.76 (95% CI: 1.06–2.46) in 2024/25.

Within historic wing submissions, there was a significant difference between months in the proportion of adult females in the adult wing sample, with adult female teal peaking within the harvested population in January ($p<0.01$, Fig. 2a). However, within the contemporary dataset there was no significant difference between months ($p=0.21$, Fig. 2b). No significant differences in the proportion of juveniles were observed between months within the historic wing submissions ($p=0.53$, Fig. 3a). However, there was a significant difference in the proportion of juveniles in the bag between months within the contemporary wing submissions with the juvenile proportion declining over the season ($p<0.01$, Fig. 3b).

Table 1 The number of hunter-harvested teal and Wigeon wings analysed for each sex and age category between 1987/88 and 2024/25 in the united Kingdom

Species	Adult Female	Adult Male	Adult Total	Juvenile Total	Grand Total
Teal	3,576	4,144	7,720	10,644	18,364
Wigeon	3,666	7,950	11,616	11,969	23,585

Wigeon

Between 1987/88 and 2024/25, the proportion of females among adults in the harvested sample of wigeon declined significantly (β_1 = −0.0112, SE=0.003, t = −3.41, $p<0.001$; Fig. 1b). Modelled estimates indicate a reduction from 34.6% (95% CI: 32.3–36.9%) to 25.8% (95% CI: 22.6–29.4%). The proportion of juvenile wigeon harvested has also shown a significant decline over the study period (β_1 = −0.018, SE=0.003, t = −5.204, $p<0.001$, Fig. 1d), falling from 55.8% (95% CI: 53.3–58.4%) to 39.2% (95% CI: 34.9–43.9%). The number of juveniles per adult female showed a statistically significant decline over the study period (β_1 = −0.0328, SE=0.013, t = −2.355, $p=0.020$; Fig. 1f). Modelled estimates indicate a reduction from 3.63 juveniles per adult female (95% CI: 3.21–4.04) in 1987/88 to 2.41 (95% CI: 1.66–3.16) in 2024/25.

Within both historic and contemporary wing datasets there were no significant differences between months for the proportion of female wigeon among adults in the bag (historic: $p=0.73$, contemporary: $p=0.19$) nor for the proportion of juvenile wigeon (historic: $p=0.55$, contemporary: $p=0.48$).

Discussion

While continued data collection and participation by wildfowl hunters in the UK is needed, wings submitted from harvested wildfowl already provide valuable demographic insights into species' population trends and composition. Such data, when used alongside field studies, can reveal

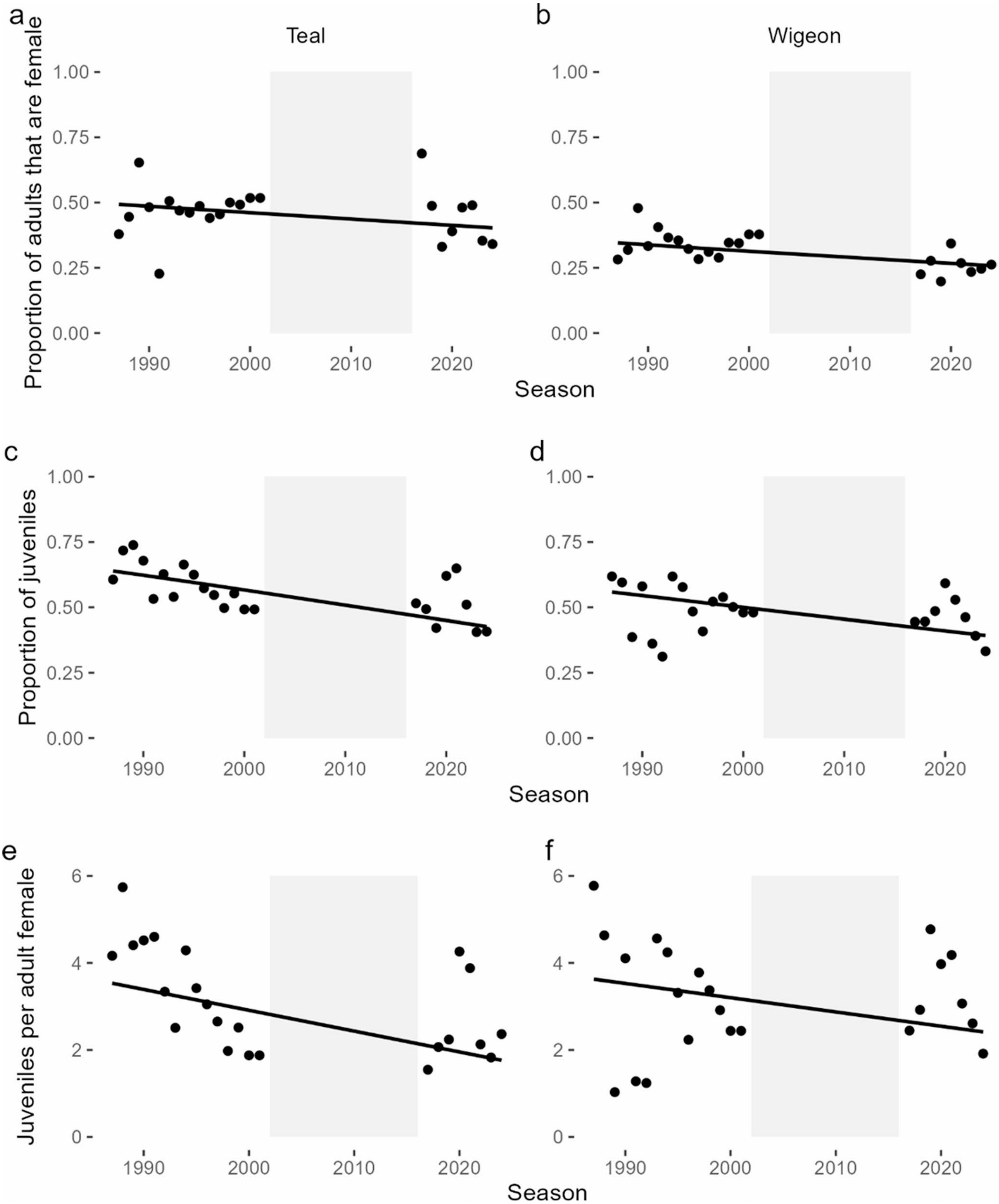

Fig. 1 The proportion of adult females (**a**, **b**), juveniles (**c**, **d**) and reproductive success index (**e**, **f**) respectively for teal and wigeon harvested by hunters in the United Kingdom between 1987/88 and 2024/25 hunting seasons. The grey shaded box indicates the seasons in which there were no wings collected (2002/03–2016/17)

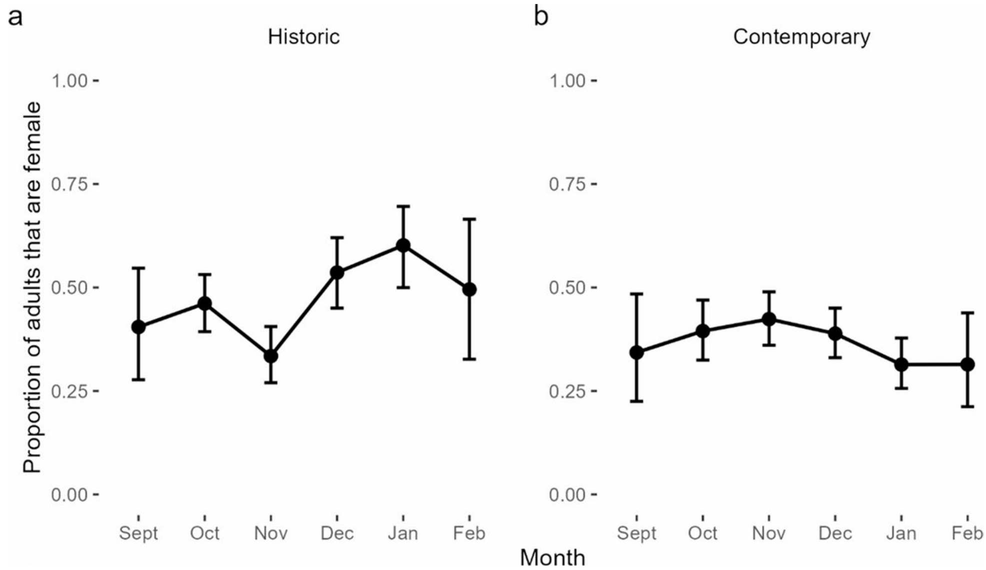

Fig. 2 The mean monthly proportion adult female teal within the adult population harvested by hunters in the United Kingdom in (**a**) historic bag returns: 1987/88–1991/92 and (**b**) contemporary bag returns: 2020/21–2024/25

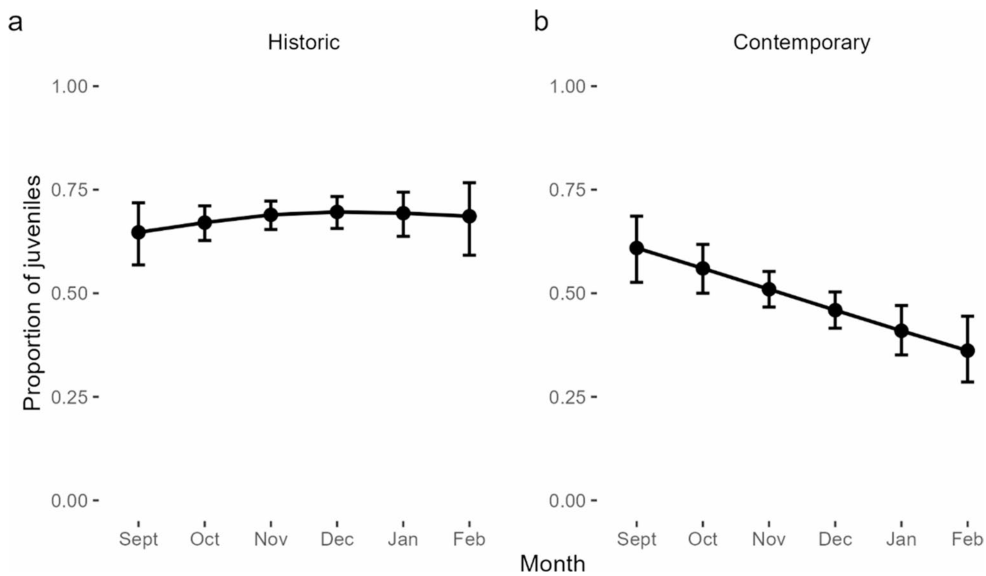

Fig. 3 The mean monthly proportion of juvenile teal harvested by hunters in the United Kingdom in (**a**) historic bag returns: 1987/88–1991/92 and (**b**) contemporary bag returns: 2020/21–2024/25

underlying population processes, such as density-dependent regulation or sex-biased mortality. These processes help to describe trends observed through conventional population counts but often are poorly understood. Although Eurasian teal and Eurasian wigeon are both small-bodied dabbling ducks with similar northwestern migratory routes, the demographics derived from wings suggest different population dynamics. As a result, strategies for their management, monitoring and harvest may need to be markedly diverse.

Teal

At a UK level, the population trend of teal appears to be increasing over the long-term (1997/98–2022/23; Calbrade et al. 2025) with some short-term fluctuations (2012/13–2022/23; Calbrade et al. 2025). This is accompanied by a moderate increase at a northwest European flyway level between 2014 and 2023 (Wetlands International 2025). However, some breeding populations have shown declines of 6–27% in recent years (2009–2018; Wetlands International 2025; European Environment Agency 2025). These conflicting trends may be indicative of short-stopping or range shift (Elmberg et al. 2014) and monitoring challenges associated with long-distance migratory species. Furthermore, given the delineation of the northwest and Mediterranean flyway, a low level of abmigration (i.e. swapping of flyways; Jonsson and Gardarsson 2001; Guillemain et al. 2017), and variation in harvest effort across flyways may be facilitating continued circulation and replacement of birds, thereby masking declines in some areas.

While our results show a significant overall decline in the proportion of female teal in the adult part of the population, this proportion has fluctuated rather than remained consistently low since surveys resumed in 2017/18 (Fig. 1a). Being smaller bodied, adult female teal are more susceptible to weather extremes which may have altered their recent migration patterns or increased migration mortality such that they are underrepresented in the UK hunting bag (Fox et al. 1992). Teal exhibit differential migration, with males migrating earlier in autumn and wintering further north than females. Therefore, increased climatic variability is likely to affect the sexes differently (Guillemain et al. 2009). Shifts in adult sex ratios may therefore reflect both greater inter-annual variability in winter temperatures and changes in migration patterns as also observed in our within-season analysis (Fig. 2a and b).

The proportion of juveniles in the teal wing sample significantly declined from 63.9% to 42.7% (Fig. 1c), with the reproductive success index halving over the 37-year study (Fig. 1e). This could be indicative of differential migration of the age classes (Guillemain et al. 2009) however, similar declines are reported in Danish wing surveys, where the reproductive success index is at its lowest since 1982/83 (Mikkelsen 2025) suggesting a flyway level decline in breeding output for teal. Although changes in hunter behaviour and efficacy may contribute (Ackerman et al. 2006; Miller 2012; Fox and Christensen 2018), consistent cross-national patterns suggest genuine changes at the population level. Teal population growth since the early 2000's, followed by recent fluctuations, suggests a shift toward equilibrium abundance under what could be density-dependant regulation (Paradis et al. 2002; Rodenhouse et al. 2003; Calbrade et al., 2025; European Environment Agency 2025; Wetlands International 2025), further compounded by climatic changes. Despite being non-territorial breeders and exhibiting spatial adaptability to seasonal habitat changes (Holopainen et al. 2014; Nummi et al. 2015), teals' short generation time (2–4 years) and *r*-selected life history make them susceptible to interannual fluctuations driven by external factors such as predation pressure, weather, and habitat quality, effects often masked by large population size (Nummi et al. 2015; Lehikoinen et al. 2016;Wetlands International 2025). One hypothesis is that a large breeding population combined with limited food availability can initiate density-dependent effects, such as reduced brood sizes and breeding success (Elmberg et al. 2003; Holopainen et al. 2014; Nummi et al. 2015). These pressures may in turn contribute to the declining juvenile proportions we observe further down the flyway (Fig. 1c & e).

Our contemporary data indicates a within-season decline of juveniles, with significantly higher proportions in early-season bags (Fig. 3a and b). Under classic migration patterns, whereby males depart early from breeding grounds, we would expect a constant or increasing proportion of juveniles within the bag as the season progresses. Thus, adult males dominate northern wintering sites, pushing adult females and juveniles further down the flyway later in the season (Guillemain et al. 2009). This pattern is clear in historic data (Fig. 3a) but appears to have been lost in contemporary bags (Fig. 3b). The reduced reproductive output we observed may be magnified when accompanied by cumulative depletion of juvenile birds across the northwestern flyway, driven by hunting and natural mortality (Guillemain et al. 2010). Collectively, these processes likely underpin the inter-annual (Fig. 1c & e) and within-season (Fig. 3b) juvenile declines observed in this study.

Future declines of the teal population are plausible if the downward trend in reproductive index, proportion of adult females and juveniles continues. Within the UK, current harvest levels of teal are potentially unsustainable, suggesting the UK is a 'sink' for the species (Ellis and Cameron 2022). However, estimates within Ellis and Cameron (2022) are limited by the quality of population data, which can be poor for cryptic species such as teal (Caizergues et al. 2011; Méndez et al. 2015). Despite this, their fast life-history may confer greater harvest resilience than previously assumed (Devineau 2007; Devineau et al. 2010; Péron 2012; Ellis and Cameron 2022). To fully understand drivers of juvenile decline, further research on breeding grounds and across the flyway is required, including data on clutch sizes, juvenile fledging and survival. Additionally, ringing and tracking studies would allow mapping of juvenile migration and harvest across the migratory route, building on research by others.

Wigeon

Wigeon populations show a different trend to those of teal, with a decreasing wintering population trend in the UK, an increasing wintering population trend at a northwest European flyway level but a declining European breeding population (Calbrade et al., 2025; European Environment Agency 2025; Wetlands International 2025). Wigeon display a strong sex bias in the adult population, with the proportion of females among adults declining from 34.6% in 1987/88 to 25.3% in 2024/25. Combined with this declining proportion of adult females, we also found a significant decline in the proportion of juveniles and in the reproductive index (Fig. 1d and f).

The significant decline in the proportion of females within the adult population (Fig. 1b) is consistent with results both from observational surveys and other hunter-harvested wing studies across the flyway (Christensen and Fox 2014; Fox et al. 2016a; Wood et al. 2021). A decline in adult females may be driven by a number of factors such as changing migration strategy, range shift or differential survival, the latter of which is likely to be primarily concentrated at breeding grounds. As with many ground-nesting birds, female wigeon are particularly vulnerable to predation during the nesting season, with an increased risk of predation in some breeding areas due to the incursion of alien species such as American mink *Neovison vison*, North American raccoon *Procyon lotor* and common raccoon dog *Nyctereutes procyonoides* (Christensen and Fox 2014; Holopainen et al. 2021; Wood et al. 2021). This differential survival may be a major driver in the observed decline in female wigeon, further compounded by habitat loss and degradation on breeding grounds (Gardarsson and Einarsson 1997; Mitchell et al. 2008; Fox et al. 2016a; Pöysä et al. 2017; van Toor et al. 2021). The overall population trends in wigeon seen across the flyway are therefore likely to be driven by this reduced adult female survival which in turn impacts the number of juveniles produced. The latter has also been noted in previous wing and ringing surveys in the UK and Denmark over a similar time period, suggesting this decline is occurring across the flyway (Mitchell et al. 2008; Christensen and Fox 2014). With a declining number of juvenile birds, which often make up the ‘harvestable surplus’ within a population, it is possible that more adult birds will be taken by hunters (Holopainen et al. 2018). As a result, this may further exacerbate the declines in female wigeon and the associated population trends.

Demographic data derived from wings strongly suggests that wigeon declines originate at breeding grounds (Mitchel et al. 2008; Christensen and Fox 2014; Pöysä and Väänänen 2018). As a result, focus on breeding grounds and their ecological condition is vital in enhancing our understanding of wigeon population trends (Fox et al. 2016b; Pöysä et al. 2017).

Data limitations

The nature of citizen science research means that the sample sizes submitted are unpredictable and highly varied. For example, this study has annual submission numbers ranging from 145 to 6,564 wings. Such variation introduces unequal statistical power, potential demographic biases, and heterogeneity of variance. Moreover, there are a number of potential biases that could confound population assessments based on wing data alone. The accuracy of determining the age of certain species from the wing has the potential to decline through the season as the birds moult, however the impact of this remains unknown for this data. Harvested samples are likely to have an over-representation of juveniles within the population due to the higher vulnerability of juveniles to hunting (Martin et al. 1979; Mitchell et al. 2008). Additionally, male biases in harvested samples may occur due to males having generally more colourful plumage making them easier to identify (Metz and Ankney 1991; Fox et al. 2015), larger body size, and potentially more gregarious behaviours. In some locations, it is plausible that, in the face of wigeon population declines, hunters are increasingly preferentially shooting males in order to preserve the adult females, a topic which requires further study. However, previous studies have compared population compositions derived from wing samples to other sampling approaches and concluded that wing surveys, although unable to provide absolute population metrics, can be good predictors of wildfowl demographics (Mitchell et al. 2008; Clausen et al. 2013; Christensen and Fox 2014; Fox et al. 2015, 2016a). Our findings are based upon the assumption that any hunter bias has remained consistent throughout the study period. Therefore, we utilise our data to generate trends as opposed to absolute population metrics, allowing us to monitor changes over time.

Future monitoring and research

To ensure the continuation of this long-term UK dataset, further efforts are required to increase participation in the BASC wing survey. This can be achieved through improved education and information campaigns targeted at both coastal wildfowlers and inland duck hunters. Increasing ease of participation through mobile app development and photograph submissions is likely to facilitate even greater, low-cost participation (Ellis et al. 2021). However, improved methods of ageing and sexing wildfowl from images requires further pilot studies and may benefit from the incorporation of artificial intelligence and machine learning (see ChassAdapt; Fédération Nationale des Chasseurs 2025).

Long-term datasets which collect data on age and sex composition of wildfowl populations, such as wing surveys, can provide valuable insight into population dynamics. When considered over greater spatial and temporal scales, data derived from hunters can provide ecologically relevant information on wildfowl populations which are otherwise poorly understood. To avoid the limitations of a purely national perspective, where changes in geographic distribution of age and sex categories may blur interpretation, it is necessary to expand the sampling frame to a flyway scale. Continued and collaborative collection of such data across the northwestern flyway, particularly through established initiatives such as the Waterfowlers’ Network (Waterfowlers Network 2025), will not only enhance understanding of current wildfowl population trends but will help shape conservation action and sustainable management plans for these quarry species.

Acknowledgements This paper is dedicated to the memory of Richard Hearn, a dear colleague who was fundamental in restarting the wing survey in 2017 and whose talent and dedication to the conservation of migratory waterbirds remains an inspiration. We thank all hunters who submitted wings to the project throughout the study period.

Author contributions MBE conceived the idea. HEW, CMM, KB, SS and MBE made substantial contributions to the acquisition and analysis of the data. HEW and CMM drafted the work and KB, SS and MBE revised it critically. MBE approved the version to be published. HEW, CMM, KB, SS and MBE agree to be accountable for all aspects of the work.

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Data availability The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

Declarations

Competing interests MBE is a waterfowl hunter and has submitted wings that form part of the dataset used in this study. The remaining authors have no interests to declare and no funding was received for conducting this study.

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