BTO RESEARCH REPORT 752

Highly pathogenic avian influenza in wild birds in the United Kingdom in 2022: impacts, planning for future outbreaks, and conservation and research priorities.

Report on virtual workshops held in November 2022

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1. EXECUTIVE SUMMARY

Since October 2021, there has been an unprecedented outbreak of highly pathogenic avian influenza (HPAI) of the subtype H5N1 in wild birds, initially in wintering waterbirds and then in breeding seabirds and other species, including raptors. Over the course of this 'emergency' period many questions have arisen about how we respond on the ground to local outbreaks, what monitoring we need to support rapid decision-making and long-term impact assessment, our understanding of the transmission of avian influenza in wild bird populations, and how to develop strategic approaches to species recovery. This report is the outcome of a UK HPAI workshop that was held virtually over two days in November 2022. It was designed to outline what was known about the impacts of this HPAI outbreak on wild birds so far, to develop thinking to support ongoing efforts to manage the outbreak, and also to consider longer-term evidence needs to enable positive conservation actions and species recovery.

The Animal and Plant Health Agency (APHA) provides weekly updates of findings where wild birds have tested positive for avian influenza. As of the end of September 2022, more than 60 species had tested positive for HPAI. Seabirds (Gannet, Herring Gull, Guillemot, Black-headed Gull), waterbirds (Canada Goose, Mute Swan, Pink-footed Goose and Greylag Goose) plus Buzzard and Pheasant were in the top 10 species in terms of the number of positive cases.

The data are biased given reports of sick or dead birds tend to come from more populated areas and because of the thresholds that apply for birds to be tested (currently in December 2022 – one or more dead birds of prey, three or more dead birds that include at least one gull, swan, goose or duck, and five or more dead wild birds of any species), and also once a species has tested positive in an area, repeat testing is not carried out. Counts of dead birds were carried out at particular sites by Country Nature Conservation Bodies (CNCBs) and Royal Society for the Protection of Birds (RSPB) reserve wardens which highlighted mass mortalities in Gannets, Sandwich Terns and Roseate Terns, Guillemots and Kittiwakes. These included striking figures such as the estimate of 2,600 Great Skuas reported dead (Falchieri *et al.* 2022 https://doi.org/10.1002/vetr.2311; Cunningham *et al.* in press http://www.seabirdgroup.org.uk/journals/seabird-34/seabird-34-C.pdf).

These patterns of mortality in the summer of 2022 were supported by an analysis of metal ring recoveries to the British and Irish Ringing Scheme. Unusually large numbers of dead ringed Great Skuas, Gannets, Guillemots, Arctic Terns, Common Terns, Sandwich Terns and Kittiwakes were recovered and reported to the British Trust for Ornithology (BTO) in 2022 compared to what would be expected from previous years. Spatially the pattern was similar to that found by the CNCBs and for species such as Gannet the timing and direction of spread of HPAI could be shown from the timing of the ring recoveries as spreading southward from Orkney, via Bass Rock to Alderney some 10 weeks after the first detection in Orkney. An increase in recoveries was also reported for Mute Swan, with many also testing positive for HPAI in the APHA statistics. Despite large numbers of Buzzards being reported dead, there was no evidence to date of significant increases in the number of bird of prey ring recoveries but this may be to do with relatively few Buzzards being ringed in the UK and the lower recovery and reporting rate due to their likely lower visibility when dead compared to highly visible species of open coastal and wetland habitats such as Mute Swan and Gannet.

Although data for the 2022 breeding season are still being collated, initial results indicate wide-ranging and large population declines having occurred for some of the most impacted species, such as Great Skua and Gannet, although surveys in 2023 will be required to verify this. Another example where HPAI is regarded as having a large-scale population impact is the Svalbard Barnacle Geese that winter on the Solway. Monthly coordinated route counts were made in fields around the estuary and recorded large-scale mortalities during the 2021/22 winter potentially representing the loss of between a quarter and a third of the individuals wintering there.

Monitoring priorities – seabirds

There was clear consensus over the importance of updated and improved population monitoring for seabirds. Immediate priorities were updated census information, recognising that fieldwork for Seabirds Count (the last breeding seabird census) was completed just before the HPAI outbreak, and enhanced collection of productivity data in the Seabird Monitoring Programme (SMP). Resources are limited so a prioritisation exercise to identify the sites and species for which data should be collected in 2023 based on the species impacted, UK and global threat status, the importance of the

UK for each species, key sites and the availability of recent and past monitoring data is being carried out following this workshop. Longer-term, increasing the amount of demographic data through collection of productivity data in the SMP, and an increase in Retrapping Adults for Survival (RAS) projects for key species to collect adult mortality data, along with ringing of chicks, are all priorities. Seabird demographics are complex, with large non-breeding and immature populations in many species and there are considerable uncertainties relating to their abundance, demography and movements. The use of colour-ringing, tracking technologies and PIT tags was recommended to address these issues. Mortality (carcass) monitoring was considered essential to track outbreaks in real time and there was a strong feeling that the current approach to data capture was inadequate with many organisations having collected mortality data in different ways during 2022.

A key priority is to harmonise the way mortality data is collected using methods that make data capture easy for observers (e.g. use of apps) and also coordinating mortality recording internationally given many of the same species are impacted in different countries. Validation of carcass monitoring was thought to be important to avoid double counting. The use of marking carcasses or photographic evidence were suggested to reduce this. As well as bird monitoring, there is the possibility for seabird ecologists to assist virologists in collecting swab samples to continue the genetic tracking of the virus movement as the epidemic progresses.

Monitoring priorities — waterbirds

For waterbirds, there are at least six monitoring schemes organised by BTO that cover the numbers and demography of breeding and wintering waterbirds. Short-term priorities were the maintenance of these long-term schemes, and not to cease/restrict monitoring in years when avian influenza is present in populations so that the impact of HPAI can be measured, and also the improvement of the collection of demographic data (e.g. counts of juveniles in flocks, mortality estimates from ringing data) to enable integrated population monitoring. The amount of demographic data on wildfowl in particular is limited. Ringing of wildfowl has declined and investment would be needed to train ringers and increase the numbers of wildfowl ringed and colour-ringed to better enable demographic modelling. Professional work would be required to support priorities for monitoring the impacts of HPAI on waterbirds in the short-term, with continuation of the ringing/resighting work on goose and swan species previously undertaken by Wildfowl & Wetlands Trust (WWT) being highlighted as a particular immediate priority in monitoring survival of those species. Priority should also be given to those species which have been impacted previously in the form of frequent (annual) monitoring to determine the impact of HPAI and subsequent population recovery. This is being given an international focus as well – at the recent African-Eurasian Waterbird Agreement (AEWA) Meeting of Parties MOP8, a specific amendment was adopted to existing annexes to enhance (population and demographic) monitoring and assessment of those species affected by recent HPAI H5N1 and to report on these data to allow population assessments for MOP9 (in autumn 2025) to be made on the basis of the most recent information on status. It is important to take a flyway approach to monitoring populations and sub-populations. As a national priority, it was noted that there was a need for updated population estimates and distributional information on wintering gulls. The last structured winter gull survey was organised in 2003/2004 to 2005/2006. Mortality (carcass) monitoring was considered important and, as for seabirds, needed to be easy to collect and coordinated amongst the agencies collecting the data. It was important to collect data on the age of the bird where possible through the observer's knowledge, or by capturing a photograph.

Monitoring priorities — raptors

For many of the rarer raptors, baseline population information is relatively poor and trends are based on limited data. There is clear evidence that a wide range of raptors are very susceptible to catching and dying from HPAI but given birds are widespread in the countryside and tend to be found singly, it is difficult to determine the population level impacts. Without better baseline information it will be difficult to understand the added impacts from HPAI on raptors, which will make conservation planning for some species more challenging.

An assessment of monitoring gaps is recommended. In particular, the ongoing review of the Statutory Conservation Agency and RSPB Annual Breeding Bird Scheme (SCARABBS), including assessment of improving trend estimation, should consider the implications of HPAI. A key priority is therefore to improve population monitoring and also, where possible, estimates of mortality. Mortality monitoring was considered difficult to do as raptors tend to die in areas where carcasses are less likely to be found and birds tend to occur singly and not in flocks. Tracking technology has been used to monitor mortality (e.g. three out of 10 satellite-tagged Hen Harrier chicks that died were found to have HPAI) and could be a way forward. Where dead raptors were found, it was thought important to test each individual for HPAI.

An analysis of which species are vulnerable to HPAI

BTO undertook a rapid trait-based assessment of the vulnerability of wild birds to HPAI to identify which are likely to be the most vulnerable species and species groups in the UK. This is to inform conservation management decisions, prioritise monitoring and research, and to guide the assessment of risk associated with particular activities. A range of ecological, demographic and epidemiological traits was used to identify the most vulnerable species and scored on three different components of vulnerability: 'exposure' (likely exposure to HPAI), 'sensitivity' (using previously published data to estimate mortality levels following exposure) and 'consequence' (the likely population impact). The merits of the traits were discussed at the workshop and the most important were thought to be associated with individuals being in close proximity to each other (e.g. breeding colonies or dense flocks of wintering birds).

Short-term responses to reduce the impact of an active outbreak of HPAI on wild bird populations

We identified 22 conservation management interventions through expert discussions and prior to the workshop, circulated a questionnaire to ask participants to estimate the potential effectiveness of interventions in reducing the impact of HPAI on different species groups of wild birds. Participants included ecologists, virologists and animal health experts and there was a consensus that the more widespread a viral outbreak is, the less important restrictions are to limit human-mediated fomite (fomite = inanimate objects or surfaces contaminated with infectious agents) spread of the virus due to high rates of bird-bird transmission. Our understanding of the pathways of infection and risk factors associated with transmission for different species is poor, but infection by direct contact and aerosols, through water and ingestion of contaminated scavenged meat are all established and credible pathways. Many at the workshop flagged i) the difficulties of estimating levels of mortality associated with the broad species categories, ii) the high uncertainty associated with the likely effectiveness of interventions and iii) the fact that the effectiveness of interventions could be site- and species-specific. The most supported interventions by those who submitted scores were carcass removal, followed by measures associated with changes in wild bird feeding and reducing disturbance. Cessation of research (surveys, ringing) was thought to be counter- productive. A high degree of uncertainty was expressed in relation to the likely efficacy of all interventions, given the limited evidence-base on which to make judgements.

Information dissemination and international collaboration

As nature conservation is devolved to the individual countries of the UK, there was strong support for having a UK-wide group made up of Country Nature Conservation Bodies (CNCBs) and other key stakeholders to better exchange ideas and information and ensure that similar approaches are taken by the different countries. This could be achieved by having a central hub that collates reports of incidents, using a standardised approach to data collection and the ability to easily collate and integrate data subsequently. Improved real time data submission and accessibility would help on the ground decisions. As HPAI is a global disease, it is important to work at an appropriate scale (e.g. site, country, UK, Europe, global) for different species to enable a global picture of the impact of HPAI on wild bird populations. This is especially important for mobile species such as terns that may change breeding areas and species such as Gannet where relatively few countries hold the entire global population. Finally, there was a plea not to forget the UK Overseas Territories and Crown Dependencies of the Isle of Man, Bailiwick of Jersey and the Bailiwick of Guernsey and include them in appropriate fora.

Research and conservation requirements

(i) Understanding the spread of HPAI in wild bird populations

A key gap is understanding how HPAI spreads between seabird colonies, and studies on spatial use around breeding colonies and maintenance areas are recommended, together with studies on the movements of non-breeding and immature birds during the breeding season. One key aspect is understanding how the virus persists in the environment. Studies on carcasses have shown that it can persist in dead birds for many weeks and freshwater environments are implicated in the transmission of the virus between waterbirds and some seabirds (e.g. Great Skua 'club' areas). Bird behaviour may also impact how vulnerable they are to infection, e.g. degree of scavenging, exposure to guano, and behaviour around infected birds. Unlike in some other European countries, there has been little serological testing of live wild birds in the UK and this is important to understand the background rate of HPAI across different species and degree of immunity.

Similarly, for waterbirds, workshop participants considered understanding the pathways of transmission a priority, considering both the spatio-temporal movements of birds and also associated HPAI surveillance in both live and dead wild birds. Additionally there is a need to consider the associations between waterbird species (especially including gulls), as potential vectors for transmission between sites and species (e.g. seabird breeding colonies), and to understand risks of transmission from prey to predators (e.g. raptors). There is also considerable uncertainty over the importance of potential transmission pathways more closely linked to anthropogenic sources, such as released gamebirds and wildfowl, and the poultry sector.

(ii) Understanding population impacts

Among all three groups, the aim should be to improve population monitoring using the methods and protocols identified in the monitoring sections above.

(iii) Informing and assessing short-term interventions – how to manage an outbreak of HPAI

The primary short-term mitigation highlighted of potential value in all three groups, was carcass removal, to reduce the risk of birds scavenging infected carcasses, although the possibility of this promoting disease spread through disturbance at colonies was noted. Participants also noted the need for further understanding of the potential benefits of reducing public feeding of waterbirds on the spread of HPAI among waterbirds and also what the impact of releasing large numbers of gamebirds was on the spread in terrestrial environments.

Biosecurity was thought important, especially when moving between sites (e.g. breeding colonies, areas where wintering birds congregate) and when moving to and from areas in which poultry are kept. Within sites, there was a consensus that the disease is extremely transmissible between individual birds and that research and monitoring activities were very unlikely to increase the risk of bird-bird activity. The loss of these valuable monitoring data through the restriction of access that occurred in 2022 was felt to be counter-productive. This applied to collection of data for long-term monitoring schemes as well as research aimed at investigating the impacts of HPAI and other research.

(iv) Informing and assessing long-term conservation measures

HPAI is one of a series of pressures acting on wild birds in the UK (e.g. for seabirds extreme weather, invasive mammals, climate change, contaminants, recreational disturbance, renewables, overfishing etc) and it is important to understand how HPAI will interact with these. Better targeted monitoring of populations will help answer some of these questions. Reducing pressures elsewhere may help overcome some of the impacts for HPAI. This could include improving breeding success in seabirds by restoring colonies (e.g. by eradicating rodents), improved management of protected areas for waterbirds to improve over-winter survival, habitat restoration in the wider countryside or creation of new protected areas over a wide scale.

Given that this disease has been reported in humans there is a risk that it might become more transmissible in future. The introduction of a One Health approach, that recognises that the health of people is closely connected to the health of animals and our shared environment, would enable a much more inclusive and coordinated approach that would include stakeholders ranging from the poultry sector, conservation and research institutions, animal and human health sectors and government agencies. Impacts on wild birds need to be addressed alongside mitigation actions to reduce prevalence in domestic flocks.

2. BACKGROUND TO THE WORKSHOP

Since October 2021, there has been an unprecedented outbreak of Highly Pathogenic Avian Influenza (HPAI) of the subtype H5N1 in wild birds in the UK, initially in wintering waterbirds. It carried over into the spring and summer of 2022, greatly increasing mortality in some breeding seabirds and other species including raptors. This outbreak is now continuing into its second year, impacting waterbirds and other species for a second autumn and winter.

The outbreak is a global phenomenon. Between 2020 and 2022, the virus was detected in wild birds across Asia and Europe (EFSA *et al.* 2022) and spread into North America, initially into Canada before moving into the United States (Alkie *et al.* 2022), and many countries in Africa (Letsholo *et al.* 2022). The outbreak is causing mortality in some species at a level that is significantly reducing populations and is of serious conservation concern. Many of the wild bird species affected to date by the current outbreak of HPAI H5N1 are migratory and therefore not confined to single countries. An international approach is required with good communication pathways between agencies in different countries. This means that the success of conservation actions taken in one country may often be partly or fully dependent on actions taken elsewhere. In the UK, the monitoring of bird populations is also undertaken mainly through the national schemes, including those covered by the Joint Nature Conservation Committee (JNCC) / British Trust for Ornithology (BTO) Partnership and a multi-agency and country approach is required when responding to this outbreak.

Over the period from May to July 2022, the devolved administrations in the UK (England, Scotland, Wales and Northern Ireland) each established working groups to consider the emergence of HPAI in breeding seabirds, bringing together conservation policy leads, animal and human health experts, statutory advisers, NGO experts, researchers, and others to identify adaptations to existing management approaches for addressing this novel situation. Significant progress has been made, but over the course of this 'emergency' period many questions have arisen about how we respond on the ground to local outbreaks, what monitoring we need to both support rapid decision-making and long-term impact assessment, our understanding of the transmission of avian influenza in wild bird populations and how to develop strategic approaches to species recovery.

This culminated in the JNCC and BTO organising a virtual workshop to develop thinking to support ongoing efforts to manage the outbreak and also to consider longer-term evidence requirements to enable positive conservation actions and species recovery.

The UK workshop on wild birds sought to bring practitioners and experts together to:

- Identify whether there are any short- or medium-term (conservation) management interventions that could be beneficial.
- Consider whether there are novel longer-term management interventions that could be prioritised to address HPAI impacts and increase population resilience in impacted species.
- Share experiences in collecting data on mortality in different species groups and consider what future mortality monitoring could look like.
- Discuss what developments would be beneficial for UK bird monitoring schemes for improving understanding of impacts, including demographic parameters, and identify where these schemes are unlikely to meet these needs.
- Assess the impact of loss of data, resulting from restrictions to fieldwork in 2022, from national monitoring schemes and research on species assessments, indicators, and marine management.
- Outline new research areas that could help us understand the effects of HPAI on populations, improve risk assessments, and improve management for species conservation and recovery in future.

The workshop was split into three sessions as follows.

SESSION 1 – Wild bird monitoring
2 November 13:30–17:00
The aim of this session was to discuss how the monitoring of wild bird populations could be enhanced to enable effective estimation of local

and national impacts of HPAI on populations, and the role of monitoring of bird mortality. It also reviewed the initial draft of the BTO vulnerability assessment. Breakout groups considered the population and demographic monitoring requirements for seabirds, waterbirds and raptors.

SESSION 2 – Management interventions
10 November 2022 10:00–13:00
This session was dedicated to the management of outbreaks – what practical management interventions can we consider during an outbreak, with a number of key presentations from disease experts. This involved discussion of pre-scored questionnaires, breakout groups and rescoring.

SESSION 3 – Long-term evidence requirements to support species conservation and recovery
10 November 2022 14:00–17:00
The final session of the workshop focussed on longer-term needs for evidence to inform our understanding of HPAI in wild birds and approaches to mitigating impacts and recovering species impacted by the virus.

The aim of this report is to summarise the content of these discussions and to identify the main conclusions. To do this, we have reviewed the notes of the workshop discussions, the content of virtual whiteboards (Jamboard) that were populated during some of the breakout sessions, and some of the workshop presentations. All of the presentations are available online to accompany the publication of this report, enabling the information shared to be fully available.

3. UNDERSTANDING THE SPREAD AND IMPACT OF HPAI IN WILD BIRD POPULATIONS

Despite the relatively comprehensive nature of bird monitoring schemes in the UK, the full impacts of HPAI on bird populations in 2022 may take several years to fully understand, even in the absence of ongoing mortalities. This is because: i) submissions from the 2022 field season are still being collated prior to analysis, ii) many seabird colonies were not surveyed in 2022 due to gaps in coverage or as a result of access restrictions linked to HPAI, iii) mortalities occurred during the breeding season and afterwards, and so will not be fully represented in 2022 data as many of the survey visits will have been in advance of the spread of the virus and iv) the impacts of the virus on breeding success will not be apparent on bird populations until next year or beyond, depending on the species. Some seabirds take several years to reach maturity, and it will take a few years for the population-level impacts on breeding success and the survival of non-breeding individuals to be apparent in breeding populations.

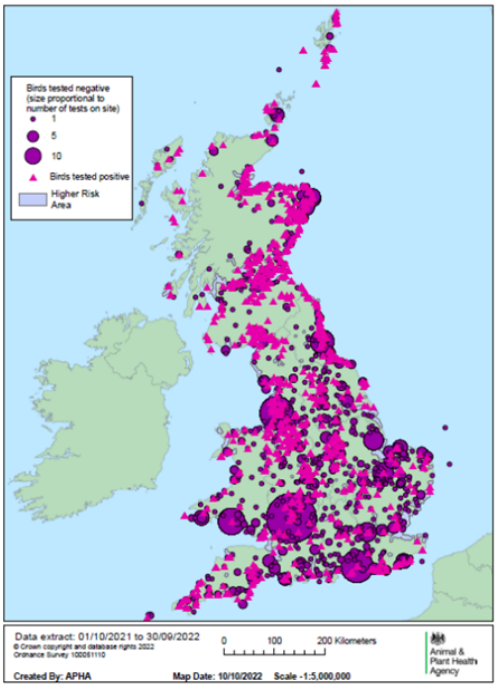
Despite these lags, a number of sources of information are available to already indicate the species most affected and the potential magnitude of those impacts, and were presented at the workshop. A summary of these is outlined below.

APHA HPAI testing results
The Animal and Plant Health Agency (APHA) provides weekly updates of findings where wild birds have tested positive for avian influenza. These records come from ongoing routine surveillance for avian influenza in wild birds which is made up of patrols by nature reserve wardens and collections of found-dead wild birds reported by members of the public. Given the thresholds that generally apply for birds to be collected for testing and the biases in reporting (birds are most likely to be reported by the public in areas with lots of visitors, large and obvious birds are more likely to be reported, repeat testing of species does not occur once positive individuals have been recorded in an area), these statistics are not a good measures of overall mortality, but they do indicate the overall geographic and taxonomic spread of mortalities. The data can also be compared with previous years.

As of the end of September 2022, more than 60 species had tested positive for HPAI, with the top listed species and geographical spread of cases shown opposite (Figure 3.1).

The HPAI outbreak has highlighted a lack of systematic bird mortality recording in the UK. During the 2022 breeding season, each CNCB started to collect records of mortality from their own staff, site managers and some NGO staff e.g., RSPB wardens. These data provide a summary of likely minimum levels of mortality, as for example reported by NatureScot in Falchieri *et al.* 2022 (https://doi.org/10.1002/vetr.2311) where more than 2,200 Great Skua individuals were reported dead by July 2022 (an estimated 11% of the GB breeding population and 7% of the world population). These figures have since been updated to more than 2,600 individuals (Cunningham *et al.* 2022 http://www.seabirdgroup.org.uk/journals/seabird-34/seabird-34-C.pdf). Large numbers of mortalities in Gannets, a number of tern species, including Sandwich Terns and

Figure 3.1. The geographical spread of positive (pink triangles) avian influenza findings in wild birds compared to null tests (purple circles). The top listed species testing positive are given in the table. Data from October 2021 to September 2022. *Figure and data courtesy of the Animal and Plant Health Agency (APHA) and Department for Environment, Food and Rural Affairs (Defra) (https://www.gov.uk/government/publications/avian-influenza-in-wild-birds).*



Species	Total
Gannet	152
Canada Goose	142
Mute Swan	129
Herring Gull	128
Buzzard	124
Guillemot	76
Pink-footed Goose	74
Greylag Goose	68
Pheasant	41
Black-headed Gull	40
Mallard	21
Great Skua	19
Great Black-backed Gull	18
Kittiwake	15
Eider	13
Puffin	10

Roseate Terns particularly on North Sea coasts, Guillemots, Kittiwakes and some other gull species were also recorded. For example, Natural England highlighted that an estimated 30% of the breeding Roseate Terns at Coquet Island were reported dead (Rebecca Jones presentation). At other colonies, particularly in the Irish Sea, species (e.g. terns) fledged before HPAI hit. Although useful to identify where large mortalities were occurring, there were no previous data against which to compare these figures. The data will also be patchy in distribution, dependent on staff being available on the ground to count and collect the information.

Mortalities of ringed birds

About 3,000 licensed ringers ring almost one million birds annually as part of the British and Irish Ringing Scheme, providing important data on the survival and breeding success of a range of bird species. Whilst the marking and recapture of ringed birds enables annual variation in survival and breeding success to be monitored, summer 2022 has shown how the reporting rate of dead ringed birds can be used to make a rapid assessment of unusual mortalities, given a sufficient sample of ringed birds in the population. Figure 3.2. shows a large and significant increase in the number of dead Great Skuas reported with rings (recoveries) in 2022, compared to previous years, whereas no such increase was apparent for Great Black-backed Gull.

Figure 3.2. Changes in the number of dead ringed birds (recoveries) per year reported to the BTO through the BTO/JNCC ringing scheme. The red line with grey estimates of uncertainty indicates underlying changes through time, with the numbers for each year given as grey circles.

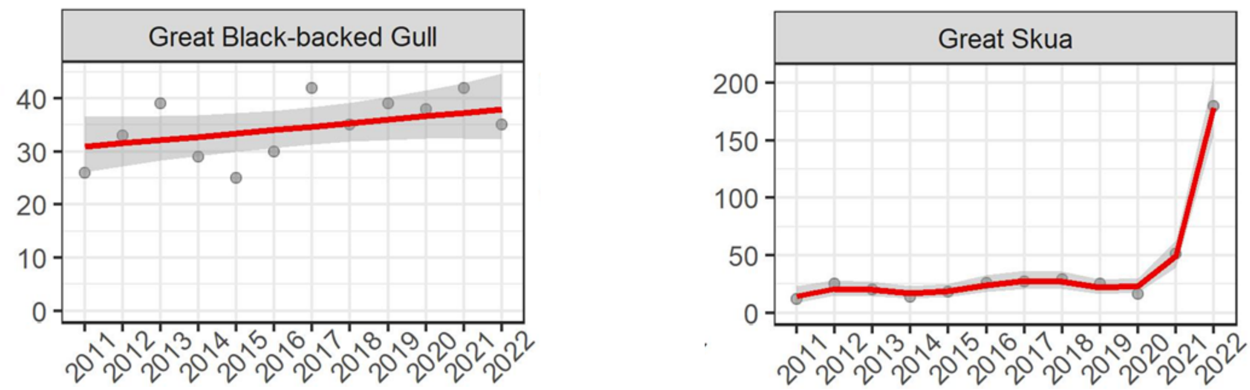
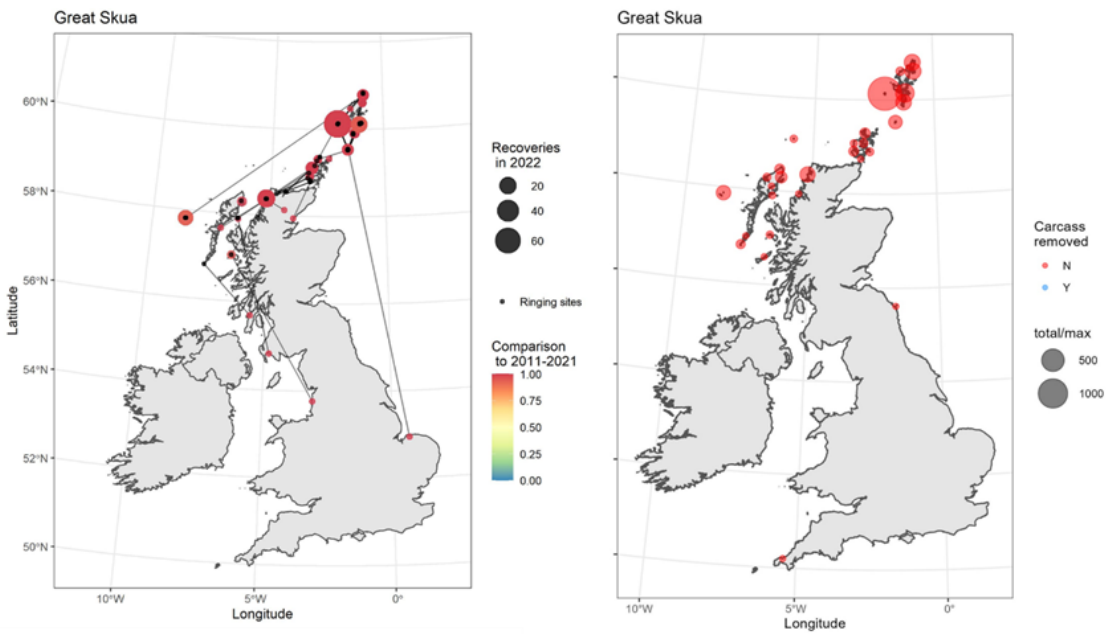


Figure 3.3. Spatial distribution of the number of Great Skua ring recoveries reported to BTO to the end September 2022 (left), compared to the number of mortalities reported to CNCBs (right). The lines join the location of dead birds reported away from colonies to the colony they were ringed at (left). Recoveries were of birds ringed at any time and recovered during the outbreak.

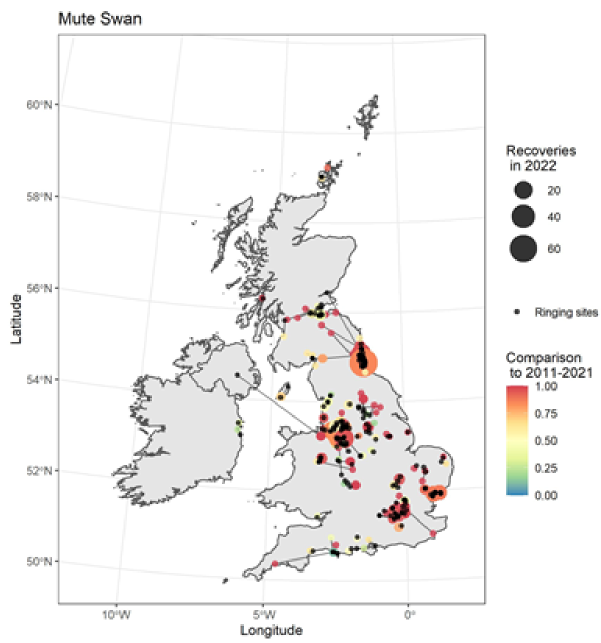


Across seabird species, unusually large numbers of dead ringed Great Skuas, Gannets, Guillemots, Arctic Terns, Common Terns, Sandwich Terns and Kittiwakes were recovered and reported to the BTO in 2022 compared to what would be expected from previous trends. The only other species with a potential increase in recoveries reported was Mute Swan, with many dead Mute Swans also testing positive for HPAI in the APHA statistics (Figure 3.4). Despite relatively large numbers of Buzzards also being reported dead, there was no evidence at the time of the workshop of significant increases in the number of bird of prey ring recoveries, but this is something that ongoing monitoring (e.g. the [Scottish Raptor Monitoring Scheme]) will help to track, noting that the APHA testing data include a number of White-tailed Eagle and Hen Harrier records, both species of significant conservation concern.

The spatial pattern of ring recoveries shows a similar pattern to the mortalities captured by the CNCB data, for example showing extensive Great Skua mortalities across their breeding range (Figure 3.3). Comparisons for Gannet, Guillemot and Sandwich Tern show similar patterns. These are strongly correlated with areas where populations are heavily monitored and losses are very obvious. It is worth investigating where ringing data flags up mortality not observed through other methods and to determine whether ringing data have value as an early warning of problems.

Mute Swan reported recoveries are already pretty widespread across the UK (data shown to end September 2022; Figure 3.4.), showing locations where concentrations of recoveries have occurred and as shown by the red colours. The levels of mortality also appear unusual compared to previous years.

Figure 3.4. Spatial distribution of Mute Swan ring recoveries reported to BTO to end September 2022. The size of the circle indicates the number of ringed birds and the colour indicates the proportion of mortalities reported from 2011 onwards that this relates to. Lines join the ringing location to where the bird was found dead.



Early assessments of bird surveys.
As noted, data from the 2022 breeding season are still being collated for subsequent reporting. Despite the gaps in coverage, initial feedback from these data is supportive of large-scale population declines having occurred for some of the most impacted species, such as Great Skua (Figure 3.5). Another example where HPAI is regarded as having a large-scale population impact is the Svalbard Barnacle Geese that winter on the Solway, where large-scale mortalities during the 2021/22 winter were estimated to have resulted in the loss of a quarter to a third of individuals compared to similar coordinated route counts in previous years (Griffin 2022), apparently supported by observed reductions in abundance on the breeding grounds (Figure 3.6). Repeat surveys during winter 2022/23 will provide further like-fo-like comparisons to confirm the magnitude of impact.

Figure 3.5. The timing of the latest available Great Skua data in the SMP database (left); yellow are colonies last counted before 2019. Initial estimates of change in Great Skua abundance at particular colonies (right) suggest most show large-scale declines in 2022 compared with the last count.

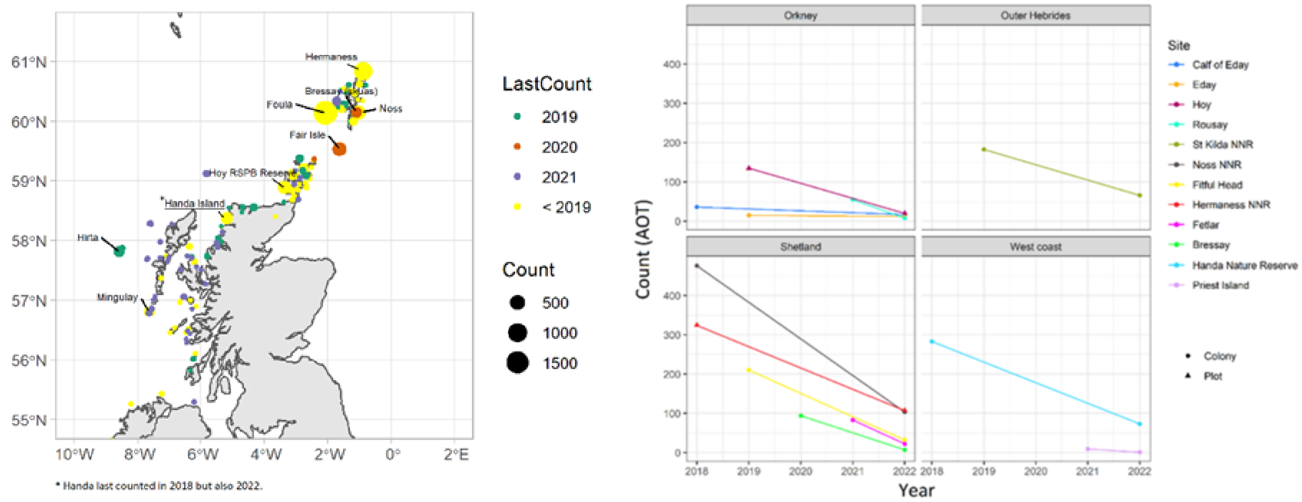
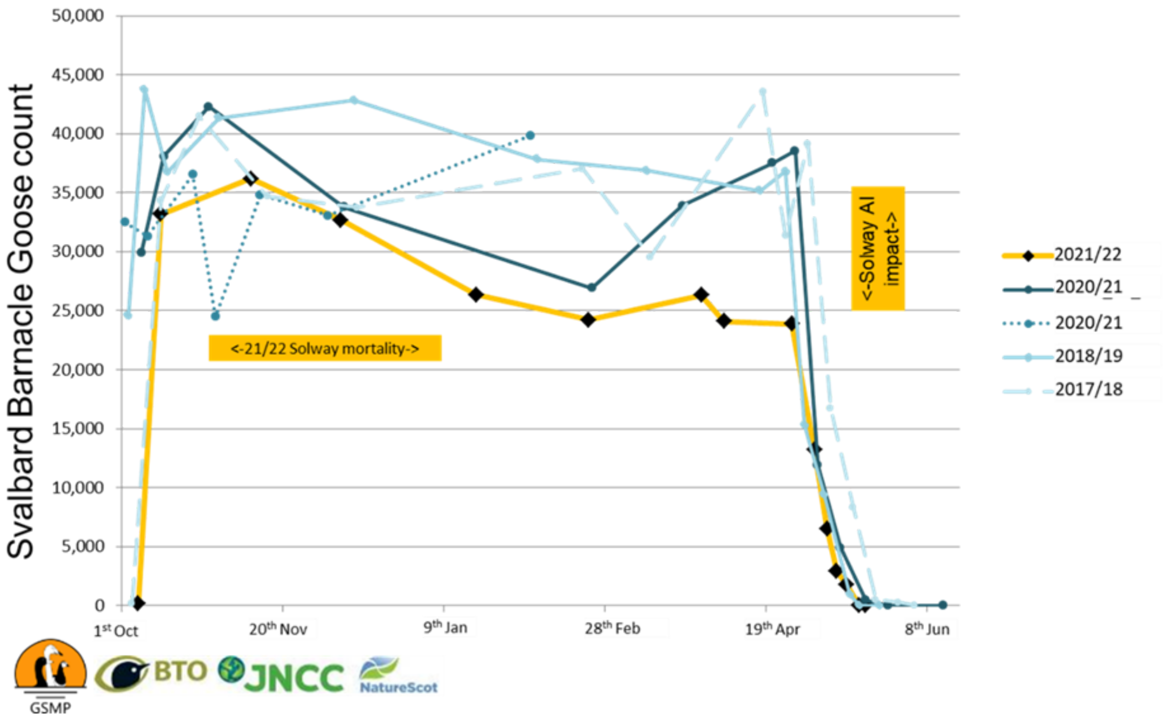


Figure 3.6. Monthly changes in the abundance of Svalbard Barnacle Geese from 2017/18 to 2021/22. HPAI-driven mortalities in 2021/22 were associated with a decline in the numbers counted (yellow) which compared to previous years did not recover in the spring, hence the suggested mortality of a quarter or a third was inferred (Griffin 2022).



4. IMPLICATIONS FOR MONITORING

To discuss the implications of the HPAI outbreak for short- and longer-term population and demographic monitoring, three breakout groups were set up and the approximately 80 participants self-allocated themselves to their chosen group. They were also free to move between groups. The breakout groups dealt with (i) seabirds, (ii) waterbirds and (iii) raptors and all other wild bird species. The 60 minute discussion was structured around a Jamboard with seven slides (Table 4.1). These asked participants to first identify any information needs that were not currently covered under existing monitoring schemes and then led them through different aspects of population and demographic monitoring. The facilitators were asked to initially allow participants to freely enter text using 'sticky notes' on the Jamboard. When the rate at which sticky notes were being added slowed, facilitators took the participants through the different slides and drew out common themes and asked them to identify any gaps that had been missed. A note taker in each session was also designated to capture ideas arising from the verbal discussion

Table 4.1. Jamboard slides from the monitoring breakout session.

Slide	Total
1	Information Requirements (1a – short term and 1b – medium-long term)
2	Population counts – criteria for prioritisation
3	Population counts – priority species and sites
4	Demography – productivity and survival – Additional criteria for prioritisation / improvements to existing schemes
5	Demography – productivity and survival – priority species and sites
6	Demography – productivity and survival – 6a – mortality monitoring and 6b: How can we improve mortality monitoring?
7	Information networks and dissemination

4.1. Seabirds

4.1.1. Background – population and demographic monitoring of seabirds in the UK

The Seabird Monitoring Programme monitors the population changes of internationally important breeding seabird species at coastal and inland colonies across the UK. Britain and Ireland are home to the majority of Europe's breeding seabirds, and these seabird breeding colonies – both coastal and inland – are of international importance. The Seabird Monitoring Programme collates data from professionals and volunteers to monitor both changes in breeding numbers as well as breeding productivity of seabirds throughout the United Kingdom, the Isle of Man and the Channel Islands on an annual basis to provide data for the conservation of their populations.

Scheme participants, both non-professional and professional surveyors, visit sites at both inland and coastal locations to count numbers of breeding seabirds and, where possible, their chicks to monitor breeding success. Additional data on survival, diet and phenology are collected at key sites. The scheme also provides the foundation for enabling complete breeding seabird censuses of Britain & Ireland at approximately 20 year intervals.

4.1.2. Overarching information requirements

There was clear consensus over the importance of updated and improved population monitoring for seabirds, recognising that current levels of monitoring can be improved. This took the form of updated census information (six responses), recognising the value of repeating the fieldwork for Seabirds Count (the last breeding seabird census) completed just before the HPAI outbreak. A resurvey of colonies would provide updated population information for key species known to have been significantly impacted. This is therefore likely to require fieldwork over multiple-years in order to be comprehensive, and of course, the results may be impacted by ongoing HPAI impacts in future years, which could impact future priorities for monitoring. Revised information will also be essential to inform updated offshore wind farm assessments.

There was also significant support for improved annual monitoring through the Seabird Monitoring Programme (three responses) noting that some sites are counted but the data not entered. There is an urgent need for the SMP database to be up to date, requiring data submissions from those with data. Some concerns were also expressed about changes in the implementation of SMP methods through time at one site in particular. BTO are intending to review methods and publish a revised methods handbook, as well as developing a wider plan to support surveyors over these issues. With respect to 2022, the timing of any count in relation to the timing of HPAI will be important to guide interpretation. In order to better track future disease outbreaks through the breeding season, a series of colony counts could ideally be implemented at a range of sites in future years. Whilst BTO is currently reviewing coverage in order to inform a future engagement strategy, having a good representative spread of regularly monitored sites using standardised methods for a representative suite of species was identified as really important. Part of the output from the workshop should therefore help identify the criteria to prioritise extra coverage.

In addition to annual abundance monitoring, the importance of ongoing demographic (survival/productivity/recruitment) information was also highlighted (six responses). Whilst the SMP provides productivity data, improved information on survival rates, particularly in the context of HPAI mortality, is really important, noting that estimates for a number of species are already provided through RAS, but generally based on a limited sample of colonies; BTO is actively seeking to grow capacity here. Additional suggestions included ideally having more frequent resighting data to capture mortality through the year (e.g. at the start and end of breeding seasons), and to improve the capture of colour-ring resighting information (e.g. through BTO's DemOn database) to make that more readily available for analyses. Analyses of 2022 data have highlighted the value of ringing data to track mortality quickly, but this does require relatively rapid data submission. Weekly data collection on productivity from Les Etacs Gannet colony in Alderney rapidly identified the spread of HPAI in the colony and preceded the timing of increases in ring-recoveries reported to the Channel Islands Bird Ringing Scheme by about a week.

There was recognition about the complexities of seabird demographics, with large non-breeding and immature populations in many species associated with considerable uncertainties about their abundance, demography and movements. Metapopulation dynamics are likely to be important, which may require an increase in the level of marking birds and perhaps use of colour-ringing if we are to understand them. New technologies may be able to assist with this, such as the use of PIT tags and MOTUS. The importance of collecting viral data was recognised, particularly to look at changes in the genome to understand how the virus spreads between colonies and through time, which potentially could be linked to greater understanding of bird movements.

One final key recommendation was for fieldworkers and site staff to be in place to undertake early surveillance of colonies at the start of the breeding season as a mechanism for early warning detection of potential HPAI mortalities. The need to understand the potentially negative consequences of monitoring was flagged-up as a priority – to what extent does human interference with birds increase the spread of HPAI? In the vulnerability analysis it was thought that HPAI spreads very easily between birds and careful monitoring would be unlikely to lead to significant additional spread of the virus. It was noted that there was a need to balance the risks of monitoring against the benefits of the information gained, and that the loss of data in long-running monitoring schemes would lead to barriers to understanding the impact of HPAI on the species in question. Implementing good biosecurity is likely to be important and is a no-regret action but needs testing to quantify any residual risk. It is critical to understand the pathways of viral spread to understand how important these interventions are likely to be.

4.1.3. Population counts

The following criteria were listed to inform priorities for population monitoring:

Species criteria:

- Populations of species where the UK holds a significant percentage of global the population.
- Species of global and UK conservation concern.
- Species with known high mortalities resulting from HPAI, or likely to be vulnerable.
- Species vulnerable to other stressors, e.g. offshore renewables.
- Well-monitored species with recent SMP trend data.
- Colonial nesting species where transmission likely to be high.

Site criteria:

- Sites that hold a high percentage of the UK population. For RSPB, species with a high percentage of their UK population on RSPB reserves.
- A spread of (both coastal and inland) sites that are geographically representative – HPAI had different timings/impacts across the UK (e.g. northern Gannet colonies were impacted 10 weeks earlier than southernmost ones).
- Sites with recent counts in order to most confidently look at change following HPAI.
- Sites that already have established long-term monitoring projects as it is easier to continue and build on existing infrastructure.

We were also urged not to forget UK Overseas Territories, where there is an urgent need for accurate baseline information on seabird populations, and the Crown Dependencies of the Isle of Man, Bailiwick of Jersey and the Bailiwick of Guernsey.

Participants suggested the species that they considered the greatest priorities to understand more about their populations (Figure 4.1), noting in particular four responses highlighting urban/inland nesting gulls, and another highlighting the lack of winter gull information – the last structured winter gull survey was organised in 2003/4 to 2005/6 (Burton *et al*. 2013). Prioritised species tended to be those with relatively high levels of recorded mortality, or those with relatively poor monitoring data. Fulmar was flagged up by one individual, as the species that appears not to have suffered high mortality that could provide a useful counterfactual to compare against species known to be impacted by HPAI. The discussion flagged a particular need for more information on petrels and shearwaters given the importance of the UK populations in a global context, and the uncertain impact given their remoteness and difficulties of detection being nocturnal burrow-nesters on remote islands. It was recognised that drone surveys worked well this year, particularly for gannetries (e.g. Bass Rock, St Kilda).

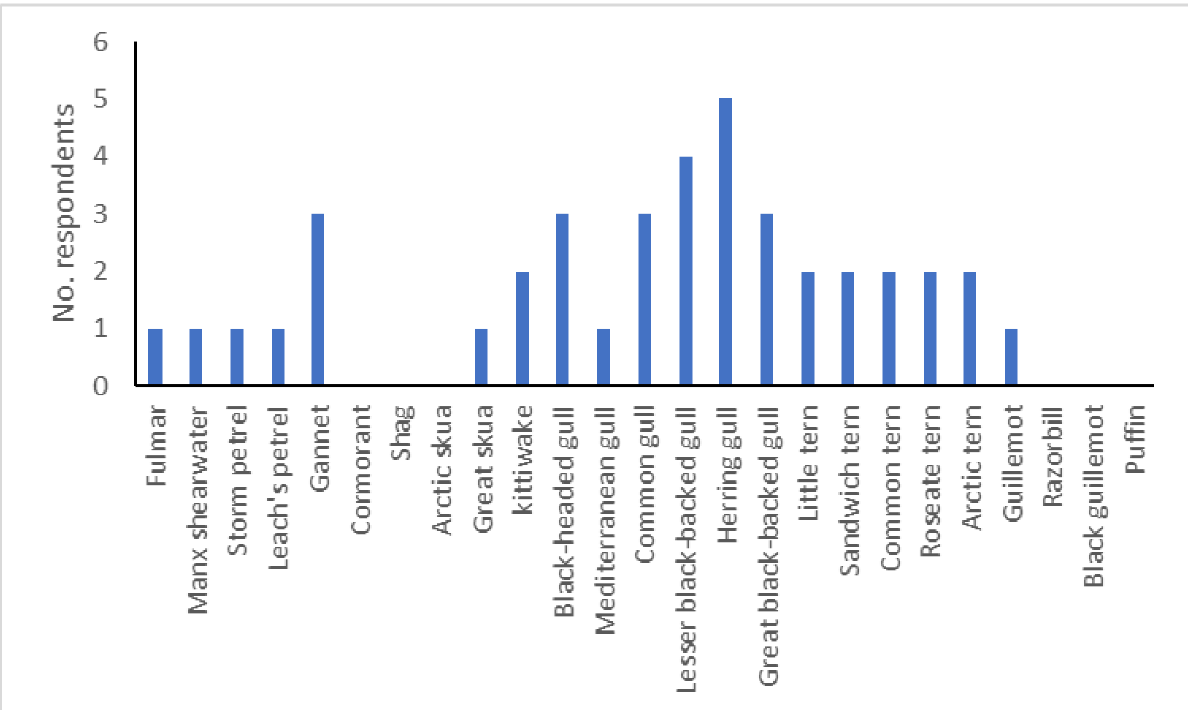
Although the focus of the discussion was on enhanced professional coverage in 2023 and beyond to fill gaps and resurvey sites covered in the recent census, many colonies are also covered by a cohort of volunteers through the SMP. As the SMP scheme organisation was transferred to BTO in July 2022, there is also an urgent need to fully understand coverage for 2022 as the data are submitted and particularly to work with JNCC to understand where there are gaps in coverage following the census, and, where possible, to prioritise engagement to increase non-professional coverage moving forward. This will be taken forward through the SMP work programme.

4.1.4. Demography – productivity and survival

The following criteria were listed to inform priorities for demographic monitoring:

- Practicality – long-term demographic studies are difficult to run and therefore need to be realistic when established.
- Whether sites are already established long-term longitudinal studies that should continue.
- Sites and species where multiple data can be gathered regularly from the same site.
- Need a good geographic spread of sites.

Figure 4.1. The number of respondents who suggested particular species should be prioritised for population surveys. Some of the responses represent interpretation of generic terms (e.g. urban gulls meaning Herring Gull and Lesser Black-backed Gull).



The importance of being able to understand age-specific survival (three responses) and recruitment (one response) was highlighted. We recognised the mechanism which facilitated the southerly transfer of the virus across Gannet colonies was uncertain – could it be the movement of young birds? Quite a few respondents emphasised the value of colour-ringing (five responses), either to support RAS projects or for international coordination to look at movements between colonies – one of the main ways to look at this important biological process. We were urged to consider how seabird monitoring could be tweaked to improve inference – such as increased resighting effort at the start and end of the breeding season to separate mortalities into breeding and non-breeding periods. The importance of understanding interactions between breeding and non-breeding populations was highlighted, with evidence of non-breeding birds moving in to fill gaps in colonies as they appear in Gannets (this year in relation to HPAI) and Guillemots (the year after historical pollution incidents).

Given the challenges of establishing long-term studies, existing studies were valued for a number of reasons i) the difficulties of setting-up new studies; ii) to provide historical data against which to compare current estimates of demographic rates; iii) to disentangle the complexities of seabird demography with multiple age-classes and iv) to have sufficient sample size of marked birds to estimate survival. Sites where multiple data (abundance, productivity, recruitment and survival) on the same species, and or data on multiple species were collected, should also be prioritised. Funding long-term studies can be difficult, whilst the value of long-term studies maintained by non-vocational specialists (amateurs) such as through key ringing groups, should also be recognised, given the contribution they make to our understanding of seabird demography. This is often at significant cost to ringers and ringing groups in terms of time and finances – is there more we can do to support this work? There was some discussion about the quality of methods, with examples highlighted where the application of field methods has changed through time. Considering the need for more checking of the application of methods and data should be something for BTO to consider now it has taken on the organisation of the SMP.

4.1.5 Mortality monitoring

Mortality recording was regarded as important to:

- Inform vulnerability assessment.
- Identify impacts on populations (particularly in close-to-real time).
- To prioritise sites/populations for management/intervention measures.
- To understand disease prevalence.

There was discussion about how to disentangle recorded mortality from background mortality. The analysis of ringing data presented showed how that was possible for ring recovery data, at least in circumstances where the level of ringed birds was likely to be fairly constant – the case for many seabirds given their longevity. The lack of structure to mortality recording was noted, and the potential value of making use of the RSPB beached bird survey approach highlighted (six responses) as a mechanism to provide more of a standardised approach.

The potential role of remote technology to record mortalities was also highlighted, such as using aerial surveys and digital photography both at colonies, but also at sea for mortalities. UAVs enabled rapid assessment of mortality at the Bass Rock, and at St Kilda, demonstrating their value even in remote circumstances. The potential to use ecological consultants and other professionals to also gather and submit data was mentioned in two responses, which could perhaps be enforced through conditions of consent, or by regulators.

The need for easy approaches to mortality reporting was identified (two responses), although there were some concerns about having too many sources for reporting information (two responses). At present though, there was a strong feeling that the current approaches to data capture were inadequate. Some uncertainty was expressed about the quality of the information gathered and the potential for double counting, particularly across multiple data sources (eight responses). This could be addressed through photographic validation of mortality reporting, marking carcasses and adopting a harmonised approach for handling multiple records (i.e. person x reports three birds on Monday, person y reports six birds on Tuesday = max estimate nine birds, conservative estimate six birds). The need for coordinated mortality reporting internationally was highlighted by eight respondents, with the example of Sandwich Tern highlighted given the need to understand the population level impact around the North Sea for what can be a highly mobile species.

The need to join mortality reporting with disease surveillance was also emphasised to make sure mortality is correctly attributed to HPAI. This requires good coordination and communication between agencies on the ground, those doing the testing and the CNCBs collating mortality information.

4.2. Waterbirds

4.2.1. Background – population and demographic monitoring of waterbirds in the UK

The BTO/RSPB/JNCC Wetland Bird Survey (WeBS; Frost *et al.* 2021) is the monitoring scheme for non-breeding waterbirds in the UK, which provides the principal data for the conservation of their populations and wetland habitats. The WeBS Core Counts scheme is the principal scheme of the Wetland Bird Survey. Counts are made annually at around 2,850 wetland sites of all habitats; estuaries and large still waters predominate. Some sites are large and split into separate count sectors. Monthly coordinated counts are made mostly by volunteers, principally from September to March, with fewer observations during summer months. Coverage of estimated populations by WeBS varies by species, with those species using large (estuarine and freshwater) wetland sites more fully monitored than those that use the wider countryside or open coast. A recent feature of the scheme is recording the age and sex composition of flocks seen during a WeBS Count that aims, in the future, to provide monitoring of the breeding productivity of selected species.

The BTO/JNCC/NatureScot Goose & Swan Monitoring Programme (GSMP) complements WeBS in providing species-specific surveys to monitor the different populations of geese (including Pink-footed, Barnacle, Bean, Brent, Greater White-fronted and Greylag) throughout the UK and Ireland, to provide data for the conservation of their populations. The scheme also includes a quinquennial International Swan Census, which focuses on Whooper and Bewick's Swans. In addition to monitoring numbers, the annual breeding productivity of each of the UK's migratory swan and native goose populations is assessed through the GSMP, and involves observers recording the number of young birds present amongst flocks.

In addition to WeBS and GSMP, the periodic Non-Estuarine Waterbird Survey (NEWS; last run in 2015/16; Austin *et al.* 2017, Humphreys *et al.* 2021) monitors waterbirds on the UK's open coast, while the Winter Gull Roost Survey (WinGS; last run in 2003/04–2005/06; Burton *et al.* 2007, 2013) similarly provides periodic updates on the UK's gull populations and distributions.

The BTO/JNCC/RSPB Breeding Birds Survey (BBS; Harris *et al.* 2021) and Waterways Breeding Bird Survey (WBBS:) together provide annual monitoring of some more widely distributed breeding waterbird species.

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Further to these schemes, the demography of waterbirds is monitored through the BTO/JNCC Avian Demography Schemes, i.e. the British and Irish Ringing Scheme and Nest Record Scheme. Under the Ringing Scheme's **Retrapping Adults for Survival** (RAS) scheme, which focuses on species breeding in the UK, survival rates of six waterbird species are currently monitored: Mute Swan, Greylag Goose, Eider, Ringed Plover, Little Ringed Plover and Common Sandpiper (Appendix 1). Ringing data have the potential to provide further information of the age ratios, and thus productivity, and also survival rates of wintering waterbirds, but there is no formal facilitation of this.

4.2.2. Overarching information requirements

Initial discussion in the workshop breakout group on overarching information requirements to assess the impacts of HPAI on UK waterbird populations highlighted: (i) the need for baseline data on populations and (ii) the importance of long-term population and demographic monitoring to enable integrated population modelling.

Given the established monitoring schemes that exist for waterbirds, there was a focus on long-term development needs, particularly of demographic monitoring, to be better able to determine and assess the population consequences of HPAI. However, in the short-term, the particular importance of maintaining the long-term integrated monitoring of swans and geese previously provided by the Wildfowl and Wetlands Trust was highlighted. There have been recent changes in both the WeBS and GSMP monitoring partnerships, with the BTO now contracted to provide the coordination role of GSMP, and the Wildfowl and Wetlands Trust stepping back from being an associate partner of WeBS to focus on other wetland conservation issues (WWT 2022). The successful transfer of historical GSMP data to BTO, and good communication with the network of surveyors, is critical for successful ongoing maintenance of goose and swan monitoring data for the 2022/23 winter and beyond.

4.2.3. Population counts

Frost *et al.* (2019) provided updated population estimates for 98 different waterbirds species that winter in Great Britain, using data collected principally from WeBS and GSMP. The review considered either the average peak winter population over a five year window from 2012/13–2016/17, or the most recent possible estimate. These estimates are due to be updated as part of the ongoing WeBS programme by 2024, considering the five year window from 2017/18-2021/22 (although again, for some species, potentially older estimates), thus providing an important pre-HPAI baseline for establishing the potential impacts of HPAI on waterbird populations.

Existing WeBS prioritisation is based on long-term monitoring needs and is used to encourage new counters at the most important sites: **www.bto.org/webs-vacant-sites**; this prioritisation particularly considers the importance of covering protected sites and their waterbird features. Breakout group participants highlighted the need for maintenance of the long-term datasets provided by WeBS and GSMP, noting that it was important to have systematic monitoring across species to ensure that impacts of HPAI were not missed and to be able to assess relative impacts between species. While recognising this point, though, participants suggested that prioritisation to better understand the potential impacts of HPAI on waterbird populations might consider: (i) those species or specific populations already known to be impacted by HPAI, such as the Svalbard Barnacle Goose population, to monitor the progress of population impacts, and (ii) those that might be considered vulnerable. At the recent African-Eurasian Waterbird Agreement (AEWA) Meeting of Parties (MOP8: **https://www.unep-aewa.org/en/mop8**), a specific amendment was adopted to existing annexes to enhance (population and demographic) monitoring and assessment of those species affected by recent HPAI H5N1 and to report on these data to allow population assessments for MOP9 (in autumn 2025) to be made on the basis of the most recent information on status.

It was highlighted that there was a need to consider wider monitoring being undertaken across species' flyways, to ensure coordination of priorities, but also that there was a need to consider impacts not just at the population level, but also on sub-populations, and thus on species' distributions and consequently their resilience. It was recognised that the frequency of surveys and volunteer capacity – and thus the potential needing for additional professional support – would need to be considered in meeting priorities.

Over and above existing prioritisation and the comments above, a particular priority noted again was the need for updated population estimates and distributional information on wintering gulls. The last structured winter gull survey was organised in 2003/4–2005/6 (Burton *et al.* 2013).

4.2.4. Demography – productivity and survival

Improved demographic monitoring was highlighted as a particular requirement to understand the impacts of HPAI, and of other environmental drivers, on waterbird populations. During outbreaks, demographic data should be collected where possible (e.g. nest monitoring, ringing and resighting of colour rings) to track the impact of the disease on populations of birds. Without annual data it will not be possible to determine these impacts.

GSMP provides monitoring of the breeding productivity of a number of goose and swan species, and has been supported historically by WWT's programme of ringing on selected species, providing survival and thus integrated population monitoring. However, wider monitoring of the productivity and survival of other waterbird species, through WeBS and the British and Irish Ringing Scheme, is limited.

While, as above, the importance of systematic monitoring across species was highlighted, in practice, prioritisation of demographic monitoring would be necessary, given the extent of current waterbird ringing and the investment needed to be able develop capacity. Specific prioritisation to better understand the potential impacts of HPAI on waterbird demography should be aligned with the prioritisation for population monitoring.

Reviewing recent ringing effort would provide an understanding of the potential for both productivity and survival monitoring of waterbirds from the British and Irish Ringing Scheme and inform priorities.

Supporting professional work would be required to support priorities for monitoring the impacts of HPAI on waterbirds in the short-term, with continuation of the ringing/resighting work on goose and swan species previously undertaken by WWT being highlighted as a particular immediate priority in monitoring survival of those species.

There is the potential to incorporate wintering waterbird projects into the RAS scheme, which at present is focused on breeding populations (Appendix 1), building on the notable work of some ringing groups that focus on waterbirds and providing direction to wider ringing efforts. Longer-term development of a volunteer-based ringing programme to monitor waterbird productivity and survival would require investment in training and support for rings and equipment. A particular requirement for survival monitoring of waterbirds is the need to invest not only in ringing activities, but also in associated resightings of colour-ringed birds. Such a programme should also consider coordination with wider international work through, for example, the international specialist groups including the International Wader Study Group and Goose Specialist Group. With the appropriate support and collaborative framework, such groups may also provide capacity for serological sampling of live birds.

It would also be beneficial to consider bringing together different potential sources of age-ratio data – from ringing, field observations (from GSMP, WeBS) and BASC duck wing surveys – to assist with the monitoring of productivity.

Further to the above, the benefits of a more structured programme of waterbird ringing for understanding the dispersal of juvenile birds and the movements of non-native goose populations, and their role in the spread of HPAI, were also highlighted, with colour-ringing work undertaken by Sovon in the Netherlands providing an exemplar for the latter.

4.2.5. Mortality monitoring

While improved monitoring through ringing of the survival of waterbirds will help provide the information needed to assess and predict the impacts of HPAI on populations, participants also noted the value of direct monitoring of mortality for more immediate surveillance of the spread of HPAI across the UK and species.

Both WeBS and BirdTrack, a BTO-led partnership with the RSPB, BirdWatch Ireland, the Scottish Ornithologists' Club and the Welsh Ornithological Society, provide potential platforms for collecting mortality data for waterbirds over a wider geographic area than currently provided by the monitoring of mortality by CNCBs, which is focused on protected sites. All provide the potential for assessing the impacts of HPAI on different age-classes, although the information collected would need to be combined with background monitoring data on the age-classes in populations (see above). Since the workshop, BTO has promoted the potential for BirdTrack as a means for birdwatchers to record dead, sick and injured birds, and asked GSMP and WeBS surveyors to record mortalities on their monthly surveys, providing enhanced potential for recording numbers of dead birds across the country, whilst also signposting the need for dead birds to continue to be reported through official channels.

Such recording only provides minimum estimates of mortality and there will also be biases in the detectability of mortality between species; more structured recording combined with assessment of the detectability of corpses over time is thus desirable in interpreting data. Further, as such monitoring does not necessarily differentiate as to the cause of mortality, it is important that observations of dead birds are still reported to Defra via the online reporting system, or by calling the Defra helpline (03459 33 55 77), to inform the surveillance of HPAI in wild birds by APHA.

4.3. Raptors

4.3.1. Background – population and demographic monitoring of raptors in the UK

The approach to monitoring status and trends of birds of prey is mostly not consistent across the UK and information comes from several different monitoring schemes. For common raptors, national schemes like BBS, the British and Irish Ringing Scheme (including RAS) and Nest Record Scheme provide data on trends in abundance during the breeding season and demographics. For rare raptors, monitoring is done by individuals or small groups of raptor surveyors. In Scotland there is collaboration between raptor surveyors via the Scottish Raptor Monitoring Scheme (SRMS), with methods standardisation, training and data collation and analysis all supported. Some raptor study groups also provide data on the commoner raptors. The Rare Breeding Birds Panel collates data annually from raptor surveyors across the UK, including SRMS data, to provide information on abundance and trends, although population coverage is very variable. Periodic censuses of individual species are organised, if funding is available, through a collaboration between the Statutory Conservation Agency and RSPB Annual Breeding Bird Scheme (SCARABBS). Information on raptors outside of the breeding season comes primarily through data collection platforms like BirdTrack, but there are no systematic surveys. Although the methods are not ideal, Barn Owl, Tawny Owl and Little Owl trends are reported through BBS, supported by periodic surveys, whilst populations of other owl species are poorly covered. Some raptor study groups also monitor owls, whilst many Barn Owl populations are relatively well covered through various nestbox projects.

4.3.2. Overarching information requirements

For many raptors, baseline population information is poor and trends for many species are based on limited data. An assessment of monitoring capability across all UK breeding/non-breeding birds would be useful to understand where we have important gaps or need to adapt existing schemes to support conservation efforts in general. In particular, the ongoing review of SCARABBS, including assessment of improving trend estimation, should consider implications of HPAI. In any birds that do recover from HPAI infection, it would be useful to monitor fecundity/breeding success as this might be reduced and have longer-term population impacts, but this would require testing individuals to assess their prior exposure status so is perhaps a research question linked to existing monitoring.

Without better baseline information it will be challenging to understand the added impacts from HPAI on raptors, which will make conservation planning for some species more challenging. However, it would be helpful to look at the policy questions that any additional data collection could answer, and consider evidence quality requirements, etc., to meet these needs.

4.3.3. Population counts

There were different views on how to prioritise species for increased monitoring to better understand population sizes. One suggestion was to select focal species across certain categories, e.g. habitat or taxonomic. Others included: monitoring species that were high in a vulnerability index or where the UK has high biogeographic responsibility and hence higher conservation responsibility; species that are poorly monitored, for example Merlin; raptors that interact with other species with possibly high levels of HPAI infection rates, e.g. poultry, gamebirds and waterfowl; and species known to frequently visit poultry premises. However, there were concerns about just focusing on birds of conservation concern when other species could be sentinels and alert us to impacts earlier than BOCC/UK/IUCN species. Several mentions were made of certain crow species, including Chough, and the need to consider these more carefully.

More geographically focused monitoring was suggested to improve understanding of populations in regions or selected areas, e.g. targeted monitoring at a smaller spatial scale linked to specific management measures or species' SPA networks.

A key message was that we still require structured surveys based on consistently applied methods to produce robust information and reduce biases.

4.3.4. Demography – productivity and survival

There were contrasting views on the value of enhancing demographic monitoring for understanding HPAI impacts, with the challenge that we might not know enough about likely effects of HPAI on productivity, and so it is perhaps too early to spend efforts on enhancing monitoring. Views expressed were that abundance monitoring should be the priority, with demographic monitoring combined when efficient to do so or as a secondary priority if funding was available. However, it is worth noting that if chicks or young birds are particularly vulnerable to HPAI mortality compared to adults, then in long-lived k-selected raptors, the population-level impact of the virus may not detected for a few years, making ongoing productivity monitoring also important.

Options to consider were whether there are sufficient RAS projects for raptors and whether more could be encouraged, feasibility of determining changes in demographic metrics, e.g., fledging success and first year survival, and whether nest box study species may offer the best estimates of survival.

4.3.5. Mortality monitoring

A range of uses of mortality data were highlighted:

- Understanding HPAI prevalence and impact pathways, including through comparison of the proportion of submitted samples that are positive/negative.
- Understanding sublethal impacts (sickness) as well as mortality rates.
- Understanding other causes of mortality, including illegal activities.
- Exploring differences in mortality between non-breeding and breeding season.
- Understanding whether carrion feeders and those species predating infected birds differ in exposure and vulnerability, and why that might be, i.e., the different sources of transmission.
- Risks of transmission associated with group feeding activities, including between species.
- Assessing the impact of bird of prey feeding stations, e.g. for Red Kites.
- Indicating species with apparently higher vulnerability for which enhanced monitoring, short-term management interventions and longer-term research and holistic management actions might be needed.

It was recognised that mortality monitoring was extremely difficult to do in any meaningful, representative and statistically robust way, and that existing APHA monitoring is, by design, self-limiting at any site, i.e. once reported further collections/testing is not made. It is worth noting that satellite tagging has been used as a means for monitoring raptor survival, particularly to highlight incidents of wildlife crime — could such data and approaches also provide the potential to pick-up HPAI mortality, noting that a significant sample size of birds would need to be tagged? Wing-tagging has also been used successfully as a means for monitoring survival rates in raptors (e.g. Smart *et al.* 2010) and therefore, in the context of HPAI, there may be value in promoting this more broadly. In the context of the existing Scottish Raptor Monitoring Scheme, which is currently being reviewed, there may be value in considering more systematic population monitoring to improve our understanding of HPAI impacts.

Despite this, it was felt in discussion that HPAI monitoring should be properly geared towards understanding prevalence in wild bird populations to meet conservation needs as well as food industry priorities. It was noted that detection of dead raptors was far less likely than for waterbirds and seabirds due to typically solitary/territorial behaviour, habitats occupied and remote areas, monitoring effort and cryptic colouration. However, it was noted that it would be helpful to consider what mortality monitoring was already occurring for raptors (e.g. associated with crime, second generation anti-coagulant rodenticides, etc.) and evaluate how HPAI testing can be done within those schemes to add data, plus birds dying in wildlife rehabilitation centres and vet practices. It was noted that it would also be really helpful to get more information on birds that have died from HPAI to check for comorbidities, but this will require rigorous post-mortem examination (PME) protocols and cause of death information, including AI serological status, and there is limited ability to do complete PME due to costs (high containment labs are a legal requirement where HPAI concerned as it is a notifiable disease). Despite this, it was considered helpful to have better clarity/collaboration on when/where/how to submit dead raptors routinely in all devolved nations.

Testing of live birds, e.g. by swabbing during licensed ringing or blood sampling for HPAI serological status, including live birds collected by wildlife hospitals, etc. was raised. Could this be an additional monitoring option for birds of prey that would be worth exploring, as noted earlier for other taxa? This is perhaps a research question and could involve a trial if there was funding to support sample collection and processing.

4.4. Other species

The workshop focused on groups that have been visibly affected by HPAI and did not consider in detail species that were not seabirds, waterbirds and raptors. Many of these susceptible species occurred in large groups in breeding colonies or wintering congregations, or were predatory or scavengers, but many other species with different traits may also be affected but not picked up in the current routine HPAI monitoring and testing because they might occur in areas with a low density of people, occur singly and maybe have cryptic plumage. The relative reporting rate of different species can be estimated using dead recoveries reported to the British and Irish Ringing Scheme, although separating out finding and reporting probabilities is currently not possible.

Without an extensive program of testing in live wild birds, apart from occasional studies of the prevalence of HPAI viruses in wild birds (e.g. Wade *et al.* 2022), it will be necessary to use national bird monitoring schemes to highlight unusual changes in bird populations. The Breeding Bird Survey and the British and Irish Ringing Schemes are the two key schemes and a mechanism to flag up unusual, potentially HPAI-related, changes in populations should be put in place.

4.5. Information networks/dissemination

There was strong support for better communication between stakeholders both within the UK and internationally as currently information is gathered by many different organisations. This could be achieved by having a central hub that receives all the reports of incidents, or by having a standardised approach to data collection and the ability to easily collate / integrate data subsequently. Improved real time data submission and accessibility would help on the ground decisions.

Finally, there was a plea not to forget the UKOTs and Crown Dependencies. RSPB has a small UKOT team to work with local conservation bodies but it was unclear how much HPAI has been discussed by this team with the UKOTs. The Crown Dependencies (Guernsey, Jersey and the Isle of Man) have their own ecologists and veterinary teams who are largely operating outside of the coordinated UK HPAI response despite having several seabird species that are important in an international and UK context. They would welcome more interaction with the UK HPAI response.

5. ASSESSING THE VULNERABILITY OF SPECIES TO HPAI

5.1. Background

As part of BTO's response to the unprecedented impact of HPAI on wild birds in 2022, BTO has undertaken a rapid assessment of the vulnerability of wild birds to avian influenza. This was initiated in response to the apparently changing nature of the virus with respect to the impacts on wild birds (Falchieri *et al.* 2022), and attempts to provide a transparent methodology to identify what are likely to be the most vulnerable species and species groups to HPAI in the UK moving forward. This was undertaken to prioritise bird species for monitoring and surveillance, to inform any assessment of risk associated with particular activities, and in the longer-term, to guide the prioritisation and planning of conservation organisations and agencies in the UK. Previous risk assessments of HPAI have primarily focussed on the risk of incursion into domestic flocks of economic value (e.g. Snow *et al.* 2007, Veen *et al.* 2007) and have not considered how a combination of susceptibility to HPAI and the population dynamics and conservation status of species' might interact to influence vulnerability.

Building on approaches to climate change vulnerability assessment (Foden *et al.* 2019), a series of traits were used to identify the most vulnerable species. Each species was given a score of 1 (low) to 4 (high) for a range of ecological, demographic and epidemiological traits, which were averaged to provide scores with respect to three different components of vulnerability: exposure which scores species by their likely exposure to HPAI, sensitivity which uses previously published data to identify the species most likely to suffer mortality following exposure and consequence which assesses the likely population impact of any large-scale mortality as follows:

i) Exposure
The following 12 species traits were used to assess variation between species in terms of likelihood of exposure to HPAI in either wild birds or domestic flocks: Migratory status, Likelihood of making cold weather movements, Gregariousness (separating breeding and migration/winter periods), Degree of

mixing with other species (separating breeding and migration/winter periods), Predatory behaviour, Scavenging behaviour, Occurrence on farmland, Occurrence on wetlands, Contact risk with humans and Contact risk with poultry.

ii) Sensitivity
Two factors were used to score i) the likelihood of a species becoming infected/infectious if exposed to the virus, or the prevalence of low pathogenic avian influenza (LPAI) or HPAI among the species group from published active surveillance data and ii) the severity of infection and likelihood of rapid mortality occurring among infected individuals.

iii) Consequence
The potential population level impact of significant mortality occurring for the species was assessed using the following eight traits: UK breeding population size, UK wintering population size, UK breeding distribution, UK wintering distribution, UK conservation status, Europe conservation status, Global conservation status and Breeding strategy.

Two methods were used to convert the traits into vulnerability assessment. The first was the product of exposure, sensitivity and consequence:

Vulnerability Index = i) Exposure x ii) Sensitivity x iii) Consequence

The advantage of a multiplicative index is that the highest vulnerability scores emphasise large values for each of the three criteria, although the strength of associations with each of the individual criteria were examined to test if this was appropriate. The second used the relative rank within each component of vulnerability to identify the most vulnerable species (see Foden *et al.* 2013). The number of reported positive samples in the British surveillance data from the testing carried out on dead birds (APHA 2022) were used to assess whether the vulnerability assessment has any predictive value, recognising that those dead bird data also have biases associated with them due to detectability and the variable overlap of different species with people.

An initial draft of the BTO vulnerability assessment was circulated to participants at the end of October, in advance of the 2nd November 2022 workshop. A summary of the approaches used were presented at that workshop [available online] to inform discussion, at which the following questions were posed, to guide BTO's revision and update of this assessment.

- What makes a good vulnerability assessment?
- Are the methods used appropriate?
- How should an assessment be validated?
- What is the importance of different criteria used for assessing vulnerability?
- Should new traits be considered?

The first three questions were considered separately by individual groups, and then each group separately reviewed the criteria used to assess vulnerability. A virtual whiteboard was used to capture brief responses, and note takers to summarise the concurrent discussions. Further responses and suggestions were encouraged after the workshop by email. Below, we synthesise the responses to these questions, in order to summarise the key recommendations to produce a revised draft of the vulnerability assessment.

5.2. What makes a good vulnerability assessment and how will it be used?

A good vulnerability assessment was regarded as one that informs conservation management decisions (seven responses), with the need for assessments to be consistent or objective emphasised by some, particularly across the UK. It is also needed to prioritise monitoring (four responses) and research (four responses), and to guide the assessment of risk associated with particular activities (three responses). Some recognised the potential horizon-scanning nature of the assessment to identify species not yet showing signs of mortality (one response), although others were sceptical about this value depending on the likely robustness of the methods used (see below). The potential benefit of using the outputs for communication to the public was also regarded as useful (two responses).

A good vulnerability assessment must be evidence-based with a robust methodology and scoring procedure (four responses), but sufficiently generalisable that it can be widely applied to all species (two responses). There was considerable discussion about uncertainty which should be reflected in the assessment (three responses), recognising that there is a lot that we don't know about the impact of HPAI on wild birds. In discussion, some felt that this limited the likely value of the vulnerability assessment (for example given the potential for the nature of the virus to change through time) and that simply tracking changes in mortality was most useful – although others recognised that we don't currently have a good approach to do this, and that there are considerable detection biases in those mortality data. Others identified particular traits or criteria that are likely to be important including gregariousness, the ability in species to survive infection, the ability of species to be buffered against large-scale mortality and the percentage of the global population in the UK.

There was agreement that it was useful to compare the performance of different assessments (three responses), although recognising that changes in the virus could alter the results of the assessment. Some expressed concerns that some species known to have suffered high mortality in 2022 were not highlighted by the assessment (e.g. some of the terns), although that partly reflects the draft nature of the current assessment.

The need for an assessment to be dynamic, repeatable and able to be updated as new information becomes available was repeatedly emphasised (11 responses). Outputs should be easy to understand by non-scientists (two responses) but yet provide an indication of why particular species do appear to be vulnerable or not (one response). Finally, one attendee identified the need to be clear what is meant by 'vulnerability', suggesting that the goal is to estimate the likelihood and extent of population-level impacts of HPAI on various species of wild birds in UK.

5.3. Are the methods used appropriate?

There was considerable discussion about the value of the methods used to provide a logical framework to assess vulnerability based on species' traits (five responses), compared to some uncertainty about how useful the assessment will be compared to responding to observed positive findings (two responses).

A range of potential improvements were suggested including assessing vulnerability seasonally (two responses) and between populations of the same species (two responses). The apparent differential effect of the virus on sites of the same species during 2022 was noted, adding to the uncertainty which if understood could be used to apply different risk scores to different sites (two responses) although another felt that mapping the distribution of vulnerable species would be useful to identify where interventions should be prioritised. The uncertainty associated with particular traits, particularly with the traits that contribute to sensitivity, was recognised in five responses, and there was felt to be a degree of repeatability in some of the traits (two responses).

There was some uncertainty regarding the validity of simply multiplying the components of vulnerability (two responses), either because it would fail to identify the important components or because it would not enable interactions to be considered. Two identified the approach of Certain *et al*. (2015) as one to consider, which was followed-up after the workshop.

5.4. How should an assessment be validated?

The use of validation was welcomed and regarded as important (four responses), with some suggestions made about how this could be done. Recognising that there is considerable uncertainty, the potential to use improved understanding of the virus to identify the key factors influencing vulnerability was highlighted once the impacts in 2022 have been better documented (one response).

The known biases in the APHA mortality data were discussed around reporter bias in detection and distribution (two responses) and the importance of population size (one response) – which are recognised in the draft vulnerability assessment. Moving forward, the need to capture data on observer effort was highlighted in order to understand these biases (two responses), whilst the use of these data in the vulnerability framework would ideally control for these reporting biases (e.g. using body size). Underlying this is the uncertainty over the true sensitivity of species to the virus, and the need for more work on the virus such as genome sequencing (one response), serological evidence to identify the frequency of birds that have been exposed to the virus but survived (five responses) and systematic testing of corpses (one response). It was recognised that improved population monitoring through time will also help identify the species that have been most impacted and therefore which have been most vulnerable (four responses), whether using remote sensing or site visits – for example repeating the recent Seabirds Count surveys to assess change. The potential for using other sources of mortality data, such as from BirdTrack was highlighted by two respondents and is a capability that has been subsequently developed after the workshop.

5.5. Comments on suggested traits

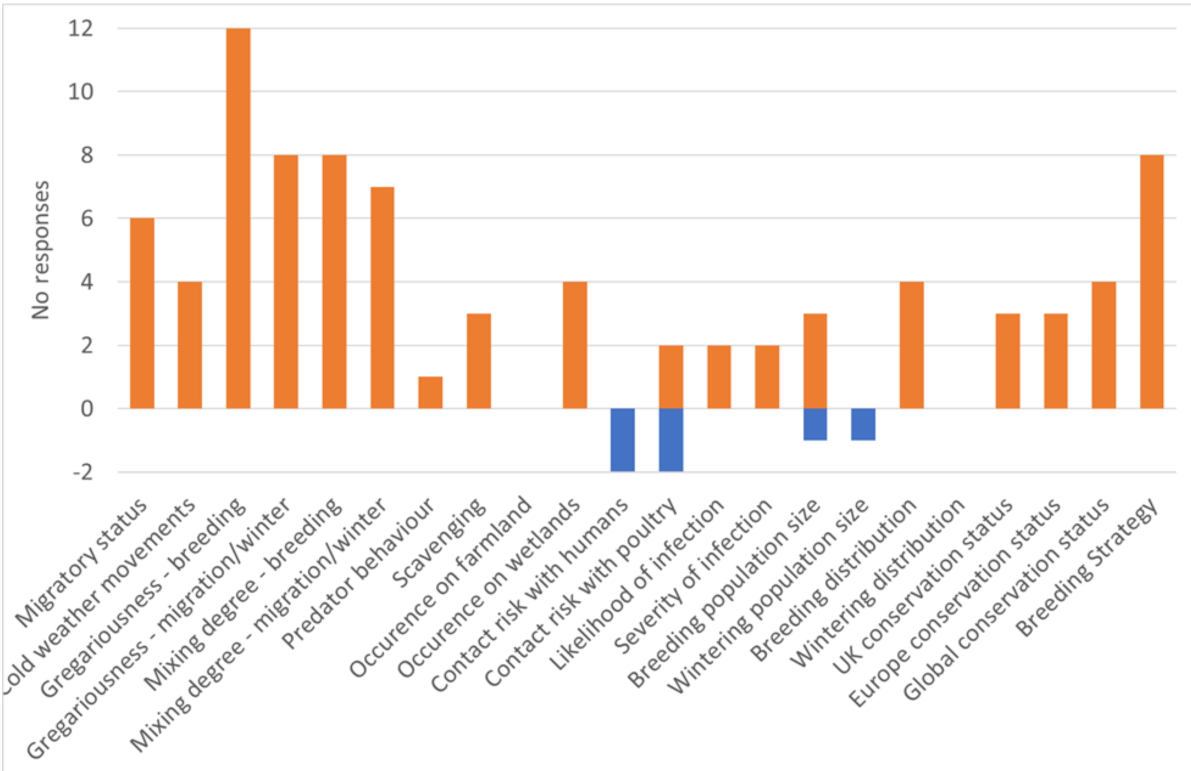
We asked attendees to identify the traits they would regard as i) unimportant or ii) important. The uncertainty associated with the traits was again highlighted, recognising that this is difficult to avoid (three responses) – hence the need for the workshop. In response, it was suggested that including an assessment of the strength of evidence associated with different traits or scores could be useful. Picking-up on earlier discussion about the need to understand the pathways by which birds are exposed to the virus, it was noted that as understanding improves, that will help improve future iterations of the assessment. The potential to disaggregate the components of particular indices to understand why species are regarded as vulnerable or not was re-iterated as being important. There were a few responses that some of the traits were too broad (three responses), whilst others noted the uncertainty that makes it more difficult to be confident about specifics.

Traits were scored based on the number of times they were listed on the virtual whiteboard as being unimportant or important, or based on suggested traits that were similar to existing traits. The traits which were regarded as most important were those associated with individuals being in close proximity, either within species or between species. There was most scepticism about the importance of traits linked to contact risk with humans or poultry, although it is worth noting that the focus of this discussion was to identify traits that impacted the vulnerability of wild birds, not traits that might be important in limiting spread between wild birds and domestic poultry, and that therefore are likely to be important from a One Health perspective. Uncertainty about the mechanisms of interactions between wild bird and domestic poultry was highlighted, and further research on those interactions would be helpful to identify whether such traits may influence species' vulnerability to HPAI. Quite a few respondents also made suggestions about ways of identifying slow-maturing or breeding species (i.e. k-selected species) which might be least likely to recover from large-scale mortality, and potentially with some tweaks, is closely aligned with the breeding strategy trait.

A number of additional traits were suggested, but many of these were more specific elements of already existing traits, and therefore have been considered earlier, although that feedback will be useful in terms of considering individual species scores. However, the following additional traits should be considered, although for some of these there may be difficulties in assessing this for all species:

- Association with the marine environment
- Sensitivity to disturbance (four responses).

Figure 5.5. Number of responses that suggested particular traits were important to highlight (orange) or unlikely to be important (blue).



- Extent of viral shedding (three responses).
- Behaviour likely to increase spread (method of defecation, grooming behaviour) (two responses).
- Daily movements (three responses).

5.6. Conclusions

The workshop identified a range of potential reasons why a vulnerability assessment could be useful, particularly to inform conservation responses, prioritise monitoring and research needs, to inform assessments of risk associated with different activities and to aid communication about the disease. Key elements of a vulnerability assessment that were identified were that it should be evidence-based with a robust methodology, it should be repeatable and easily updated, and easy to communicate. The ability to identify which components contributed to particular scores of vulnerability was also regarded as important.

There was considerable discussion about the methods used and how the significant uncertainty currently associated with predicting the impact of HPAI on wild birds should be incorporated. As more information about the virus and its epidemiology becomes available, that should help inform future iterations of the assessment. The approach of Certain *et al.* (2015) was recommended as one that should be considered.

The validation of a vulnerability assessment was welcomed, but with considerable discussion about the challenges of doing so using the APHA mortality data. The ability to undertake this validation could be improved as more evidence becomes available about the impact of the virus on populations.

Traits associated with the proximity of individuals and how they may interact to pass on the virus were generally regarded as most important, whilst an ability to also identify the species where large-scale impacts would be most damaging for their conservation status, either linked to their conservation status and / or population dynamics to identify slow-breeding k-selected species, was also highlighted.

The next steps will be for the BTO to consider this feedback and produce a revised version of the vulnerability analysis. Traits within the existing scoring system could be weighted based on comments received at the workshop and the scores assessed by external experts. The use of the Certain *et al.* (2015) approach should also be considered, along with the potential for incorporating measures of uncertainty around various traits. Until this additional work is undertaken, the provisional analysis presented here may still have some utility for assessing the likely broad vulnerability differences between groups and to help guide surveillance prioritisation. However, predicting vulnerability at a species or site level based on these results would not be advised until the more detailed work is carried out. This is in line with other work relating to HPAI which may include 'living documents' and be updated periodically based on new information.

We would also recommend that information from surveillance testing or mortality reporting are included in determining the sensitivity of species as these represent the most current information, even if with a high degree of uncertainty, and the vulnerability scores are ultimately validated against changes in national population monitoring programmes, accepting there may be a lag of one or more years before those data are available.

In addition, during the discussion a number of key knowledge gaps were identified as follows:

- An understanding of seabirds behaviour and ecology throughout their annual cycle and particularly outside of the breeding season when birds may be particularly pelagic (two responses).
- Understanding the dynamics associated with non-breeding/immature birds – again particularly for seabirds but also relevant for raptors and other long-lived species with significant non-breeding populations. We do not know enough about the movements of these individuals and how they could spread the virus.
- Understanding the pathways by which different species are exposed to the virus at different stages, which could be important to inform both vulnerability and also consideration of intervention points to reduce the risk of that spread.
- Our knowledge of the impacts of the virus on birds, the extent to which birds can spread the virus before falling ill, variation in susceptibility with age, the ability of birds to recover and the duration of any resulting immunity is really lacking and would dramatically improve our ability to assess the vulnerability of different species groups (five responses).

- The need for a full assessment of the impacts of the virus on populations, which will require the prioritisation of resurvey and monitoring needs, as covered elsewhere in the workshop.

6. SHORT TERM RESPONSES TO HPAI TO REDUCE THE IMPACT OF AN ACTIVE OUTBREAK ON WILD BIRD POPULATIONS

6.1. Introduction

The unprecedented spread of highly pathogenic avian influenza (HPAI) caused large-scale mortality in some seabirds and other species in 2022. This led to a range of responses from conservation organisations and government bodies, including restrictions on access to affected sites and carcass removal. Ongoing discussions highlight uncertainty about the potential effectiveness of these different interventions, which needs to be resolved in order to inform future decision-making. In an attempt to address that uncertainty and make the most of the information and knowledge that exists, we designed a questionnaire to be circulated to experts in order to summarise the current state of knowledge regarding the potential effectiveness of a range of potential management interventions to reduce the frequency of highly pathogenic avian influenza outbreaks in wild bird populations across the UK.

The questionnaire was based upon a structured approach for eliciting expert judgement to allow us to be as informed as possible when making decisions about which interventions to prioritise in the immediate future. We identified 22 conservation management interventions through expert discussions and prior to the workshop, circulated a questionnaire to ask participants to estimate the potential effectiveness of interventions in reducing the impact of HPAI on different species groups of wild birds. Following best-practice with this approach (e.g. Hemming *et al.* 2018), this was done twice: the first in the week prior to workshop session two on 10 November at which the submitted scores will be discussed in order to learn from each other about the interventions and supporting evidence. The second round of scoring will be after the workshop, allowing participants to reflect on the workshop discussion, and is ongoing at the time of writing.

The HPAI management interventions expert elicitation used followed the IDEA protocol set out by Hemming *et al.* (2018; Figure 6.1.), because previous studies have demonstrated that feedback and discussion followed by the opportunity to rescore original estimates can improve individual judgments by resolving ambiguous language, and introducing new evidence (Burgman *et al.* 2011, Hanea *et al.* 2017). This approach involved a diverse group of participants (Step 1; those registered to attend the workshop), estimating the likely effectiveness of the different interventions (Step 2). These estimates were then aggregated (Step 3) and fed-back to workshop participants who discussed the findings and their scores along with other participants (Step 4) during the breakout sessions in session 2 of the JNCC and BTO HPAI workshop on the 10th of November. Attendees were only able to attend one of the three breakout sessions, and therefore to have only discussed around a third of the interventions. Although the main elements of discussion for each break-out group were summarised in plenary for all participants, notes were also taken during each session. These were collated and circulated to participants before they were invited to rescore (Step 5). At the same time, we invited workshop participants who had not originally scored the interventions to also do so.

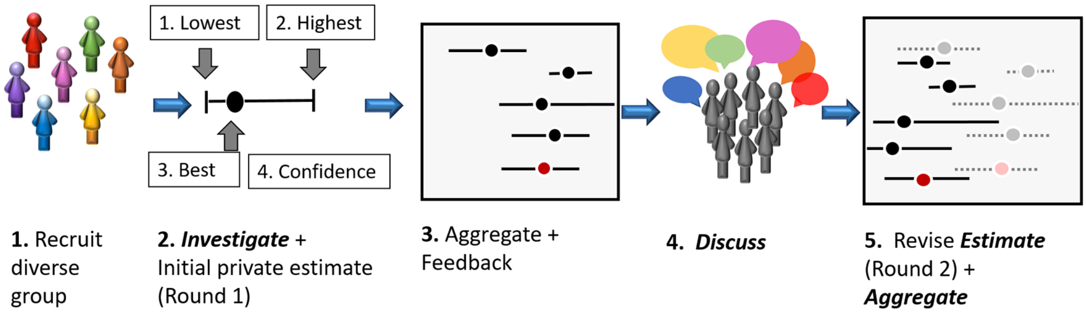
In the questionnaire, attendees were asked firstly to assess their expertise, before assessing in a situation where HPAI is circulating widely amongst wild birds in the country, what would be the best estimate of the percentage of breeding seabird colonies/wintering wildfowl and wader sites/raptor populations where mortalities (5+ individuals) would occur in the absence of intervention. Participants were also asked to estimate the lowest and highest plausible value and what they thought would be the chance that the truth is within the bounds of their estimate (between 50–100%). In combination, this allows bounds of uncertainty to be put around each estimate.

6.2. Discussion

What follows is the collation of discussion points from each of the three breakout sessions with focus on points made about observations and evidence for the effectiveness of particular management interventions, listed by intervention or cluster of related interventions. A number of key general points were also made that are highlighted first.

General comments. Context is important. The more widespread a viral outbreak is, the less important restrictions are to limit human spread. We don't have a good understanding of the pathways of infection and risk factors associated with transmission for different species. Experiments suggest the virus is

Figure 6.1. Key steps of the IDEA protocol from Hemming *et al.* 2018



transmitted by direct contact, through water and ingestion of contaminated meat, but what is puzzling is why patterns of mortality can be very different between years, even at the same site. Many at the workshop flagged i) the difficulties of estimating levels of mortality associated with the broad species categories, ii) the high uncertainty associated with the likely effectiveness of interventions and iii) the fact that the effectiveness of interventions could be site and species specific. In response to the latter point, it might be useful to develop a decision-tree to inform local decision making.

Cessation of bird surveys (intervention 1). We recognise the difference between infection that is restricted to one species and one that affects many. This disease affects migratory and resident species. The impact of human disturbance, for example caused by bird surveys, was suggested to be small, as disturbance from other factors, with an example of planes flushing Great Skuas on Fair Isle twice a day, is likely to be much worse.

Suspension of ringing (intervention 2) may cause more harm than good, as we are still trying to understand the population level impacts of HPAI, and ringing could be beneficial to such efforts. Others agreed that it is unlikely that ringing carried out in a sensible manner would be very unlikely to increase the risk of introducing infection or spreading infection to further colonies. Cleanliness during handling is important to minimise spread between individual birds. Passerines can be susceptible to the virus if they come into contact, but are less likely to be exposed than waterbirds.

Suspension of ringing and research activities (interventions 2 and 3) such as GPS tagging, it was suggested that additional stress caused to birds by these activities could have an additive or synergistic effect on transmission or the way in which the virus might affect these birds. As stress is immunosuppressive at an individual level and also birds are more likely to defecate when handled, then it was thought that might have an impact on outcome for individuals, but that this was unlikely to be important at population level given the relatively small number of individuals involved and the ability of the virus to spread. The importance of collecting demographic data (e.g. resightings of colour rings and nest monitoring) was thought to be extremely important and that it should be collected if possible during an outbreak, particularly as a failure to mark or resight individuals in a year can negatively impact the ability to monitor survival rates over multiple years through mark-recapture techniques.

It was generally agreed that cleanliness and biosecurity protocols, like using different bird bags, (interventions 6, 7 and 8), would be important for bird handling going forward . However, care must be taken as disinfectant might affect waterproofing of bird feathers. We need to think about the effects of chemicals used as these could have a negative effect on birds. Biosecurity is likely to be put in place for future ringing and research activities at seabird colonies as a precautionary measure. This should be applied for all sorts of reasons but given that the virus still infects commercial poultry units with apparently good biosecurity, the likely impact on the spread of HPAI in wild birds would be likely to be minimal. In recent outbreaks in South Africa boots and gloves were required when handling sick birds, along with disinfectant.

Interventions related to suspending (intervention 5) or reducing (intervention 9) public access to vulnerable sites. The effectiveness of these would depend on whether there are biosecurity measures also in place and the extent of measures to control visitor access at sites. Disturbance from access may also depend on the species/nest density as more open colonies where access can go through the middle may potentially disperse birds into new areas. This will also be affected by factors like accessibility (e.g. ground nesting vs. cliff nesting).

Closure of the countryside (intervention 10), inspired by the approach taken during foot-and-mouth disease (FMD) outbreaks in the UK during 2001, noting that FMD is very different in its transmission characteristics. People thought this was a drastic intervention for HPAI that would cause significant public issues and that the cost probably wasn't worth the benefit. The group were urged to think of the potential effectiveness instead of practicality, and agreed that it could help reduce risk of transmission between sites.

Strict disinfectant and biosecurity protocols in place for all visitors (intervention 11). There is limited evidence for this intervention in how it may reduce transmission between sites, which is the focus of this questionnaire. Need to consider both the risk of introducing the virus to the colony and the risk of spreading it through a colony. At Coquet Island disinfectant was applied prior to the major mortalities and staff avoided areas where mortalities were occurring. However 55% of the colony was still lost, although stopping access may have reduced this?

A potential ban on shooting/wildfowling across the countryside (intervention 20) and at vulnerable sites (intervention 21). It was suggested that if shooting drives untypical behaviour such as causing birds to disperse to areas not usually used by the local population, it could promote the spread of HPAI to other sites. PhD research at Bournemouth University has apparently indicated that shooting caused very little disturbance or change in behaviour. It was noted that it was hard to answer the question as framed because shooting of wildfowl is very different to gamebird shooting. There is also a need to consider the natural context of what the birds are already doing with regard to seasonality and associated movements, distributions and abundances. Wildfowlers can assist with the monitoring of HPAI.

Ban on gamebird release (Intervention 22). It was argued that clusters of HPAI in seabirds occurred in early spring at a time when gamebirds are not being released or shot and their populations are at their lowest, although the autumn can also provide an increase in cases. Spread in the Netherlands gives examples of interactions between prey and predators in absence of gamebird releases. It was suggested that any inference here would need to be evidence-led, given that it is a sensitive issue. For the purposes of this discussion, gamebirds were defined as including Galliformes – primarily Pheasant and Red-legged Partridge, but the discussion also considered the release of Anseriformes – primarily Mallard.

Interventions (12, 13, 14) regarding removal of dead carcasses. In terms of possible interventions, the removal of dead birds from colonies has probably received the most attention and potential support. The biggest challenge in deciding whether the removal of carcasses is an important measure, in reducing the impact of a HPAI outbreak at a colony, is the lack of peer reviewed evidence in this area. Whilst this could reflect the fact that wide scale outbreaks in the UK only occurred in 2022, there is limited scope to generate experimental data and hence there can never be a counterfactual measure. However, if such removals are undertaken in future, attempting to monitor the impact of this would be valuable given the current uncertainty.

Across the group, however, there was general consensus that the likely effectiveness of carcass removal at colonies will be determined by a combination of the following factors: i) species affected (and their breeding behaviour/ecology); ii) presence of waterbodies where birds aggregate; iii) the type of breeding sites (e.g. ground, cliffs), and; iv) the likelihood of scavenging behaviour (by seabirds and other bird species as well as mammals). However it was also highlighted that accessing colonies should not exacerbate an ongoing HPAI outbreak, with concerns raised about disturbance increasing likelihood of transmission and the need to ensure that sufficient biosecurity measures were in place. Another issue which needs further investigation is whether early intervention with respect to removing carcasses will help reduce the scale of the outbreak – hence a more highly reactive approach could be advocated. It was also noted that it may not always be possible to achieve 100% removal at a site. One potential option discussed was the development of guidance or a decision tree aimed specifically at site/reserve managers, to help decide when the removal of carcasses was likely to be a benefit.

Interventions 15 and 16 both considered changing wild bird feeding. Supplementary feeding is a relatively common activity in the wider landscape and arises for a number of reasons including: i) putting out food in gardens or in public spaces where waterfowl aggregate for personal enjoyment; ii) as an activity related to a species conservation plan (e.g. turtle dove; iii) baiting for wildfowlers; or iv) for public engagement events (e.g. showing Red Kites). Concerns around supplementary feeding were raised as they result in artificially high numbers of birds at very localised sites which is likely to increase the risk of transmission, although some of the negative effects may be minimised by appropriate bird feeding hygiene measures. It is also important to understand the impacts of ceasing supplementary feeding, especially in the case of reason number ii above.

The use of diversionary feeding (intervention 17) to manipulate behaviour/restrict movements of scavenging birds. Whilst diversionary feeding could be considered as a means of moving birds away from certain sites, there are likely to be significant risks of aggregating birds (see above). Therefore when deciding upon when to continue supplementary feeding, or to use diversionary feeding, should be considered on a case by case basis.

Interventions concerning vaccination of birds, either of gamebirds prior to release (Intervention 18) or vaccination of wild birds (Intervention 19). There was little evidence to provide here as this intervention has not been tried yet. There could be scope for a two-phase approach on vaccination: gamebirds initially, using the opportunity to collect key data and information which could then be peer reviewed and then used to design a programme on how to vaccinate wild birds. The former was recognised as potentially falling under the jurisdiction of animal health agencies however.

The vaccination of poultry and captive birds excluding those in licensed zoos against avian influenza is not currently permitted. Vaccination is not a routine control measure and is a practice restricted by legislation. While authorised avian influenza vaccines are available in the UK, these vaccines are unlikely to provide full protection for the current strains of HPAI circulating in the UK and Continental Europe, or cross-protection to other strains which may circulate in the future. At present, vaccination can help to reduce mortality, but it is likely that some vaccinated birds would still be capable of transmitting avian influenza if they became infected. This would increase the time taken to detect and eradicate the virus and many trading partners will not accept the use of vaccination in commercial birds. For these reasons vaccination is not permitted in the UK outside of zoo animals in England.

6.3. Conclusions

The most supported intervention in the initial scoring was carcass removal, followed by measures associated with changes in wild bird feeding and reducing disturbance. The possibility of carcass removal increasing disease spread as a result of disturbance at colonies was noted. This may mean that it is likely to be beneficial in some cases but maybe not all, and therefore should be adopted with regard to site-specific circumstances and risks. Participants generally noted a high degree of uncertainty in relation to the likely efficacy of all interventions, given the limited evidence-base on which to make judgements. Given the value of the data provided, the cessation of research (surveys, ringing) was thought to be counter- productive. These recommendations are supported by the following management recommendations from Thijs Kuiken's presentation at the workshop (available online), citing Bekedan *et al.* (2021) and Kuiken & Cromie (2022):

- Avoid activities that disturb affected wild bird populations to reduce the risk of spread.
- Coordinated removal of infected bird carcasses from affected sites where appropriate.
- Enhanced protection of seabird and waterbird sites.

In addition to the need to improve surveillance in wild birds and potentially exposed wild mammals, record wild bird mortality data and collect appropriate samples for virological analysis. Experience in South Africa, as described at the workshop by Laura Roberts, also highlighted the removal of sick and dead birds from colonies, the former then being euthanised. Data collection was maintained in South Africa, as this was regarded as providing important evidence, but with appropriate biosecurity measures and controls.

7. RESEARCH AND CONSERVATION REQUIREMENTS

This session dealt with evidence needs and recommendations for future research to fill gaps in knowledge. What evidence is needed in order to understand how HPAI impacts wild bird populations, develop approaches to mitigating impacts in the short term and help the long term recovery of species. Participants were allowed to join any of three breakout groups and to move between them. These comprised discussions about seabirds, waterbirds and raptors and other species.

7.1. Seabirds

7.1.1. Understanding the spread of HPAI in wild bird populations

7.1.1.1 Bird movement data based on biotelemetry studies, ringing projects and at-sea distribution data (boat/aerial).

How is the virus being transported as a consequence of 'normal' bird movements?

This could be addressed by looking at the following areas and will vary according to species, sex and age class:

- Spatial use at and around colonies of birds during the breeding season (e.g. foraging and maintenance areas).
- Movements of immature/non-breeding birds between colonies when prospecting for nest sites.
- Non-breeding season movements of birds (migration routes/wintering areas). For gulls and other scavenging species there is particular value in GPS tracking to understand their movements and interactions in and around domestic poultry settings. Doing this in combination with serological testing (see below) could be particularly valuable.

Are there changes in individual bird movements as a consequence of being infected with HPAI? This is with respect to the following aspects:

- Spatial use at and around colonies during the breeding season. This is likely to be based on a limited number of cases where HPAI status was unknown at the point of deployment e.g study on Lesser Scaup (Prosser *et al*. 2022). There are likely to be licensing restrictions for deployment of birds known to be infected, and infected birds are more likely to die.
- Non-breeding season movements (migration routes/wintering areas). Most relevant for birds that have survived infection as sick birds unlikely to live more than a week.
- Are there changes in individual bird movements as a consequence of widespread breeding failure at colonies due to HPAI.
- Spatial use at and around colonies of individual birds during the breeding season – are non-infected and asymptomatic birds more likely to move around and interact with birds of other colonies e.g as cited for Gannet anecdotally?

Are there changes in individual bird movements as a consequence of disturbance and hunting activities and what does this mean with respect to risk of transmission?

7.1.1.2. Virology – data collection

Viruses can be shed from infected individuals via a range of routes including faeces, nasal secretions, respiration, carcasses eaten by scavengers and released passively from corpses into the air, soil and water bodies. Of these options, which result in the highest virus loads being shed or allow the virus to survive for longer and therefore is the most likely to result in the infection of others?

How does persistence of the virus vary in the wider environment:

- Testing of water bodies and soil plus other substrates around breeding sites .
- Experimental testing of carcasses left in situ compared to removal. How does this increase virus amounts? This will inform need for biosecurity measures and relevance of carcass clean up.
- Testing relative importance of salt, ultraviolet light, relative rainfall and wind (acting as a desiccant) in reducing amount/determining persistence of virus. What studies are already out there (e.g. penguins in South Africa) and what aspects would be a priority for future research?

There are a number of likely outcomes following a bird being infected with HPAI which are as follows; a) shows symptoms and subsequently dies, b) shows symptoms but survives, c) asymptomatic but dies, and d) asymptomatic but survives. In terms of understanding transmission of the virus need to have the following wider surveillance measures:

- Serological testing for antibodies in wild birds to check if they have been exposed to HPAI or other viruses or not – to what extent can we use ringing networks and volunteer ringers to collect these data?
- General screening for the presence of HPAI and other viruses/diseases through swabs of live birds (trachea or oropharynx and cloaca) and faeces. This will also reduce in biases in detection of HPAI. Species such as passerines which are smaller and tend to die away from public view and not meeting APHA testing/triage criteria are likely less well represented in current testing criteria.
- Use of rapid HPAI detection kits on dead birds and faecal samples in the field (i.e. lateral flow tests). This could allow rapid/early detection AND rapid implementation of interventions.
- Of the birds infected, how many are likely to recover and how long does immunity last for – implications for future outbreaks at a colony level?
- Opportunistic studies of birds in captivity that are infected.

7.1.1.3. Epidemiological modelling

How does the virus move around within colonies and does this match observed patterns of infection and mortality?

- Characterisation of colonies to identify which features might predict the response of birds to HPAI outbreak at colonies e.g. colony characteristics (e.g. cliff vs flat sites), nesting density, environmental factors, proximity to standing water bodies, species affected etc.
- Data on Susceptible, Infectious, and or Recovered (SIR) is needed.
- How does the virus move between colonies/sites/species based on bird movement patterns over their annual/daily cycle. Tracking studies will be required.
- Collection of serological samples to determine the different strains/clades of HPAI present in sites to allow the tracking of the virus in time and space as well as the characterisation of the evolution of the virus itself.
- What is the likelihood that HPAI will evolve to be more or less pathogenic for wild birds?

7.1.2. Assessing vulnerability of species

What features make species more susceptible to being infected, or more sensitive to exposure?

- Behaviour with respect to the likelihood of being in close proximity to conspecifics and other species, e.g. tendancy to aggregate in breeding colonies, or through flocking at maintenance or wintering sites.
- Foraging, and non-breeding season movements.
- Relative amount exposure to faecal matter e.g. colonies where guano can build up.
- Association with standing water or damp environments.
- Likelihood of scavenging infected carcasses.
- How do uninfected/healthy birds respond to infected birds showing symptoms e.g tendency to attack sick birds, or for necrophilia to occur (the latter cited for terns and penguins)?
- What features make species more likely to develop immunity?
- Collation of data on body condition, physiology or immunocompetence – can this vary within and between individuals, by species, age class, sex or stage in the annual cycle?
- Previous exposure to other viruses – leading to higher immunity e.g is there evidence that this is true in larger gulls?

7.1.3. Predicting bird population impacts

7.1.3.1. Bird monitoring data - assessing the demographic impact on bird populations

There is an urgent need to update abundance counts for species and sites for which HPAI mortality has been reported or thought to have occurred. It may also be necessary to revise country/UK level population estimates where necessary since data from Seabirds Count, the most recent national census, might now be out of date. Priority should ideally be given to combinations of species and sites for where there are reasonable baseline data available. Also for 'mobile' species such as terns, a more international-based approach to coverage might be needed. Consideration over how to fund extra surveys and the co-ordination of extra effort will be critical.

- Colony based counts of breeding adult birds e.g. as coordinated by SMP.
- Wintering roosts (e.g. Winter Gull Roost Survey, WinGS).
- At sea distribution and abundance – boat and aerial surveys.
- Colony-based counts of non-breeding adult birds (e.g 'floaters' that could breed if space became available, indicative of how well breeding populations might recover).

Collation of mortality data is now possible through a range of surveys or apps (see list below). Overarching guidance could be developed on which of the range of options would be best suited to a particular site/species would be useful, along with better guidance on species identification and age class reporting. The scope for mortality data to be used in population modelling is likely to be limited, however, since the data are likely to be an underestimate but mortality data can identify the range of species and geographical scale of impact.

- Bird Track (BTO bespoke app, more detail captured under comments).
- WeBS (BTO online reporting using comments).
- Epicollect (bespoke app but mainly limited to CNCB and NGO wardens).
- Ringing data (recovery of ringed dead birds, which can also identify colony of origin).
- Beached Bird Surveys.
- BTO's Garden BirdWatch (under existing wider disease monitoring and Garden Wildlife Health).
- Counts of dead birds at sea – although there are likely to be major challenges with species identification, it may pick up birds that die away from the natal/breeding colony and could be incorporated into estimates of mortality e.g. has been done for Gannets in the German sector of the North Sea.

7.1.3.2. What impact has HPAI had on breeding success in the northern summer of 2022, and what impacts might be observed in future years?

Gannet breeding productivity tends to be characterised by reasonably stable productivity between years. However, productivity was shown to be reduced in 2022 at a number of sites, and is likely to be due to mortality of breeding adults – the extent to which chicks died from HPAI is unknown. In Alderney, adoption of chicks whose parents had died/abandoned them was observed but apparently healthy chicks also died suggesting that HPAI was the cause:

- Sub-lethal effects on productivity of parents that survive e.g. lower provisioning, poorer body condition for future years?
- Will there be density-dependent changes in breeding success as a consequence of lower breeding population?
- Will there be changes in breeding success due to less experienced, younger birds taking up vacant breeding sites for the first time in their lives?

7.1.3.3. Improved estimates of survival and dispersal rates

- General augmentation of colour ringing and resighting effort to improve estimates of adult survival and dispersal rates. This is essential in studies where most birds are ringed as chicks, as adult survival cannot be calculated with any confidence without an independent estimate of adult reporting rates (Warwick-Evans *et al.* 2016).

7.1.3.4. Population modelling

HPAI has highlighted the need for a different strategic approach as to how we monitor seabirds in the future. At heavily impacted colonies, participants supported the implementation of studies focusing on foraging behaviour and estimating demographic rates and population abundance but it was recognised that only a few species and colonies will have the data from recent previous years to be able to estimate all of these, or to compare with previous years. This will highlight any density-dependent effects in these metrics due to a reduction in the breeding population. Concurrently, it is essential that the regular (ideally annual) collection of SMP abundance and productivity data continues and is enhanced by the addition of new sites and regular monitoring of sites that have been regularly monitored in the past. SMP ideally needs to take a stratified, regional approach to data collection to ensure a wide representation of species and regions in the UK. Due to the non-random location of colonies and logistical difficulties, it is not going to be possible to take a fully random stratified approach to sampling as in the Breeding Bird Survey, but a review of what data is being collected where would be a useful way of identifying gaps in species and site coverage so that SMP can be used as a more robust regular surveillance tool.

- Review the data in the SMP database to identify species and sites where (i) abundance monitoring, (ii) productivity data, (iii) estimation of adult survival data and (iv) other research initiatives such as looking at foraging areas are regularly (e.g. annually, or for a period of years in the past) carried out. This is likely to be a relatively small number of sites and will identify gaps in coverage and will allow a more strategic approach to developing the SMP to become a more robust surveillance tool.

- Linked to the point above, population modelling to be underpinned by better 'regional' or colony level estimates of demographic rates using long-term studies with particular focus on changes in survival rates, incorporating stochasticity, e.g. two studies estimating Gannet survival and the additional mortality caused by wind farms, based on c. 30 years of ringing data (Warwick-Evans *et al*. 2016, 2018).

- Need for meta population approaches to data collection and modelling. Some seabird species (e.g. terns) may move to a greater or lesser extent between colonies to breed, which may result in buffering of impacts on seabird populations at individual colonies (source/sink dynamics).

- The prospecting and subsequent settlement patterns of immatures will be an important part of the mortality/productivity and immigration/emigration equation and is poorly understood. Tracking studies of immature birds would allow this to be estimated.

- Gaps in time series due to HPAI-related access restrictions to colonies will have an impact on long-term monitoring programs. Background mortality monitoring based on metal ring recoveries of dead birds are unlikely to be affected but colony specific estimates of productivity and adult survival through colour-ring resighting will mean that some of the key questions about the impacts of HPAI populations will not be able to be answered. Access restrictions that prevent monitoring will have a large impact on our understanding of HPAI impacts.

- Participants noted that we did not need to reinvent the wheel. There are a number of other studies that have estimated the impact of disease on bird populations and monitored the subsequent recovery. A brief treatment of this should be included as part of follow-up from this workshop.

7.1.4. Impacts for renewable industry

During the assessment process for offshore wind farms, an assessment of the additional mortality that they would cause has to be undertaken in light of the likely population impact. With the potential loss of a large number of birds, there will be a loss of 'head room', which is the gap between how many birds are predicted to be killed by current wind farm projects & the number that can be killed before significant population level impacts are observed. As this will have an impact on future operation of wind farm companies, this creates the opportunity to have discussions with them about funding some of the resurveys and population modelling.

- Need for resurveys to generate new colony level population estimates

- Rerun PVA models including an metapopulation level approaches

7.1.5. Informing and assessing short-term interventions

There is a critical need for empirical evidence of the effectiveness of interventions and predicting likely outcomes in terms of reducing mortality, in particular around the use of carcass removal. Whilst an experimental approach may not be possible, in cases where interventions are used, a detailed account of what was carried out and measure of mortality should be recorded. This would form the basis of much needed guidance on how to deal with HPAI or other outbreaks of diseases at colonies.

7.1.5.1. Biosecurity

- Generic guidance as to biosecurity protocols should be developed and implemented country-wide as currently there are no clear guidelines. For example, information on the type of disinfectant, how it should be dispensed and how to get rid of waste products is needed. Any access to colonies and handling of birds must follow the appropriate biosecurity protocols.

- Cleaning/disinfecting artificial nest sites, as cited for terns – can this be extended to burrow entrances?

7.1.5.2. Carcass removal

There was a great deal of uncertainty regarding whether the removal of carcasses significantly reduces the background virus levels circulating in the environment and hence transmission risk? Are these risks elevated by scavenging activity by seabirds and other birds as well as mammals e.g. rats, Red Foxes and seals or even insects? There are notable concerns around the virus becoming more transmittable to humans from other mammals as opposed to avian species. There is a need for guidance of carcass removal on the following aspects:

- Minimising impacts of disturbance at a colony and risks around biosecurity.

- Can infected carcasses scavenged by mammals cause those scavenging to contract and potentially spread HPAI to other species (e.g. raptors and, in the case of small mammals, owls)?

- How to dispose of carcasses safely and legally.

- Use of PPE.

7.1.5.3. Vaccination

- Are there any existing vaccines that could be used immediately? Significant challenges around costs and administering-use of injections versus aerosols (would use of aerosol over large areas be an option?). For rare and susceptible species (e.g. Hen Harrier where chicks fitted with satellite trackers have subsequently died due to HPAI), an experimental trial of vaccination of chicks could be an option. It is important to note that vaccination of birds against avian influenza is currently illegal outside of licensed zoos who have received authorisation from APHA to vaccinate.

- The release of reared gamebirds into the environment is a contentious issue as many of these will be caught and eaten by raptors and dead individuals may be scavenged. Given the likely potential of this being a transmission pathway, should the release of unvaccinated reared game birds into the environment be prohibited?

7.1.5.4. Supplementary feeding

- There was uncertainty in terms of the role of supplementary or diversionary feeding on spreading HPAI between individuals of the same or different species and guidelines for this need to be developed.

7.1.5.5. Euthanasia

Euthanasia of infected birds may reduce the spread of HPAI but, again, there is a great deal of uncertainty associated with this. This may also not be ethical if some of the birds go on to recover. Euthanasia has been used in some other countries during outbreaks of HPAI. In helping make this decision it would be useful to collate a full list of symptoms shown by avian species – which ones are associated with imminent death (e.g. neurological)?

- Collation of species specific guidance on symptoms with supporting specific images/videos.

7.1.6. Informing and assessing long-term conservation measures

Collectively we need to think about how we facilitate our overall approach to disease outbreaks – as nature conservation is a devolved matter in the UK, there is a clear need for a high level UK level coordination group to ensure that data are collected in similar ways across the UK and responses are similar between agencies. This group could set out organisational responsibilities, communication pathways, messaging to the general public, shared resources and guidance, and a tool kit on interventions for site managers. Greater cooperation is also needed between individual devolved UK countries (e.g. CNCBS, NGOs, animal health agencies, veterinarians), in order to be more strategic and consistent with the guidance coming out of agencies with different roles.

There is also a strong case for greater coordination of effort across different sectors with respect to health organisations, and agencies with responsibility for food production.

- The lack of a One Health perspective (an approach that recognises that the health of people is closely connected to the health of animals and our shared environment) in tackling the disease is potentially short-sighted. For example, are the risks of HPAI infecting humans increased by the virus successfully transmitting to other mammal species e.g. seals, Red Foxes, Pine Martens, Otters?

There could also be a greater level of communication between organisations working within the conservation sector which should result in greater efficiency and a higher likelihood of successful implementation.

- How will HPAI interact with other pressure acting on seabirds and to what extent will they impede recovery of populations e.g. extreme weather, invasive mammals, climate change, contaminants, renewables, overfishing – is it possible to separate effects?

- Similar initiatives looking at the monitoring and conservation of seabirds are being discussed with the renewables sector and also country-level Seabird Conservation Strategies are being developed. Much of what is being recommended here in response to HPAI will be part of these other initiatives. These other initiatives need to consider what additional measures will be required in light of HPAI.

- Who has the responsibility for implementing any conservation measures associated with HPAI e.g. government, CNCBs?

- International cooperation will be beneficial in terms of sharing data (e.g. across flyways and biogeographic populations) and targeting effort for collecting monitoring data (e.g tern species which tend to be more mobile in terms of moving between breeding sites). One example would be the Joint OSPAR/HELCOM/ICES Working Group on Seabirds.

In terms of overall approach, could early detection be critical in managing outbreaks of HPAI and other avian diseases through:

- More general surveillance by sampling/screening live birds.

- Collation of images and videos resources being widely available on how species behave/look post infection?

- Use of rapid interventions at colonies.

7.2. Waterbirds

7.2.1. Understanding the spread of HPAI in wild bird populations

The main priority area for research identified by workshop breakout group participants to understand the spread of HPAI in waterbirds was the need to better understand the pathways of transmission, considering both the spatio-temporal movements of birds and also associated HPAI surveillance.

Participants highlighted the need to consider the associations between waterbird species (especially gulls), as well as interactions with other species groups, such as raptors, released gamebirds and wildfowl, and the poultry sector, and thus their potential role as vectors of HPAI. Given the range of different life strategies adopted by waterbird species, this would need to consider seasonal patterns, taking account of different species' migratory movements (Wernham *et al.* 2002), the interactions between migratory and resident species, and differential movements between populations (see https://wpe.wetlands.org/, https://www.unep-aewa.org/sites/default/files/uploads/aewa_agreement_text_2023-2025_mop8.pdf and the dispersal of juvenile birds. Current work by EURING and the BTO on behalf of the European Food Safety Authority (EFSA) has looked at the seasonal patterns of waterbird movements across Europe with the aim of predicting outbreaks within poultry (https://euring.org/research/migration-mapping). Expanding this work to consider outbreaks among wild bird populations would be of great value.

The need to better understand the distribution and movements of non-native or re-established species, especially geese – notably the most numerous species: Greylag Goose, Canada Goose, Barnacle Goose, Egyptian Goose – and their role in the persistence of HPAI in the environment across the year was also highlighted. GSMP focuses on monitoring of the UK's internationally important wild non-breeding goose and swan populations, and while WeBS considers non-native species, coverage of these is limited in the wider countryside away from wetland sites. The last national survey on the populations and distributions of introduced Canada Geese and re-established Greylag Geese was in 2000 (Austin *et al.* 2007, Rehfisch *et al.* 2002), results from which also informed understanding of habitat associations in wider countryside (Austin *et al.* 2002). An additional consideration noted was the need to better understand the numbers, distribution and seasonality in releases of Mallard for hunting (Madden 2021), and those birds' subsequent movements, and thus their potential role in the spread of HPAI in waterbirds.

Further related considerations highlighted included the importance of considering habitat associations in understanding interactions between species and thus the pathways of HPAI transmission, as well as the role of associated environmental conditions in the persistence of the virus. The value of ringing and tracking datasets in understanding seasonal movements and habitat associations and thus potential interactions between species groups was particularly noted.

Existing surveillance of HPAI in wild birds through APHA is primarily focused on the testing of dead birds, reported by the public and reserve wardens. Wider surveillance of HPAI in live birds would add value to this and should be considered. The value of wider collection of faecal and blood samples, aided by the existing volunteer ringing network, and of testing of harvested quarry species, for research and tracking of the spread of HPAI was also highlighted, although the use of volunteers in collecting samples needs to be carefully considered. In association with this, there was particular discussion on the value of RNA sequencing in tracking the prevalence of HPAI in wild birds, understanding the links between outbreaks and the species that might act as vectors.

7.2.2. Assessing the vulnerability of species

In assessing the vulnerability of waterbird species to HPAI, participants highlighted the need to consider species' ecological or behavioural traits, but also in association with this, variation between populations, age classes and individuals. Apparent differences in the vulnerability of different populations of geese to HPAI in the current outbreak were noted, for example. A key additional aspect, linked to understanding the spread of the HPAI among waterbirds, were the associations between migratory and resident species and populations, and use of habitat. Laboratory-based studies may be of value in assessing variation in species' vulnerability.

The possible variation in species' vulnerability through different outbreaks of HPAI was noted, and thus the need to understand the possible role of resistance generated by a history of infection with current or previous variants of HPAI. Surveillance and associated molecular diagnostic work would be of benefit in understanding both the spread of HPAI variants and thus potential resistance in wild bird populations.

In association with this, and the collection of data on mortality, the potential to collect field data on birds displaying possible clinical signs of HPAI infection was also discussed. It was noted, however, that as with the collection of data on mortality, it may not be clear that observed sick birds had been infected by HPAI, as other factors may cause similar clinical symptoms.

7.2.3. Predicting bird population impacts

In predicting the impacts of HPAI on waterbird populations, participants highlighted the needs for (i) improved background information on demographic rates (survival, productivity) (see: https://www.bto.org/understanding-birds/birdfacts, Méndez *et al*. 2020) and (ii) ongoing monitoring for improving data used in population modelling and validating predictions. Population modelling should also consider the variation in demographic rates spatially and between species' populations and consider stochasticity. Existing monitoring of waterbird demography is summarised in section 4.2.4, together with recommendations for improving this with respect to be able to assess and predict the effects of HPAI on populations. As noted there, there is a need to consider international initiatives, given the migratory flyways of many waterbird species. Recognising this, modelling work should also consider when and how HPAI might be affecting species across their annual cycles. For example, might the spread of HPAI in populations during the winter have carry-over effects on breeding success, either negatively due to impacts on individual fitness or, conversely, positively through density-dependence.

In assessing impacts, participants also highlighted again the need to understand pathways of transmission, and thus associations between migratory and resident species across the year, and interactions with other species' groups.

7.2.4. Informing and assessing short-term interventions

The primary short-term mitigation highlighted of potential value for waterbirds – and other species, such as raptors, that might prey upon them – and thus requiring further research, was carcass removal. Participants also noted the need for further understanding of the potential benefits of reducing public feeding of waterbirds on the spread of HPAI among waterbirds.

Experimental approaches would be valuable, for example, for understanding whether reduced public feeding might reduce the spread of HPAI, or through the use of fencing in understanding risks to breeding colonies of birds. However, it was also noted that the design of any study would need considerable thought given the movements of birds both locally and through the year, while experimental approaches may be difficult to employ reliably through the course of an outbreak.

7.2.5. Informing and assessing long-term conservation measures

The role of protected areas for waterbirds was particularly highlighted as a measure for aiding the resilience of waterbird populations to HPAI. However, it was also recognised that large proportions of the populations of many species may be supported on a small number of protected areas, thus increasing the risks of HPAI to these populations. Adaptive habitat management approaches to support populations and reduce this risk might include increasing the quality of habitats available within protected areas and the creation of new habitats.

To inform and assess such measures, there is a need to maintain and develop long-term monitoring of populations and their demography, while ensuring that new habitats are also monitored. This would need to be combined with long-term surveillance of HPAI in wild bird populations to assess the potential value of protected areas in providing resilience.

Bringing together a knowledge bank of information on the effectiveness of conservation responses to mitigate the impact of HPAI on populations would facilitate best practice moving forward.

7.3. Raptors

7.3.1. Understanding the spread of HPAI in wild bird populations

The main priority area of research to understand the spread of HPAI in raptors was to understand the pathways of transmission (eight responses). Three participants questioned the mechanism by which hen harriers were being infected – is it gamebirds or passerines? Another participant asked a similar question of Sparrowhawks which also particularly predate passerines – leading to another participant to suggest that raptors may be acting as sentinels for HPAI infection in passerines and therefore the need to understand levels of infection in passerines. Two participants asked why rodent specialists are also being infected. Scavenging behaviour was suggested to increase exposure. Linked to this, two participants identified the need to understand the impact that gamebird release may play in exposing birds of prey to the virus. The potential role of raptor:raptor transmission was also flagged by two individuals, either through mixing between species or at winter roosts.

There was some recognition from two participants that raptor population dynamics are relatively well-known from existing surveillance schemes (such as raptor study groups), although the impacts of HPAI on raptor demography is not known. It was suggested that Population Viability Analysis (PVA) or Integrated Population Modelling (IPM) could be used to estimate the population-level impacts of different levels of mortality. Four participants particularly flagged up the need to better understand variation in vulnerability to HPAI between different species; for example – are Buzzards reported frequently in the APHA statistics by virtue of their abundance and visibility, or because they are particularly vulnerable?

7.3.2. Assessing the vulnerability of species

One participant regarded it as well-known that raptors would be vulnerable to HPAI because they are at the top of the food chain (van den Brand *et al*. 2015). Diet was regarded as partly-known to be important for raptors by three participants, although one noted that this can vary between populations and seasonally, creating an additional complication. Vulnerability could be categorised according to diet and rates of infection in prey. Other factors mentioned included long-distance migration or association with waterbirds.

A key component of vulnerability is to understand the population-level consequences of infection (six submissions). This has a number of components, including the contribution that mortality may pose for extinction risk, other pressures on species which may lead to comorbidity or add additional demographic pressures, the ability of species' to recover from periods of infection or high mortality, given that larger raptors are k-selected. That different ages may have different associated mortalities was recognised as a need for research, given anecdotal information of HPAI mortalities particularly in chicks. The potential role of low genetic-diversity in increasing the vulnerability of small populations was also suggested as a key knowledge gap, as well as the greater threat of local extinction for isolated or scattered populations.

The lack of serological information in live raptors was flagged as a key knowledge gap by two participants.

7.3.3. Predicting bird population impacts

That we have good estimates of background survival and productivity in some raptors was recognised by two participants, but not for most. Two flagged up the need to understand the impacts of HPAI upon mortality rates and breeding success, which is not currently known. This was flagged as a key research need, noting that levels of mortality could differ between age-classes. The need to understand the dynamics of non-breeding or juvenile populations was also identified, either because they could buffer breeding populations against the loss of adult birds, or as a mechanism for transmitting the virus as such individuals can be more mobile. It was recognised that understanding the impacts of HPAI on rarer populations may require improved population monitoring information - particularly for species whose populations are only monitored periodically as part of the SCARABBS cycle. It is worth noting the potential for improved monitoring information from raptor study groups (e.g. Scottish Raptor Monitoring Scheme) to deliver improved understanding of HPAI impacts.

7.3.4. Informing and assessing short-term interventions

There was considerable discussion about the potential implications of HPAI for diversionary feeding, which can be a significant management tool to reduce the conflict between raptor conservation and game management (four responses) or used as a conservation tool. As noted earlier (Section 6.2), there are concerns that supplementary feeding could result in enhanced disease transmission at feeding locations, and so there is uncertainty about whether such management should continue, or whether it could be used as a tool to reduce the risk of infection by infected wild birds. Two attendees again wondered whether gamebird releases were a mechanism for infection in raptors (e.g goshawk) and therefore whether restricting such releases could help reduce raptor vulnerability. Another attendee suggested gamekeepers could and wanted to play an improved role in monitoring the impact of HPAI on raptor populations, for example by checking for sick or dead birds. It was noted that HPAI could have significant impacts on reintroduction schemes, if as occurred this year, chicks removed for reintroduction can carry HPAI. One attendee flagged carcass removal was an approach that was partially known to reduce the incidence of HPAI in raptors.

7.3.5. Informing and assessing long-term conservation measures

Relatively few suggestions were made about long-term conservation. Two participants identified the need to quantify the effectiveness of different interventions in the long-term, whilst another two emphasised the need to reconsider raptor action plans in the light of HPAI. The need to understand the vulnerability of different raptor species to HPAI was identified by one participant whilst another suggested that PVA/IPM would help model likely future population changes in response to different scenarios of infection risk. Finally, one participant suggested that research into the potential role that the vaccination of released birds could play in helping to protect vulnerable populations was important, noting that there is a good track record in the release of captive-bred birds of prey. It was also suggested that we should learn from the conservation intervention put in place to support the long-term recovery of birds of prey from DDT.

8. Key points and next steps

The workshop focused on seabirds, waterbirds and raptors which are all groups that have been visibly affected by HPAI in the UK in 2022. The vulnerability analysis exercise suggested that species that occurred in close proximity to each other were likely to be more susceptible to infection. However, many other species with different traits may also be affected but not picked up in the current routine HPAI monitoring and testing because the finding and reporting rates of dead birds will be different between species. For example, a dead Gannet washed up on a beach is (i) extremely visible and (ii) is probably more likely to be reported than a small passerine that dies of HPAI on farmland. The relative reporting rate of different species can be estimated using dead recovery data from the British and Irish Ringing Scheme, although separating out finding and reporting probabilities is currently not possible.

Without an extensive program of testing in live wild birds, apart from occasional studies of the prevalence of HPAI viruses in wild birds (e.g. Wade *et al*. 2022), it will be necessary to use national bird monitoring schemes to highlight unusual changes in the populations of these other groups. The Breeding Bird Survey and the British and Irish Ringing Scheme are the two key schemes but a mechanism to flag up unusual, potentially HPAI-related, changes in populations would need to be put in place.

The workshop highlighted a number of areas (e.g. strengths of different disease transmission pathways for different species, interventions such as carcass removal, access etc) where there was a great deal of uncertainty in terms of either what is known or thought to be known. It is important that future studies acknowledge this uncertainty and design projects, for example by taking an experimental approach, that seek to reduce these uncertainties.

8.1. Monitoring

- For all groups of wild birds, ensure abundance/population monitoring capability where not currently available. One major gap is wintering gull surveys (WinGS).

- Review the data in the SMP, GSMP and other databases (e.g. those held by raptor study groups) to identify species and sites where (i) abundance monitoring, (ii) productivity data, (iii) estimation of adult survival data and (iv) other research initiatives such as looking at foraging areas are regularly (e.g. annually, or for a period of years in the past) carried out. This is likely to only be present for a relatively small number of species sites and the exercise will identify gaps in coverage (e.g. non-native geese, Mute Swan) and will allow a more strategic approach to developing the SMP, GSMP and raptor monitoring to become a more robust surveillance tool.

- Ensure collection of baseline demographic information for population monitoring and to track impacts of HPAI through time, ideally at a stratified selection of sites.

- Encourage more appropriately designed colour-ringing projects to improve survival reporting (e.g. supporting and enhancing the Retrapping Adults for Survival scheme), especially in those HPAI-susceptible species where most individuals are ringed as pulli and estimates of adult survival are consequently poor (e.g. see Warwick-Evans *et al.* 2016). Also colour-ringing gives information on movement (see below) and needs efforts in resighting.

- Where possible, combine population and demographic monitoring to produce integrated population models (IPMs) for affected species to determine the impact of HPAI on the populations and subsequent recovery. Where not possible, expand the monitoring efforts above to enable IPMs to be constructed.

- The highest priority is to resurvey populations to identify HPAI impacts from 2022. This particularly involves seabirds as the most recent survey of breeding seabirds has recently finished (Seabirds Count 2015–2022). Prioritise species by known mortalities, key sites, UK and global conservation priorities, vulnerability to other pressures and the availability of historical data. Prioritise sites by importance and ensure geographical representation and take into account those sites monitored more recently for 2023 monitoring and other sites longer term. Some sites may be difficult to access and therefore practicality of access is a consideration. Ensure a joined-up multi-agency approach to this via the long-term Seabird Monitoring Program. This is being considered separately by a separate Task & Finish Group in December 2022.

- There is potential for more frequent sampling within a season and this already occurs at a number of sites. It should be considered to provide an early-warning system to track HPAI progress within a season, therefore in 2023, maximise early visits across sites, particularly of vulnerable colonial species, to detect early mortalities.

- Improved reporting/recording of mortalities. Currently several different schemes are used by agencies in the UK. Even if one coordinated system is not possible, each scheme should collect the same data so that they can be combined.

8.2. Research questions

Population impacts

- To fully understand the population impacts, it is necessary to be able to estimate age-related variation in mortality.

- Improved understanding of species vulnerabilities.

- Some birds carry HPAI and are asymptomatic. Is there a potential for birds to acquire immunity and how long does this last?

- Using large-scale monitoring projects (e.g. Breeding Bird Survey and the British and Irish Ringing Scheme) to develop alerting systems for unusual population changes/reporting of dead birds.

Important to understand transmission pathways

- For both seabirds and waterbirds, there is a need to understand more about the movements of non-breeding and immature birds in and outside of the breeding season. Non-breeding birds visiting colonies, and immature birds prospecting and dispersing to other breeding areas could be a transmission pathway.

- How likely are the interactions between species (e.g. seabirds behind fishing vessels, waterbird congregations) to be a cause of transmission.
- Potential for waterbird migration to act as a pathway for viruses to move.
- Increased understanding of local daily movements by waterbirds/gulls and opportunities for HPAI transmission
- Potential role of gamebird/waterbird releases to introduce HPAI into the environment from reared populations. This is considered especially important to understand for raptors.
- Two owl species have been impacted. Are small mammals scavenging on infected carcasses or being exposed to the virus from the environment or domestic poultry settings a credible transmission mechanism?
- Potential role of non-native waterbirds vs native species to harbour virus.
- Potential role of gulls to transmit virus from waterways in winter to seabird breeding colonies.
- Participants thought that understanding wild bird:poultry interactions on farms was a priority. In the early 2000s, there was a great deal of HPAI-related research that looked specifically at wild birds on poultry farms which could be examined.

Monitoring of the HPAI virus itself

- Serological sampling of live birds/collaboration between professionals/ringing network/APHA required, although the use of volunteers to collect samples needs to be carefully considered.
- It is important to note that sampling of live/dead birds must be handled in accordance with appropriate health and safety protocols, and handled and stored in accordance with the appropriate biosafety level in relation to both the Specified Animal Pathogens Order (SAPO) and the Advisory Committee on Dangerous Pathogens (ACDP).
- More work on occurrence/persistence of the virus in the environment
- How long does the virus persist in an infected bird before the bird dies, how contagious is it, how do individuals interact between each other and can the transmission and subsequent mortality be modelled in an epidemiological and/or individuals-based modelling environment?
- Continued work to understand changes in genomics of virus and how it has moved in space and time, and to disseminate this in as real time as possible.
- The vulnerability of passerines to HPAI is unknown but positive findings of HPAI in Sparrowhawks and Hen Harriers could be a sign that passerines are susceptible. There is potential for surveillance by ringers (e.g. Dutch ringers have done this) and Garden Wildlife Health to pick-up unusual mortalities.

Need to understand implications for renewable industry (seabirds particularly)

- Resurveys for counts of breeding abundance at SPAs for species (listed as features) which have shown high mortality and have connectivity (spatial overlap as shown by tracking studies on foraging ranges) with proposed wind farms.
- Implementation of intense monitoring studies (e.g. including breeding success/survival) and tracking studies at colonies/sites known to be impacted by HPAI – to look for density dependence changes in demographic rates and potential changes in foraging behaviour (e.g. ranges).
- Review PVA models which have been run, as part of the HRA and consenting process, and re-run if necessary based on new breeding abundance counts (as well as demographic rates, if such data are available).

8.3. Conservation

8.3.1. Short-term interventions

- Review evidence/guidance on i) biosecurity, ii) carcass removal, iii) vaccination in wild birds (currently not legal in the UK), iv) feeding/supplementary feeding/diversionary feeding/public feeding, v) euthanasia. High uncertainty associated with all interventions and whether any intervention will play a major role in reducing spread in wild bird populations. Modelling approaches, such as the use of individuals-based models, may be of use to assess which intervention may be most effective.
- The best supported intervention is probably carcass removal, but even for that there is some

scepticism about its likely efficacy. Data for more trials on the effectiveness of this are needed (e.g. Rijks *et al.* 2022), as even if it is unlikely to have a major, widespread impact, it could have a beneficial impact in certain circumstances, and may therefore be important in reducing mortalities in certain colonies or populations.

- Increased biosecurity is a no-regrets action, a sensible precaution and therefore should be in place when operating in an HPAI-positive environment. However, this was regarded as unlikely to play a major role in stopping what has been widespread viral spread by the birds themselves. There should be stringent biosecurity in place when moving between areas with poultry, and potentially vulnerable wild bird populations.
- Reducing disturbance may reduce the spread of the virus locally (Bekedan *et al.* 2021), but was not regarded as likely to play a major role and affect longer-distance transmission.
- Sources of artificial food may encourage aggregations of individuals and promote viral spread, as thought to be the case with Common Cranes in Israel. The provision of supplementary food may also be used to manipulate feeding behaviour of birds, but this would have to be context specific as it could also increase disease transfer, and was therefore not regarded as likely to play a major role in reducing HPAI mortality.
- Although not discussed at the workshop, there is evidence that vaccination can reduce mortality and viral shedding in falcons (Lierz *et al.* 2007 doi: 10.3201/eid1311.070705). However, the vaccination of wild birds would be associated with many practical difficulties, and perhaps may only be feasible in the case of reared individuals (e.g. translocated Hen Harrier chicks) or for small populations. There is also high uncertainty over the likely efficacy of any vaccination in the longer-term, with more studies required on bird responses to vaccination (e.g. Lécu *et al.* 2009).

8.3.2. Long-term interventions

- Greater cooperation across UK countries is important. Each country has in-country expert groups and meetings and this means the UK-wide focus can be lost. In 2022, the fortnightly meetings of stakeholders, chaired by BTO, has been valuable to provide a UK-wide update. Do we need more integration across the UK, Ireland and the three Crown Dependencies?
- All the species affected have a European or global distribution and to avoid operating in silos there should be greater international cooperation at an appropriate (e.g. European, flyway or global) level for the most affected species (e.g. Gannet and Sandwich Tern). The European Migration Atlas and Migration Mapping Tool are key tools to look at for deciding the levels. Ideally this cooperation would be undertaken by an existing body (e.g. the Convention on Migratory Species, CMS or one of its sister agreements).
- Greater cooperation across sectors – poultry industry, public health (One Health approach), wildlife disease/virologists/vets (APHA), conservation sector in relation to other pressures (e.g. renewables industry).
- An aspirational global aim should be to reduce the risk of transmission between poultry and wild birds by addressing the risk of contact in areas where high-densities of domestic birds interact with migratory wild birds around the world.
- Understand potential for protected sites and improved habitat conditions to increase the resilience of populations to disease (e.g. removal of introduced rodents on seabird islands).
- Ensure that ongoing monitoring is able to track changes in populations on, ideally, an annual basis and count mortalities as they happen. The existing schemes are in place (e.g. Seabird Monitoring Program, Goose and Swan Monitoring Programme, Breeding and Wetland Bird Surveys, British and Irish Ringing Scheme) but a review of these for the most affected species would identify any gaps in key population and demographic parameters. For example, the seabird census that occurs every 20 years is not sufficient to monitor populations in the presence of HPAI and will need more regular monitoring of an ideally stratified suite of sites to monitor population numbers and productivity. To obtain estimates of mortality, more Retrapping Adults for Survival studies will be required.
- Improved viral sampling, including of live birds, to fully understand i) the distribution of the virus around the country and between different species ii) and then relate HPAI prevalence to mortalities to significantly improve our understanding of vulnerabilities. This would ideally be part of the development of the infrastructure for wider disease surveillance.

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APPENDIX 1.

Wild bird survival monitoring: a summary of active and historical 'Retrapping Adults for Survival' (RAS) projects in 2020.

The Retrapping Adults for Survival (RAS) scheme is part of the British and Irish Ringing Scheme. RAS aims to generate annual survival rate estimates for adult birds, focussing primarily on species not encountered in large numbers during standard mist netting activities such as Constant Effort Sites (CES). In total, 200 RAS projects were active in 2020, however, due to the COVID pandemic, only 147 RAS projects were able to run. For more details see: https://www.bto.org/our-science/projects/ringing/surveys/ras/results

WATERBIRDS	No. projects contributing to survival trend	Number of projects active in 2020	Number of projects new in 2020	Survival trend quality
Mute Swan	4	5	1	Moderate
Greylag Goose	1	0	0	Uncertain
Eider	5	2	0	Uncertain
Ringed Plover	1	0	0	Good
Little Ringed Plover	1	1	0	Uncertain
Common Sandpiper	3	2	0	Moderate

SEABIRDS	No. projects contributing to survival trend	Number of projects active in 2020	Number of projects new in 2020	Survival trend quality
Fulmar	0	1	1	-
Manx Shearwater	2	0	0	Good
Storm Petrel	5	2	0	Good
Shag	4	2	0	Uncertain
Puffin	2	2	0	Good
Razorbill	4	3	0	Good
Guillemot	3	4	1	Good
Common Tern	0	1	0	-
Arctic Tern	1	1	0	Moderate
Kittiwake	6	7	1	Good
Black-headed Gull	2	0	0	Moderate
Herring Gull	1	1	0	Moderate
Great Black-backed Gull	1	1	0	Moderate
Lesser Black-backed Gull	3	1	0	Moderate

RAPTORS	No. projects contributing to survival trend	Number of projects active in 2020	Number of projects new in 2020	Survival trend quality
Sparrowhawk	0	0	0	-
Barn Owl	4	4	0	Good
Little Owl	1	1	0	Good
Tawny Owl	1	1	0	Moderate
Kestrel	0	0	0	-
Peregrine	1	1	0	Moderate

Other species	No. projects contributing to survival trend	Number of projects active in 2020	Number of projects new in 2020	Survival trend quality
Woodpigeon	1	1	0	Uncertain
Collared Dove	2	2	0	Uncertain
Swift	3	1	0	Uncertain
Jackdaw	4	4	0	Good
Rook	0	2	1	-
Blue Tit	2	1	0	Uncertain
Great Tit	4	2	0	Moderate
Coal Tit	0	0	0	-
Willow Tit	0	0	0	-
Marsh Tit	1	4	0	Uncertain
Bearded Tit	3	3	0	Moderate
Sand Martin	23	10	1	Good
Swallow	8	4	0	Good
House Martin	6	2	0	Moderate
Wood Warbler	2	1	0	Uncertain
Willow Warbler	3	0	0	Moderate
Blackcap	1	0	0	Uncertain
Garden Warbler	1	1	0	Uncertain
Whitethroat	1	1	0	Moderate
Sedge Warbler	1	2	0	Moderate
Reed Warbler	10	8	0	Good
Starling	14	19	2	Good
Dipper	7	7	0	Good
Blackbird	3	2	0	Moderate
Spotted Flycatcher	0	0	0	-
Robin	2	2	0	Moderate
Nightingale	2	2	0	Moderate
Pied Flycatcher	28	20	0	Good
Redstart	0	1	0	-
Whinchat	1	1	0	Moderate
Stonechat	2	2	0	Moderate
Wheatear	4	4	1	Moderate
Dunnock	2	1	0	Uncertain
House Sparrow	17	18	1	Good
Tree Sparrow	4	4	0	Uncertain
Tree Pipit	2	3	0	Moderate
Chaffinch	3	1	0	Good
Hawfinch	2	3	0	Moderate
Bullfinch	5	2	0	Moderate
Greenfinch	1	0	0	Moderate
Linnet	2	3	0	Good
Twite	2	2	0	Good
Siskin	8	6	0	Moderate
Reed Bunting	1	1	0	Uncertain

Cover image: Gannet, Esme Coles Alderney Wildlife Trust. Back cover: Greylag Geese, Sarah Kelman / BTO

Highly pathogenic avian influenza in wild birds in the United Kingdomin 2022: impacts, planning for future outbreaks, and conservation and research priorities. Report on virtual workshops held in November 2022

The Joint Nature Conservation Committee (JNCC) / British Trust for Ornithology (BTO) organised a virtual workshop to develop thinking to support ongoing efforts to manage the outbreak and also to consider longer-term evidence requirements to enable positive conservation actions and species recovery. The UK workshop on wild birds sought to bring practitioners and experts together to: (i) identify whether there are any short- or medium-term (conservation) management interventions that could be beneficial; ii) consider whether there are novel longer-term management interventions that could be prioritised to address HPAI impacts and increase population resilience in impacted species; (iii) share experiences in collecting data on mortality in different species groups and consider what future mortality monitoring could look like; (iv) discuss what developments would be beneficial for UK bird monitoring schemes for improving understanding of impacts, including demographic parameters, and identify where these schemes are unlikely to meet these needs; (v) assess the impact of loss of data, resulting from restrictions to field work in 2022, from national monitoring schemes and research on species assessments, indicators, and marine management and, (vi) outline what new research areas could help us understand the effects of HPAI on populations, improve risk assessments, and how it could improve management for species conservation and recovery in future.

Pearce-Higgins, J.W., Humphreys, E.M., Burton, N.H.K., Atkinson, P.W., Pollock, C., Clewley, G.D., Johnston, D.T., O'Hanlon, N.J., Balmer, D.E., Frost, T.M., Harris, S.J. & Baker, H. (2023). Highly pathogenic avian influenza in wild birds in the United Kingdomin 2022: impacts, planning for future outbreaks, and conservation and research priorities. Report on virtual workshops held in November 2022. BTO Research Report **752**, BTO, Thetford, UK.

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