

Whooper Swan Management Plan

Ballinlee Wind Farm

Report for Woodrow APEM Group on behalf of Ballinlee Green Energy Ltd.

By Dr Kerry Mackie

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Contents

1.0 Executive summary	5
2.0 Background	6
<i>Statement of competency.....</i>	<i>7</i>
3.0 Introduction	7
4.0 Local landscape use of whooper swans at Camas South & Ballycullane	8
5.0 Mitigation design and management measures	12
5.1.1 <i>Habitat Enhancement Measures</i>	<i>13</i>
5.1.2 <i>Method</i>	<i>13</i>
5.1.3 <i>Monitoring and measures of success.....</i>	<i>14</i>
5.2.1 <i>Habitat deterrence measures</i>	<i>14</i>
5.2.2 <i>Methods</i>	<i>15</i>
5.2.2.1 <i>Grassland management A (T3)</i>	<i>15</i>
5.2.2.2 <i>Grassland management B (T1, T2, T4 & T5)</i>	<i>15</i>
5.2.3 <i>Monitoring.....</i>	<i>15</i>
6.0 Future scenarios & long-term feasibility	16
6.3.2 <i>Regional flooding</i>	<i>1</i>
7.0 Management and monitoring schedule	1
7.1 <i>Monitoring displacement effects on whooper swans</i>	<i>2</i>
7.2 <i>Collison risk.....</i>	<i>3</i>
Appendices	1
Appendix A. Supplementary figures	1
Appendix B. Technical note on potential impacts on whooper swans from onshore wind farms & supporting information for mitigation design	5
B.1 Background.....	5
B.2 Introduction.....	5
B.3 Sensitivity of Anseriformes to wind farms (swans and geese)	6
B.3.1 <i>Collision mortality.....</i>	<i>6</i>
B.3.2 <i>Displacement and avoidance.....</i>	<i>8</i>
B.4 Icelandic whooper swan.....	11
B.4.1 <i>Demography.....</i>	<i>11</i>
B.4.2 <i>Ecology</i>	<i>11</i>
B.4.3 <i>Pasture quality</i>	<i>12</i>
B.4.4 <i>Habitat use and disturbance</i>	<i>12</i>

B.5 Mitigation	14
<i>B.5.1 Displacement risk</i>	<i>14</i>
<i>B.5.2 Collision risk.....</i>	<i>15</i>
B.6 Summary	17
Acknowledgements	19
References	19

1.0 Executive summary

The Ballinlee Whooper Swan Management Plan is a mitigation initiative that uses a combination of habitat manipulation and turbine positioning to minimise the potential impact of a wind farm development on a small over-wintering population of Icelandic whooper swans, an Annex I species under the EU Birds Directive (Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds).

The proposed plan was commissioned for Woodrow APEM group on behalf of Ballinlee Green Energy Ltd in recognition of the constraint imposed by whooper swans within the townland of Camas South, a lowland area of agricultural grassland at the northern end of the proposed Ballinlee wind farm development near Bruff, Co. Limerick, Ireland.

Camas South is one of two subsites within the area (the other being Ballycullane) used by whooper swans and regarded to belong to the same local over-wintering flock. As a subsite, Camas South represents approximately one third of the total swan-days accrued. Maximum counts at Camas South have ranged from 33 to 50 swans over the last five years from an overall flock that has declined ~ 30% from an average of 102 swans at the turn of the century along with a reduction in county and national share from 50% to 14% and 0.85% to 0.37% respectively. This downward trend is contrary to an increased national population (+22.1% between 2015 & 2020) and a flyway population that has doubled over the past two decades.

A literature review of relevant case studies (Appendix B) concerning impacts of wind energy installations on large-bodied waterfowl and swans in particular, supports the premise of low collision risk (B. 3.1). A current theoretical avoidance rate for swans of 99.5% (Naturescot, 2024), used to predict collision mortality, has been revised upwards in recent years although acknowledged that it may still be conservative, and will be subject to review as more data becomes available. The loss of foraging opportunity for swans due to displacement effects – the other potential impact of a wind farm - is also regarded to be low based on relevant case studies and to the observed proximity to which turbines are tolerated by swans (B.3.2). Within a landscape of limited human access and with documented evidence of swans (and geese) foraging near turbines (B.3.2), a 300-meter buffer distance, which falls within the lower end of NatureScot's recommended 200-600m range for human-related disturbance, is proposed for assessing feasibility and mitigation design, to which further safe-guarding by adaptive management can be incorporated.

To minimise the possibility of any barrier effect to whooper swans the proposed Ballinlee wind farm incorporates a 1km spacing between specific turbines to accommodate the regular flightline of swans between foraging fields at Camas South and the nocturnal roost at Lough Gur, 6.5 kilometres to the northwest (Figure 4, Section 5.0). Pasture manipulation combining management measures to deter swans from previously used foraging fields close to turbines and enhancement measures to encourage continued use of fields central to the flightline, are proposed to further reduce collision risk and offset potential habitat loss in close proximity to specific turbines. Management prescriptions are evidence-based and drawn from a recent mitigation program for whooper swans in relation to a road development in Northern Ireland. Enhancement measures include field amalgamation, water provision and the sowing of 2-3 hectares of a tetraploid Italian rye cultivar to provide for a maximum of 2827 swan-days (mean 2112 +/- 245) calculated using five years of swan count data collected at Camas South (2020/21 – 2024/25).

Future scenarios and long-term feasibility must include possible changes in habitat quality and potential for flood events as they are outside management control and could affect the distribution of whooper swans and their juxtaposition to turbines. The quality of enhancement measures will therefore be monitored annually to ensure they remain attractive to whooper swans and help to maintain the flightline within a safe corridor. Any swans that forage in fields outside the area of field management control and beyond the turbine array, will ultimately be facilitated to remain in the flight corridor as they are likely to use the prevailing south-westerly winds to take flight, away from turbine towers. Similarly in the few locations where localised flooding may attract swans and/or in the event of more extensive floodplain inundation, either scenarios will benefit from the prevailing SW wind direction and facilitate swan flight paths to remain within the flightline corridor and continue on to the roost at Lough Gur.

Management and post-construction monitoring of habitats using quadrats and transects will primarily ensure that enhancement and deterrence measures are implemented as designed and subsequently maintained. Regular monitoring of whooper swans' distribution will then provide a positive feedback loop, initially for adaptive management should additional or remedial measures be required, but ultimately for overall mitigation efficacy and its potential for future projects. In practice there will be a balance between testing impact prediction, proving that mitigation prescriptions work, and the additional cost benefits of being able to contribute to an evidence base that is generally acknowledged as being limited. Therefore, to further our understanding as to how whooper swans react to turbines, behavioural data should be collected in the form of flock-scans to analyse the effects of potential audiovisual drivers, turbine proximity and time.

Where avoidance levels are likely to decline with time, management measures are designed to reduce collision risk in manipulating swan distribution away from turbines. While mortality risk is regarded to be low there is still opportunity to refine and provide feedback on Collision Risk Modelling (CRM) for whooper swans if meso-avoidance and micro-avoidance rates can be quantified and collision rates back-calculated from realised collision fatalities. Monitoring of flight paths and extent of any diversionary reactions to turbines is also important when assessing overall mitigation design. It will also verify assumptions made as to the acuity of whooper swans, their ability to avoid turbines and to reduce uncertainty as flights in proximity to turbines may vary under different weather or wind conditions.

The duration of at least five years of post-construction monitoring is necessary to transcend any initial neophobic avoidance of turbines and to capture seasonal and within-year variations in conditions experienced by swans and how these might interact with wind farm design. While longer monitoring programmes may be appropriate when species of concern are in greater abundance, monitoring that extends later into the lifespan of a wind farm will always be informative and not necessarily cost prohibitive, if to assess longer-term traits such as habituation.

2.0 Background

This report, which has been prepared by Dr Kerry Mackie for Woodrow APEM Group on behalf of Ballinlee Green Energy Ltd., presents a Whooper Swan Management Plan (WSMP) for Camas South, the northern section of the proposed Ballinlee Wind Farm development. Whooper swans (*Cygnus cygnus*) that use river meadows at Camas South, as an over-wintering foraging site, have been identified as locally important and a constraint to the proposed Ballinlee wind farm development. An

appraisal of potential impacts from relevant case studies, combined with five consecutive years of systematic winter surveys at Camas South (2020/21–2024/25), supports development feasibility given turbine positioning and integration of a Whooper Swan Management Plan (WSMP) to counter risk of collision and displacement (see Section 4 and Table 1 for survey details). Habitat enhancement forms a fundamental component of the management plan to offset potential loss of foraging habitat, increase foraging capacity, and to encourage continued field-use along an established flight path. An overview providing context and possible re-evaluation of impact sensitivity concerning large-bodied waterfowl and onshore wind farms is appended as a technical note (Appendix B3). The technical note includes more detailed rationale on mitigation design that benefits from a recent study specifically on whooper swans and mitigation for a road development in Northern Ireland. Post-construction monitoring is presented to assess mitigation efficacy, how whooper swans might respond to aspects of wind farm design over time and under different conditions, and to provide an evidence base that could facilitate future planning.

Statement of competency

Dr. Kerry Mackie – Ecologist – Whooper swan specialist

Kerry has been a freelance ecologist since 2015 having worked for twenty-four years in the conservation sector with two field seasons with Birdwatch Ireland prior to working for the Wildfowl & Wetlands Trust, managing and developing their Castle Espie reserve in Northern Ireland. Now as an independent consultant he upholds a conservation profile in facilitating waterfowl research for universities, NGO's, Local Councils and stakeholder partnerships, coordinating and undertaking censuses for waterfowl, seabirds, as well as an ongoing breeding wader project. Within the industrial sector, he has provided surveys for wind farm development and advises and undertakes collision risk management for George Best Belfast City airport. Kerry recently completed a doctorate with University of Exeter - funded by Department for Infrastructure (DfI) - titled "Impact of a Road Development on Whooper Swans", focusing on the interplay of habitat quality and infrastructure on foraging distribution, behavioural effects of disturbance, revealing underlying mortality to powerlines and providing design input into - and an efficacy assessment of - DfI's associated whooper swan mitigation program.

Qualifications:

BSc (Hons) Earth Sciences, Oxford Polytechnic 1990

MSc Mineral Exploration, Imperial College London, 1991

PhD Biological Sciences, University of Exeter, 2025

3.0 Introduction

Impacts on whooper swans from wind farms can potentially include mortality through collisions with turbine blades and habitat lost, either directly through the infrastructure footprint or indirectly from localised habitat degradation. Further displacement due to audiovisual disturbance might be caused by the turbines themselves or from anthropogenic activities during operation and maintenance of turbines. Levels of displacement can vary from the potential avoidance of an entire wind farm matrix (macro-avoidance), avoidance within the proximity of individual turbines (meso-avoidance) or when taking avoidance action in flight if in close proximity to turbine blades (micro-avoidance), (May et al.

2017). Predicting levels of avoidance by whooper swans using previous case studies as a reference (e.g. Winkleman et al. 1989; Fijn et al. 2012) although useful for guidance, are rarely directly comparable. Impacts will vary on any one or a combination of factors e.g. the scale of turbines used; overall dimensions of the wind farm or its layout; the extent of alternative habitats; pre-existing levels of infrastructure or disturbance; and the extent of habituation, while overall impact assessment is often limited by the short-term nature of post-construction monitoring. Where species-specific examples are insufficient, other species within the same family group (e.g. geese as a proxy for swans (Goodship & Furness, 2022)) may be useful in providing further insight and align context for possible effects (see technical notes in Appendix B, sections B.3.1 and B.3.2). Although collision risk modelling is covered in the overall impact assessment, as this risk is interrelated with levels of avoidance and mitigation design, aspects of collision are also included within the technical note (see Appendix B sections B.3.1, B.5.2). Similarly, mitigation design may not necessarily benefit from the existence of specific case-studies and guidance must often be drawn from a number of indirectly relevant studies (see Appendix B, sections B.4 & B.5), highlighting the importance and need for improved post-construction monitoring and documentation of mitigation efficacy (Madsen et al. 2014; Hunter et al. 2021).

Aims and approach of the management plan are to: -

- Outline the significance of Camas South at a local and landscape level along with detailing recent extent and intensity of field-use by whooper swans in relation to proposed turbine positions.
- To review current knowledge and context as to the extent of likely impacts on whooper swans by wind farm development (**contained as a separate technical note, Appendix B**).
- Encourage continued use of Camas South by whooper swans while minimising any potential impacts imposed by the wind farm development.
- Detail corresponding mitigation and landowner commitments to negate wind farm effects based on the assumptions of continued site use (as supported by the overview of potential impacts) and management prescriptions based on a successful mitigation programme for whooper swans in relation to a road development in Northern Ireland.
- Assess future scenarios and long-term feasibility.
- Provide monitoring protocols to inform adaptive management and the need for remedial measures or refine mitigation design to ensure long-term feasibility.

4.0 Local landscape use of whooper swans at Camas South & Ballycullane

The southern counties of Ireland are on the periphery of southward migration for Icelandic whooper swans with internationally important flocks in excess of 340 swans (Wetlands International 2018) represented north of Limerick on the Shannon and Fergus Estuary (899 recorded in 2020 census) on the Co. Limerick/Co. Clare border and Co. Wexford (480 & 342, 2020 census), (Burke et al. 2021). Smaller flocks of national importance (>150, Burke et al. 2018) are limited to the Blackwater callows on the Co. Cork/Co. Waterford border (218 (2020 census)) and the Cashen river and Estuary in Co. Kerry (210 (2020 census)). 493 whooper swans were recorded for Co. Limerick during the 2020 census and included Ballycullane (14 WS), Camas South (43 WS), Ballysallagh (0 WS) all sub-flocks common to the Lough Gur roost (Figure 1). This wintering population has declined slightly both in

number and as a proportion of flyway share having averaged 102 swans (1998-2002, Murphy (2022)), representing ~ 50% of Limerick's whooper swans (or 0.85% all-Ireland) in the 2000 census (Cranswick et al. 2003), declining to 14% (0.37% all-Ireland) by 2020 (Burke et al. 2021; G. Murphy pers. com).

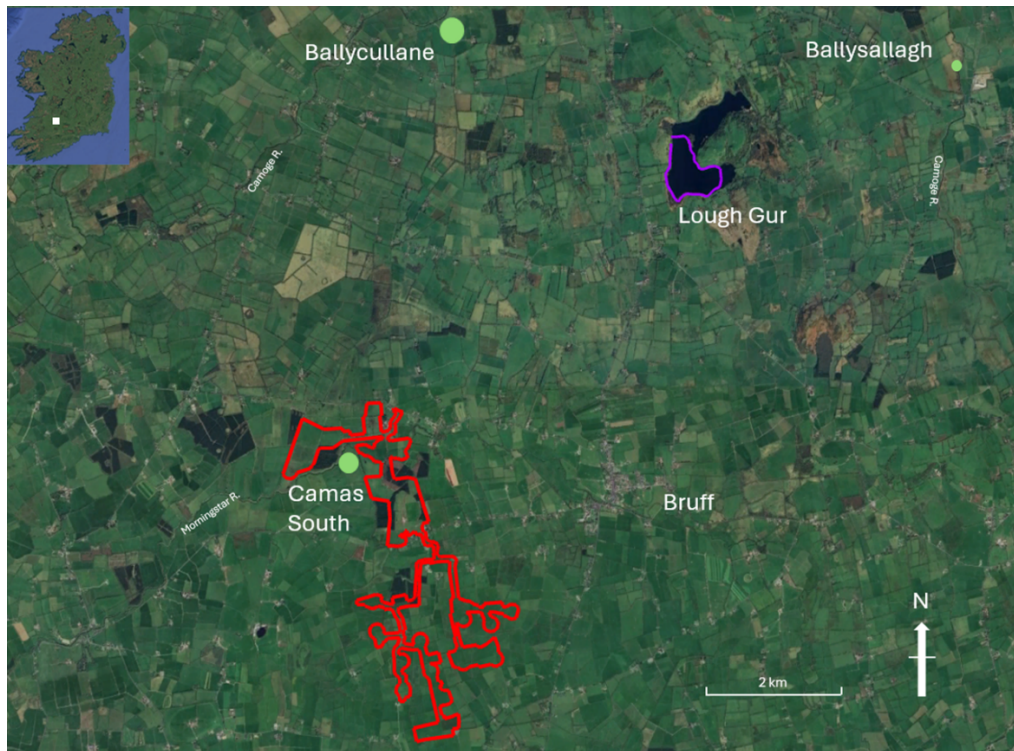


Figure 1. Lough Gur roost and foraging locations of local sub-flocks in relation to development boundary (red).

The Lough Gur sub-flocks forage on floodplain meadows along minor rivers namely the River Camoge (Ballysallagh and Ballycullane) 4 km NW and 4.5 km NE respectively, and the Morningstar River (Camas South) 6 km to the SW. While whooper swans at Ballysallagh are now rare, Ballycullane and Camas South continue to host sub-flocks regularly and are often split between both sites across the winter (Figures 2a and 2b). Both Ballycullane and Camas South receive their first arrivals in late October/early November with combined numbers increasing to peak from early January, with numbers dropping off abruptly in mid-late March with the onset of migration back to Iceland. Numbers of swans at Camas South fluctuate from representing 0 to 50% of the Lough Gur flock, with low counts in January most evident in recent winters. Site switching by whooper swans may be influenced by wind and energetics of the longer commuting flight, with lower numbers coincident to strong southerly headwinds recorded in January (e.g. 20 of 31 days in both 2023/24 and 2024/25, mean windspeeds of 9.12 and 14.8 kmph), compared to fewer southerly days in February (mean windspeeds 6.35 & 6.38 kmph; Shannon Airport weather station, Meteoblue, 2025). Over the five-year period (2020/21–2024/25), whooper swans have generally favoured Ballycullane, which accounted for 65–76% of swan-days in the most recent two years, likely due to its proximity to the roost and prevailing wind direction (see rose diagram for 2023/24 and 2024/25 wind directions – Appendix A, figure A1). No comparable data are available for Ballycullane for the earlier three years, so longer-term trends cannot be assessed.

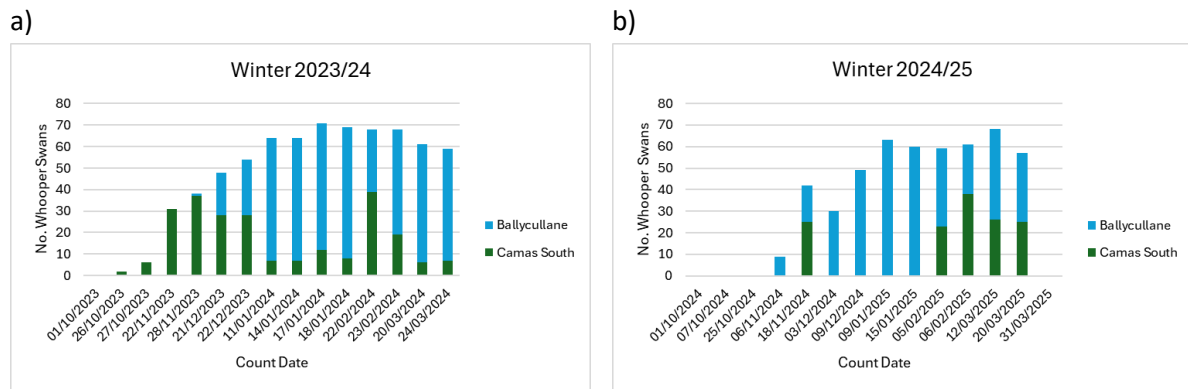


Figure 2. Whooper swan counts (same day) for Ballycullane and Camas South sub-flocks for winters a.) 2023/24 and b.) 2024/25.

To illustrate distribution and site use at Camas south, regular whooper swan surveys (WSS) were supplemented with swans counted during vantage point surveys, transect surveys and flight speed surveys, where available (all counts undertaken by contracted parties to Woodrow APEM Group). Collated counts were converted into swan-days (SDs) spreading intervening site use uncertainty across count intervals by averaging consecutive counts before multiplying by the intervening number of days between counts (Table 1). Field utilisation by whooper swans was then plotted (Figure 3.) for all winters combined (2020/21-2024/25) using a swan-day index derived by scaling annual field use for each field centroid and calculating kernel density estimates (KDE) (Worton, 1989) with the *amt* package in R (Signer et al. 2019) providing isopleth-probability bands of 1-25%; 25-50%, 50-75% and 75-100%. All maps were generated in “R” version 4.1.3 (R Core Team 2022) and google map satellite images using the package *ggmap*. Annual field use is depicted using bubble plots (Appendix A, Figure A2 a-e) and again using swan-days to represent intensity of field use. From the five years of data, fields on the southside of the Morningstar River appear to have been preferred both in the number of fields selected (5 as opposed to 2) and the intensity of use (6344 SDs as opposed to 3678 SDs on the north side). Isopleths also illustrate an east-west split with a greater likelihood of whoopers swans in fields on the eastern side - slightly closer to their roost. Occasional use of fields distal to the river included field units north of proposed turbines during Autumn 2021/22 (361 SDs) and again briefly in Autumn 2023/24 (123 SDs) see Figures A2b and A2d, attracted either by temporary flooding and/or partial reseeding (G. Murphy pers.com.). A family of whoopers swans, associating with mute swans, used a satellite pond in a field 1 km to the south of the river in late spring 2022/23 (Figure A2c.) and both roosted at a farm pond 3 kms to the south. Occasional field use away from the floodplain therefore appears to be rare and limited to Autumn or Spring and may well be transient birds associating with a few less-wary mute swans. In the absence of habitat data on sward heights, reseeding history, grass mixes and field management it is assumed that fields closest to the river are targeted for their ability to retain surface water - being flat-lying and at the lowest elevation, larger fields with open field boundaries and drainage ditches to provide additional visual and physical security from predators and human activities alike. Grass swards are perennial rye dominated (*Lolium perenne*) and contain a mix of different cultivars suited to the ground conditions and grazing or mowing regimes of each farm type. Disturbance levels recorded during field surveys have been low.

2020/21-2024/25

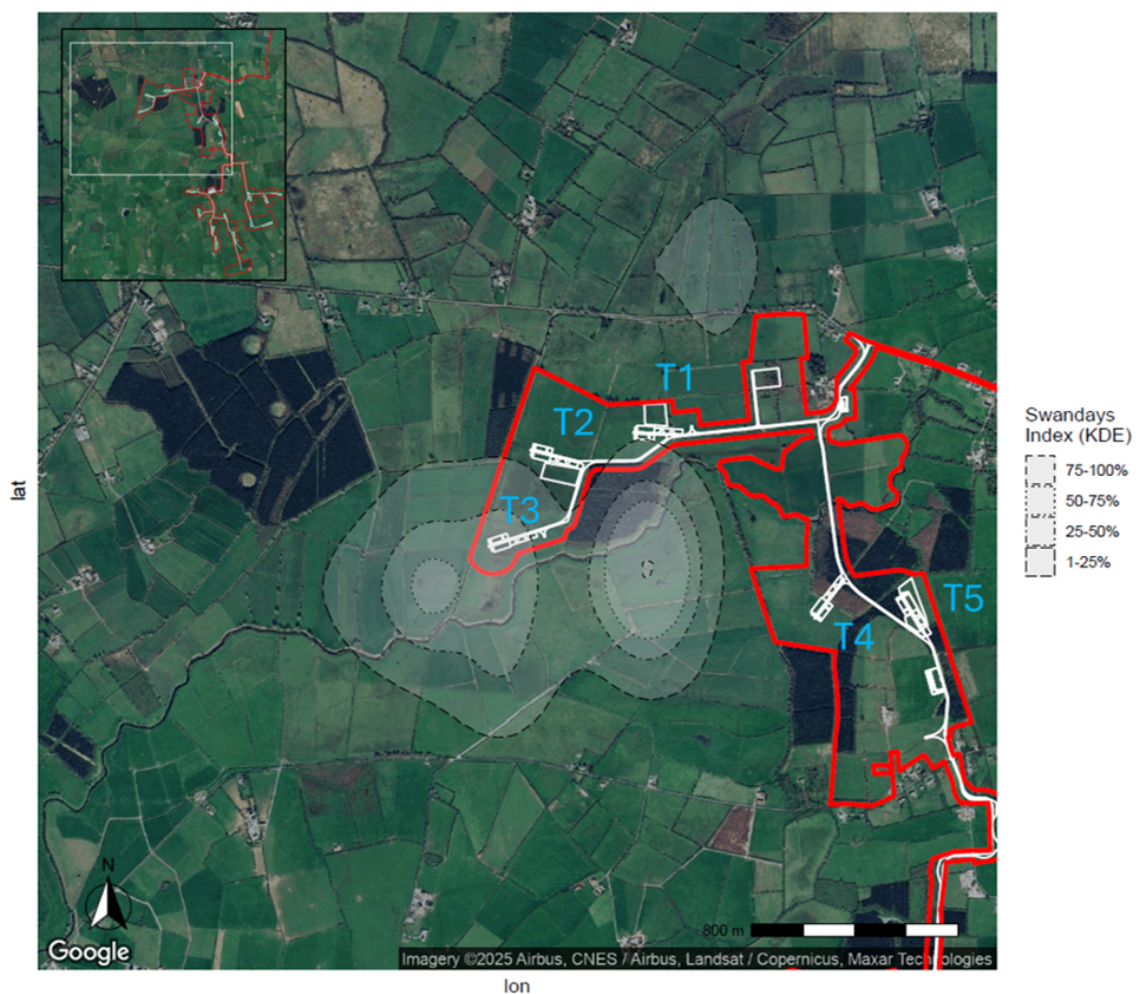


Figure 3. Kernel Density Estimates (KDE) based on swan-days calculated from 2020/21 to 2024/25 whooper swan counts at Camas South with proposed turbine positions.

Table 1. Summary table for annual swan-day totals for Camas South (5 years) and Camas South compared to Ballycullane (2 years).

		Camas South		Ballycullane		
All counts	No. Counts	Swan Days	Max Count	Swan Days	Max Count	Total
2020/21	12	1172	33	-	-	
2021/22	25	2242	50	-	-	
2022/23	14	2368	41	-	-	
2023/24	25	2827	42	-	-	
2024/25	14	1951	38	-	-	
Mean		2112 +/- 245				
Synchronised counts only						
2023/24	13	3129	39	4877	61	8006
2024/25	12	2039	38	5524	63	7244

5.0 Mitigation design and management measures

The likelihood of macro avoidance of whooper swans of the Camas South area due to the turbine array is expected to be low given the 980m spacing between turbine towers T1 and T4 (Figure 4), central to the swan's regular flightline from Lough Gur and expected tolerance to turbines reported in case studies e.g. for Bewick's swans (Fijn et al. 2012) and swans (all species) (Therkildsen et al. 2021), (see general discussion in Appendix B.5.2). With the possibility of habitat loss due to meso-avoidance of turbine T3, where the KDE (Figure 3) indicates the highest density of swan foraging, the proposal includes provision of additional foraging capacity using habitat enhancement distal to individual turbines and contiguous to previous foraging fields. Provision of additional foraging capacity through habitat enhancement, located away from turbines and contiguous with previously favoured fields, is intended to reduce collision risk by encouraging swans to forage at a safe distance from turbines and to maintain a regular flightline and safe corridor. While the KDE does not indicate a foraging density hotspot around T4, habitat deterrence measures are proposed for both T3 and T4 to proactively discourage swans from foraging in close proximity to turbines, particularly within and marginal to the existing foraging area. For fields with no recent history of feeding whooper swans (turbines T1 and T2), current management regimes will continue. Mitigation efficacy will be assessed by monitoring distribution and field-use intensity over subsequent winters and comparisons to pre-construction data to verify whether objectives for maintaining abundance and increased proportional use of the safety corridor (between turbine groups T1-T3 and T4-T5) are met.

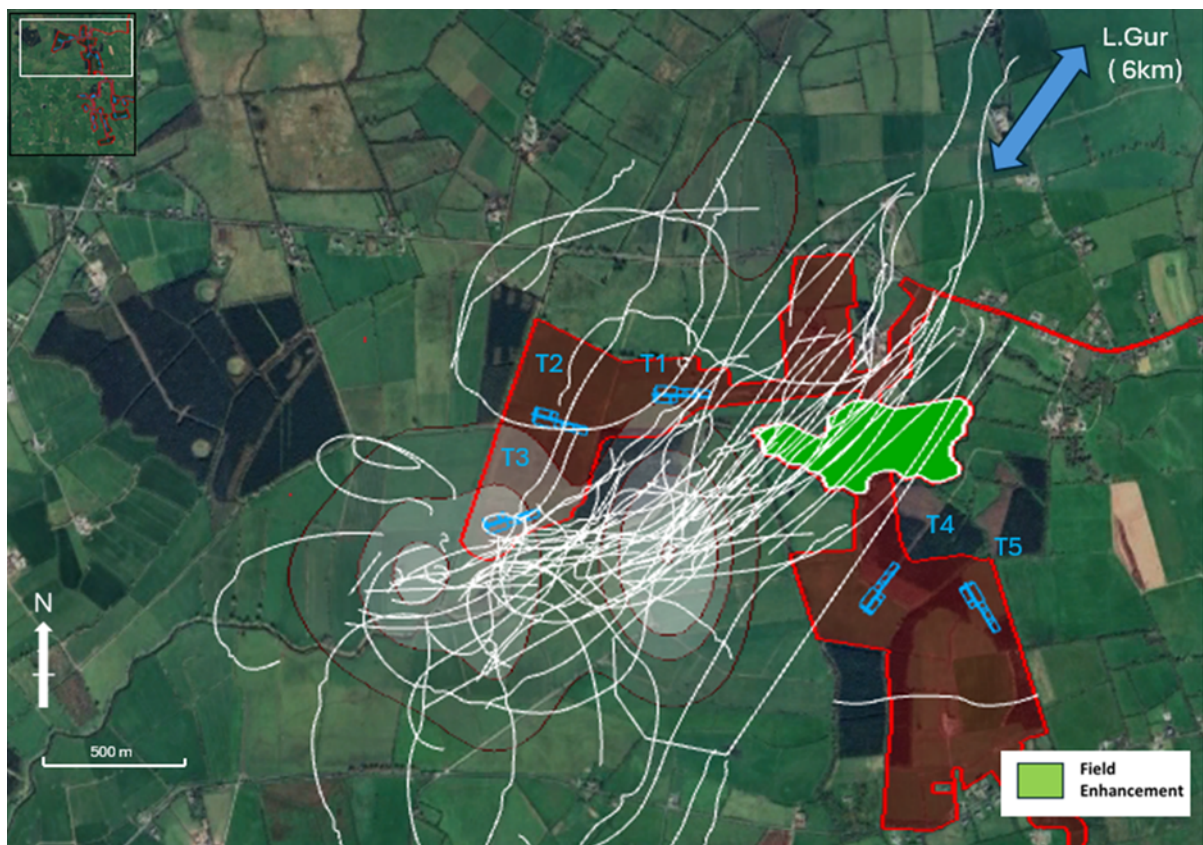


Figure 4. Projected flight lines from VP surveys illustrating SW-NE trend and the proposed enhancement area. KDE isopleth bands are used as a swan-day index for levels of site use with opacity increasing with intensity of use (1-25%, 25-50%, 50-75%, > 75%) as in Figure 3.

5.1.1 Habitat Enhancement Measures

Habitat enhancement has proven to be successful in offsetting habitat lost to whooper swans from road construction at Toome, Northern Ireland - not only maintaining whooper swan abundance above pre-construction levels but increasing the overall site use by 60% from a 4-year average of 49,500 SDs to 79,250 SDs during and post construction (McElwaine, 2018 -2024).

The area proposed for enhancement at Camas South is approximately 8 ha in area, borders the Morningstar River and is coincident to the whooper swans' flightline from Lough Gur (Figure 4.). Sowing a tetraploid Italian rye has the potential to provide a 4-fold increase in foraging capacity for fields grazed by whooper swans compared to perennial rye swards (Mackie, 2022) (see Figures A3a & A3b Appendix A). The fields for enhancement are therefore larger than required to provide biomass for an estimated mean annual use of 2112 +/- 245 SDs (2020/21-2024/25) for Camas South alone. This is necessarily sized to encourage swans to use fields with no previous history of use, its convoluted shape, and to buffer for potential disturbance from the adjacent farm.

5.1.2 Method

- Amalgamate the "Three corner field" and "Garden Field" by removing remnants of the central hedge line, roughly re-levelling to allow areas to retain rainwater (see Figure 5). All works will be planned to avoid impacts on protected species, including bats.
- Removal of single tree to reduce flight obstruction (see Figure 5). The tree will be inspected by a suitably qualified ecologist for bat roost potential prior to removal, and works will only proceed if no evidence of roosting bats is found, or under appropriate licence and mitigation if required.
- Cultivate and resow 2 hectares, or tine harrow, and "stitch in" 3.0 hectares of tetraploid Italian rye cultivar or tetraploid Italian/Perennial rye hybrid during Spring (see outline in Figure 5).
- Soil test to optimise soil chemistry for pH, P and K index for grazing stock and continued Autumn grass growth for whooper swans.
- Graze or cut as silage as farming regime dictates, removing stock from or topping by the end of October to leave a sward length of between 5 - 10 cms. NB. Sward heights may need to be reduced by topping later in the winter to maintain favourable foraging conditions for whooper swans.
- Maintain a high level of grass cover.
- Prevent poaching by removing stock before ground conditions deteriorate and to allow field to be rolled.
- Slurry, farmyard manure, organic manure, or lime application to be applied before October 1st.
- Monitor annually persistence of reseeded area and overseed where necessary.
- Retain areas that remain damp and liable to wet-up e.g. areas of compaction, slight depressions, undulations, tractor ruts - that provide temporary standing water.
- Create at least one wet area that retains water throughout the winter (Figure 5).
- Avoid disturbance of enhancement area or to neighbouring fields by cultivation, rolling, ditch clearance or reseeded between 15th October and March 31st.
- No dumping or application of herbicide, pesticide, sheep dip or poultry litter.

- Maintain swans' connectivity to adjacent foraging fields by maintaining gaps in existing boundary hedge or tree line.
- Prevent casual unauthorised access to field tracks using locked gates and signage at entry points – both from the farm as well as on bridge towards the southeast plantation and Turbine T4.
- Maintenance access to turbines to be redirected during the winter months i.e. to approach T4 & T5 from southern access routes.
- Not to permit shooting along river or neighbouring plantations where rights are retained.
- Schedule any future timber harvesting outside the whooper swan over-wintering period (mid-October – March).



Figure 5. Enhancement measures described in method section 5.1.2

5.1.3 Monitoring and measures of success

Monitoring the successful propagation of the reseeded area will be undertaken and reported annually. Initial periodic inspections of the first year will be followed by annual monitoring to assess areas that require resowing or weed control in spring and an Autumn inspection to ensure provision of a suitable sward condition prior to whooper swans' expected arrival in November. An evaluation as to the proportion and distribution of the target cultivar in the sward will be conducted using quadrats and a series of transects across the area demarcated for reseeding. Other measures such as removal of temporary fencing, water availability, and ground conditions will be assessed during the Autumn inspection and any remedial actions identified and acted upon prior to the whooper swans' arrival at Camas South.

5.2.1 Habitat deterrence measures

As detailed in Appendix B.4.3 (pasture quality), geese and swans are attracted to monocultures containing grass cultivars that are low in fibre and have high levels of soluble carbohydrates (Fox et al. 2016, Owen et al. 1977), or a specific growth stage selecting medium leaf grades rather than coarse or fine leaf grades to optimise digestibility and bite size (Mackie 2025). Fertiliser applications further increase protein levels, water content and biomass increasing both its attractiveness and ability to

sustain foraging (Prop et al. 2005; Riddington et al. 1997). Multi-species swards that contain finer grasses will be less attractive to swans if monocultures of perennial rye swards are locally available, particularly if cut late as hay with little fertiliser requirement until the following spring. Similarly perennial rye swards with cultivars that suit grazing i.e. lateral growth forms (diploid cultivars), will be comparatively less attractive than those containing more upright forms (tetraploid varieties) sown for cropping. However, species-rich swards may not be appropriate close to turbines if indirectly attracting other taxa or bird species present locally and vulnerable to turbine collision such as bats or raptors responding to an associated increase in prey density. Alternatively, as a compromise, established perennial rye swards can be made less attractive to swans by stitching in one or two more traditional grass species e.g. Meadow Fescue (*Festuca pratensis*), Timothy (*Phleum pratense*), or Meadow Foxtail (*Alopecurus pratensis*). While more targeted habitat deterrence may be appropriate for fields previously frequented by whooper swans e.g. around turbine T3, pasture inside the development boundary and within immediate vicinity of turbines with little or no history of swan-use e.g. T1, T2, T4 & T5 should continue to be managed in a way that does not inadvertently attract swans i.e. so they remain comparatively less attractive to other fields previously used by swans within the locality.

5.2.2 Methods

5.2.2.1 Grassland management A (T3)

- Stitch into existing sward a limited number of meadow grass species (e.g. Meadow Fescue (*Festuca pratensis*), Timothy (*Phleum pratense*), Meadow Foxtail (*Alopecurus pratensis*) within the immediate vicinity of the turbine to reduce any dominance of perennial rye cultivars within the sward.
- Meadows to be cut late after seed development and/or grazed prior to winter closure or grazed throughout the winter at a reduced stocking level.
- Avoid any fertiliser applications from later summer.

5.2.2.2 Grassland management B (T1, T2, T4 & T5)

- Avoid fertiliser or slurry application after Oct 1st.
- Autumn cultivation, if reseeded is necessary, should be restricted to diploid perennial rye cultivars and include at least one and no more than two traditional grass species e.g. Meadow Fescue (*Festuca pratensis*), Timothy (*Phleum pratense*), Meadow Foxtail (*Alopecurus pratensis*).
- Manipulating stock levels to reduce sward height and biomass prior to arrival of whooper swans or winter graze at a reduced stocking level.
- Maintain hedge lines and trees along field boundaries to reduce connectivity to other fields used by foraging swans.
- Ensure adequate drainage to minimise presence of surface water.
- Install post and flag deterrents if whooper swans are observed in fields until remedial management measures can be carried out.

5.2.3 Monitoring

Annual Autumn inspection and reporting prior to the expected arrival of whooper swans in November to allow for any remedial action necessary to reduce sward characteristics favoured by swans. Autumn inspection to be followed by another during mid-winter before or during construction to assess water

retainment within each field and for any evidence of field use by whooper swans (droppings) not necessarily detected during routine swan counts.

6.0 Future scenarios & long-term feasibility

Irrespective of grass quality, fields with surface water may attract whooper swans whether for refuge after a disturbance event, during dry spells for drinking, or - if flooding is extensive - as a nocturnal roost with collision risk associated with disturbance and resultant nocturnal flight. There are two areas in the vicinity of the Camas South turbine array that regularly retain water (Figure 6); one 200m to the south of Turbine T3 with dimensions $< 50 \times 50$ m in extent and the southern half of a series of fields 550m north of T1 which is more extensive ~ 200 m when floodwaters in each field should eventually merge. The surface water by T3 is unlikely to be large enough to encourage roosting behaviour and if used for drinking or as temporary refuge, will likely involve short low-altitude flights between fields and, therefore, will likely be below the rotor swept area. The fields subject to more extensive flooding to the north of T1 have been used intermittently during past surveys (see Figures A2b and A2c, Appendix A.) but more likely due to the frequency of reseeding flood-damaged swards rather than presence of water per se. This site is not known to be a regular nocturnal roost site (G. Murphy pers.com.), whether due to the flooded area being immediately adjacent to a road or the flight obstructions caused by partially submerged fence lines.



Figure 6 Geological Survey Ireland Historic Surface Water Flood Mapping 2015/16 extracted from MWP (2025) Flood Risk Assessment

6.3.2 Regional flooding

The potential for more extensive flooding has been modelled by MWP, (2025) to guide groundworks and mitigate risk to turbines and infrastructure (Figure 7). The extent and duration of a flooding event will invariably introduce unpredictability as to the distribution and behaviour of whooper swans in the area. Where fields previously used by whooper swans will be inundated, the proposed field for enhancement has been predicted to partially remain above predicted flood levels and available for foraging. Prolonged flooding elsewhere will eventually reduce grass quality and eventually cause pasture die-off – increasing the potential use of the enhanced field further. Extensive flooding will likely disrupt regular flighting to the Lough Gur roost with swans encouraged to roost at Camas South, closer to the foraging area. With improved security of open water, swans will be less inclined to take flight if disturbed and the potential collision risk with turbines, reduced.

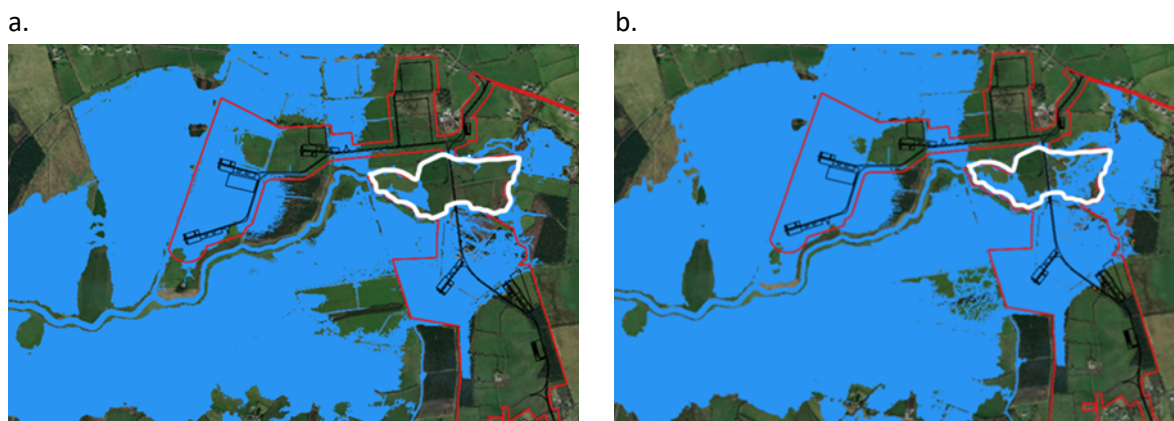


Figure 7. Predicted extent of (a.) 1:20 year event (b.) 1:100 year flooding event in relation to whooper swan field enhancement. Modified from Flood Risk Assessment by MWP (2025).

7.0 Management and monitoring schedule

Developing a coordinated approach to monitoring and the assessment of bird interactions with wind farms remains essential for guiding future development (Gove et al. 2013; Hill & Arnold, 2012), demonstrating solutions through targeted experiments (May et al. 2020), and to inform adaptive management (Gartman et al. 2017; Copping et al. 2019). Rigorous post-construction monitoring is required to fully understand the processes involved in collision risk, reducing prediction uncertainty and to backfill knowledge gaps created by everchanging turbine specifications and circumstances. Moreover, a commitment to long-term monitoring is equally important to capture effects beyond any temporary displacement through neophobia or later habituation and its implications to collision risk, while localised population effects may only be evident once the response of newly recruited individuals or carryover effects are realised (Hotker, 2017; Findlay & Bourdages, 1999; Zhang et al. 2019).

Monitoring the extent and nature of displacement is necessary to assess mitigation efficacy, e.g. turbine positioning, turbine specification or habitat manipulation, and can only be realised through more prolonged monitoring if to account for year effects, fluctuations in abundance and habitat quality due to farm management e.g. constraints imposed by inclement seasonal weather. The role of different drivers likely to cause displacement are often poorly understood (Langston & Pullen, 2003) and opportunities to monitor bird behaviour, if in proximity to turbines, may give

invaluable information as to the influence of windspeed, turbine noise, flicker effects, or wind direction and its influence on flight dynamics, or the frequency and intensity of disturbance events not necessarily related to the wind farm. Regular flock scans to record behaviour have previously been used to help understand perceptions of risk to infrastructure with levels of vigilance (Rees et al. 2005; Mackie, 2025) and/or preening (if regarded as a displacement activity) found to vary spatially and attributed to disturbance sensitivity (Mackie, 2025).

In practice there will be a balance between testing impact prediction, proving that mitigation prescriptions work, and the additional cost benefits of being able to contribute to an evidence base that is generally acknowledged as being limited (Hunter et al. 2021).

Guidelines for the duration of post-construction monitoring may vary depending on the size of wind farm, degree of mitigation and adaptive management deployed, or nature of conservation priority given to individual or assemblage of target species concerned. A minimum of 5 consecutive years of monitoring is required to provide data for operational years 1, 2, 3, 4, 5. Further to monitoring results and in consultation with Limerick City and County Biodiversity Officer and NPWS monitoring years would reduce to a frequency of every five years i.e., 10, and 15, 20, 25, 30 (SNH, 2009; SNH, 2017). Fatality monitoring will be undertaken in conjunction with active surveys in Years 1, 2, 3, 5, 10 and 15. (IFC, 2023).

The Applicant is committed to the monitoring and management measures set out in this management plan, and have landowner legal agreement to ensure the effective implementation of the measures outlined.

7.1 Monitoring displacement effects on whooper swans

Questions:

- Confirmation that swans continue to use Camas South.
- Are swan numbers using Camas South maintained to pre-development levels?
- Do turbines influence the distribution of swans?
- How do swans respond to the enhancement initiative?
- Do swans forage closer to turbines with time (seasonally or across winters)?
- Is foraging efficiency influenced by turbines?

Continuation of swan surveys or field surveys using road transects every two weeks will assess the extent to which swans continue to use Camas South as a foraging resource, while extending field counts to Ballycullane will act as a control to monitor for any change in the proportional use of either site. As site use could depend on habitat availability and quality – efforts to record information on changes to field management will be important.

Road transects in this context refer to a set driving route with a series of predetermined vantage points that together allow complete visual coverage of all fields within the survey area. The approach also allows for a degree of randomisation—such as varying the starting point or reversing the route order between survey days—to help control for diurnal movement patterns in swans and reduce sampling bias.

Monitoring abundance and frequency of use of the proposed field enhancement will inform efficacy and more importantly, in the first instance, whether decoys, baiting and the use of audio lures are required to initiate field use.

Meso-displacement of swans foraging in the vicinity of turbines can be estimated by recording the distance of the nearest bird from the centre of each flock. Dropping surveys following methodology of Percival (2022), will provide a baseline distribution of field use by swans relative to turbine proximity that can be repeated across years to assess habituation.

Comparing flock behaviours between fields and between sites using flock scans to record activity budgets (Camas South and Ballycullane) would indicate levels of perceived threat which could be modelled with distances from turbines and potentially differentiate between potential sources of disturbance (noise levels, flicker effects, proximity to roads, farm buildings, farm tracks, nearest cover etc.) to provide a more refined or informed baseline to those previously based on flight initiation distance.

Flock scan sampling will involve scanning through swan flocks at regular intervals—typically every 10 minutes—to record the activity of individuals. Behavioural categories will include feeding, alert, vigilant, preening, sleeping, drinking, and others as relevant. These behaviours are known to be influenced by a range of factors, including time of day, season, disturbance type and proximity, field size, proximity to cover, and flock size.

7.2 Collision risk

Questions:

- Whooper swans continued use of flight corridor to Camas South to forage in enhancement fields or fields within the wind farm matrix.
- How close are whooper swans to turbines during commuting flights or when taking flight from fields in the vicinity of turbines and whether proximity to a turbine's rotor swept area (RSA) is influenced by wind direction, wind strength and visibility?
- Is there evidence of collision fatalities from turbines within the vicinity of foraging or flighting swans?
- What are the operational avoidance rates for whooper swans at Camas South, and will it vary seasonally or during the lifetime of the wind farm?

Whooper swans flight activity and response to turbines would be monitored through a continued VP surveys once a month following NatureScot guidelines (2025a; 2025b) and ensuring overlap with morning and evening roost flights - mapping flight lines, flight heights, proximity to turbines, extent of collision avoidance, weather, wind direction, and wind speed.

Collision fatality for whooper swans will be monitored within the overall wind farm fatality monitoring plan and designed following established protocols e.g. IFC, (2023) with visit frequencies designed for smaller target species and therefore likely to be well within the persistence thresholds for swans. Any need for fatality monitoring at a reduced visit frequency and specifically for swans can be reviewed in the light of interim monitoring results and increased levels of habituation.

7.3 Management and monitoring schedule

Feature	Management Task	Management Schedule	Management Criteria Threshold	Reporting Criteria	Reporting Schedule
Habitat Enhancement	Field amalgamation 1	Before Autumn and prior to construction remove remnant scrub, young trees, bank and fence lines to amalgamate “3-corner” field and “Garden” field (Figure 5, section 5.1.2). Extend and bury drainage pipe from either end of existing open ditch leaving ditch open at the fields lowest point and re-level.	–	–	–
	Field amalgamation 2	Remove scrub, fence line and releve shallow open ditch that currently divides “Garden” field. Retain strainer posts on periphery, sink in sockets for seasonal posts and cap off for winter period.	–	–	–
	Scrape creation to attenuate central area of standing water	By early Autumn prior to construction, bund either side of the remaining central open drain with clay or other impervious material that incorporates a level-control pipe.	–	–	–
	Reduce flight obstruction	Remove or reduce to ground level the highest tree along the northern boundary of the “three-corner” field [52.480921°, -8.595348°].	–	–	–
	Maintain visual connectivity	Retain current gaps in southward field boundary along the Morningstar River without scrub or trees along boundary areas.	–	–	–
	Soil analysis	Continue with normal annual nutrient plan.	–	–	–

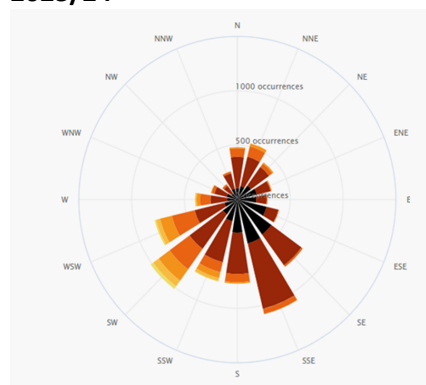
Feature	Management Task	Management Schedule	Management Criteria Threshold	Reporting Criteria	Reporting Schedule
	Sward enhancement	Harrow and stitch in 3.0 ha tetraploid Italian Rye / Perennial rye hybrid (<i>Lolium</i> × <i>hybridum</i> Hausskn), Aberecho or equivalent, into an area and at a rate to be advised. Tine harrow and stitch in every springtime areas where grass cover has been reduced.	Assess persistence and density of enhancement cultivar annually.	–	Spring
	Grazing/Disturbance restrictions	Enhancement area to be closed to grazing and disturbance between 15 October and 31 March each year.	–	–	–
	Sward enhancement (rolling)	Roll poached or uneven ground in preparation for whooper swans' arrival in Autumn and as soon as conditions are suitable.	–	–	–
Deterrence	Grassland Management A.	Shorten swards by extended Autumn grazing or low-density winter grazing; if necessary, reduce areas of surface water retention using a subsoiler; drain or temporary fence areas liable to collect standing water. In Autumn, harrow and stitch in 1–2 traditional meadow grass species if dominated by perennial rye cultivars.	Assess field suitability annually relative to previous winters' field use at local swan sites. Use quadrats and transects to monitor reseed success. From swan counts, verify decrease or absence of swan use compared to previous years.	Quadrats/transects and swan counts	Annual
	Grassland Management B.	Ensure field management within the Development boundary and vicinity of turbines T1, T2, T4 and T5 remains unsuitable for whooper swans. Shorten swards by extended Autumn or low-density winter grazing; retain old perennial rye swards; reduce surface water if necessary.	Annual transects to assess sward characteristics and compare to habitat quality at swan sites elsewhere.	–	January

Feature	Management Task	Management Schedule	Management Criteria Threshold	Reporting Criteria	Reporting Schedule
Displacement	Monthly swan monitoring	Road transect counts of Camas South and Ballycullane. Monthly behavioural monitoring using flock scans to record activity budgets.	Site use decline: >30% decline in mean flock size or swan-days compared to 5-yr baseline (excluding exceptional weather) triggers review. Sustained 2-yr decline → further enhancement/curtailment. Behavioural change: <10% swan-days in enhanced fields for 2 consecutive winters OR >25% alert/disturbed behaviour triggers corrective action.	Report and analyse enhancement/deterrence efficacy with Ballycullane as control site.	Annual, with year-on-year comparisons (Years 1, 2, 3, 5, 10 & 15)
Collision Risk	Monthly VP flight surveys	Track flight paths, altitudes, proximity and turbine response during 2 × 3 hr dawn/dusk periods, recording wind and visibility.	Swan mortality threshold: >1 collision in single winter triggers mitigation review; ≥2 collisions in 2 consecutive winters → corrective action/curtailment. Collision risk modelling: Updated modelling predicting >0.05 birds/year triggers strengthened curtailment protocols.	Monthly reporting to inform adaptive management and curtailment. Annual analysis to refine collision risk parameters with observed mortality data (Years 1, 2, 3 & 5).	Monthly & Annual

Appendices

Appendix A. Supplementary figures

2023/24



2024/25

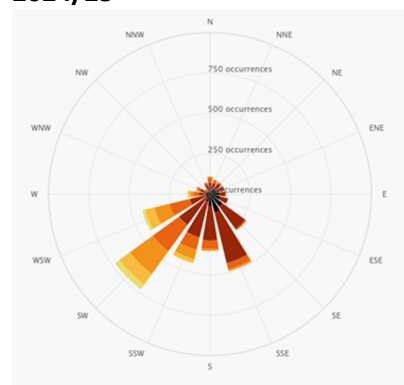
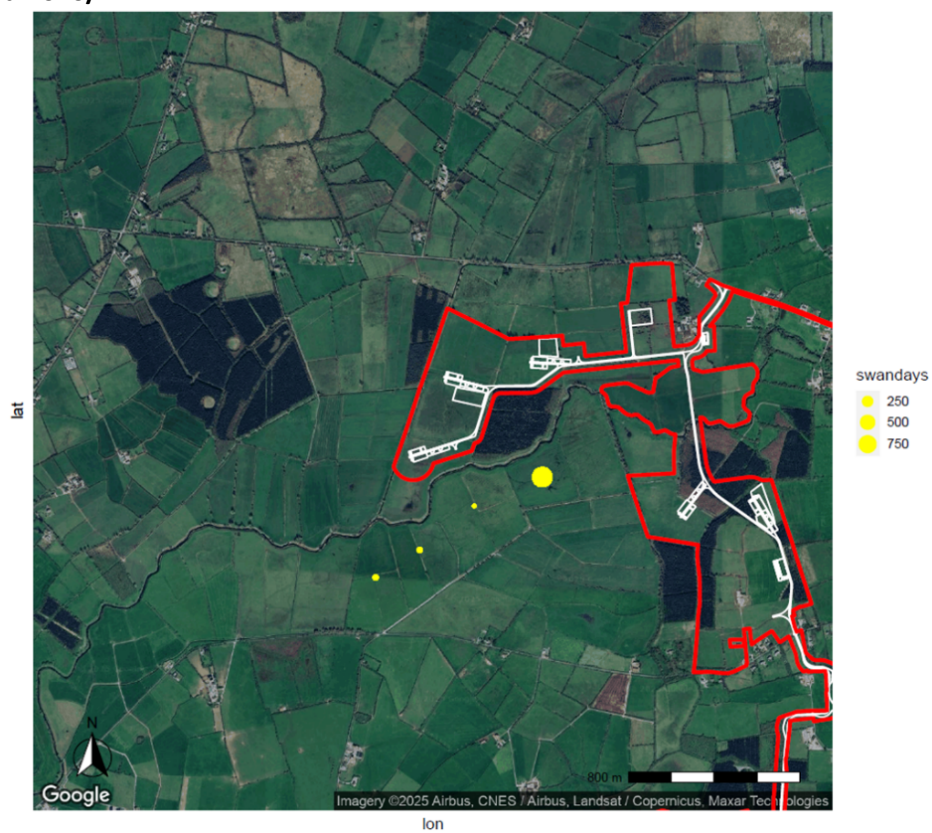


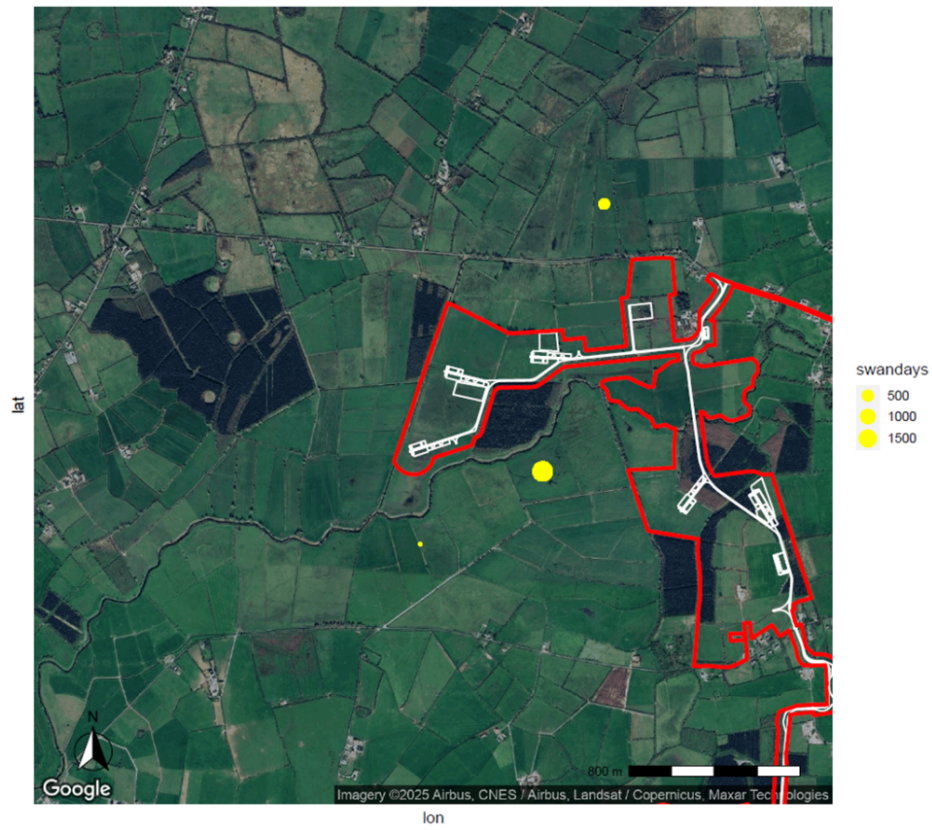
Figure A1. Wind direction and speed for Shannon Airport for Nov-Mar 2023/24 and 2024/25 (30km from Camas South).

https://www.meteoblue.com/en/weather/historyclimate/weatherarchive/shannon-airport_ireland_6296700

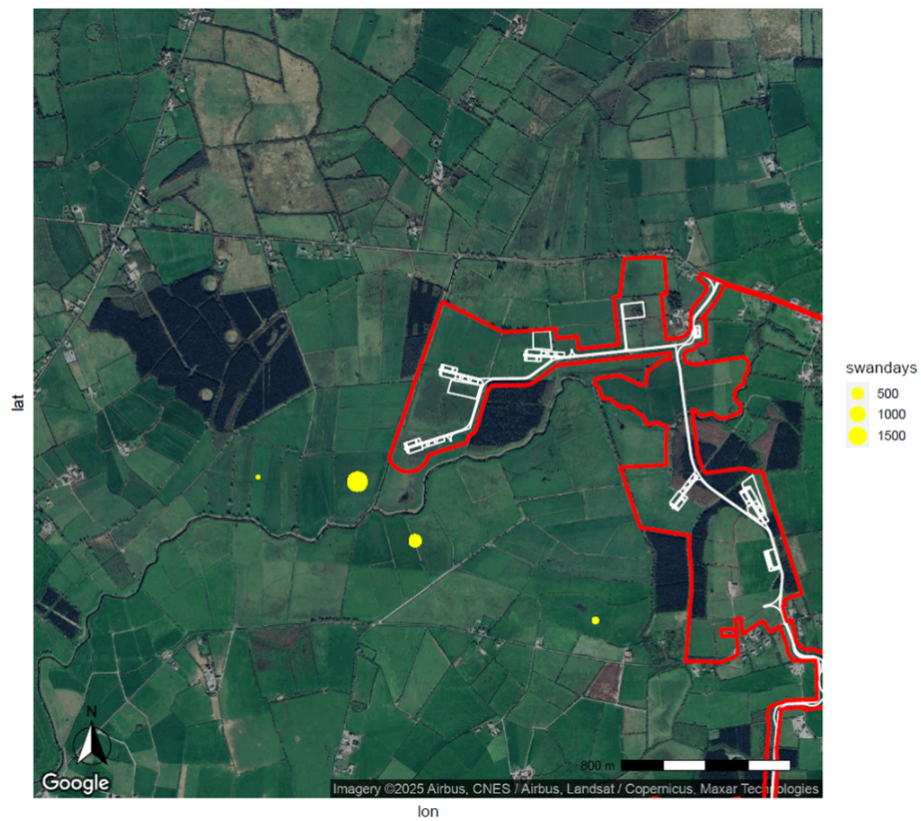
a.2020/21



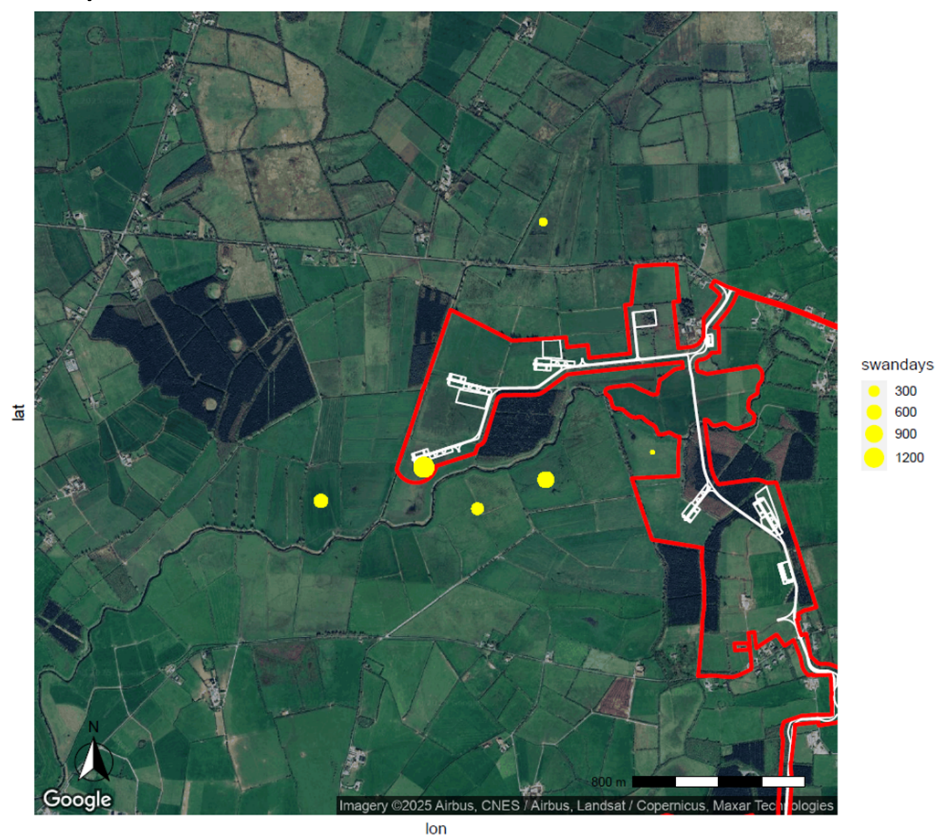
b.2021/22



c.2022/23



d.2023/24



e.2024/25

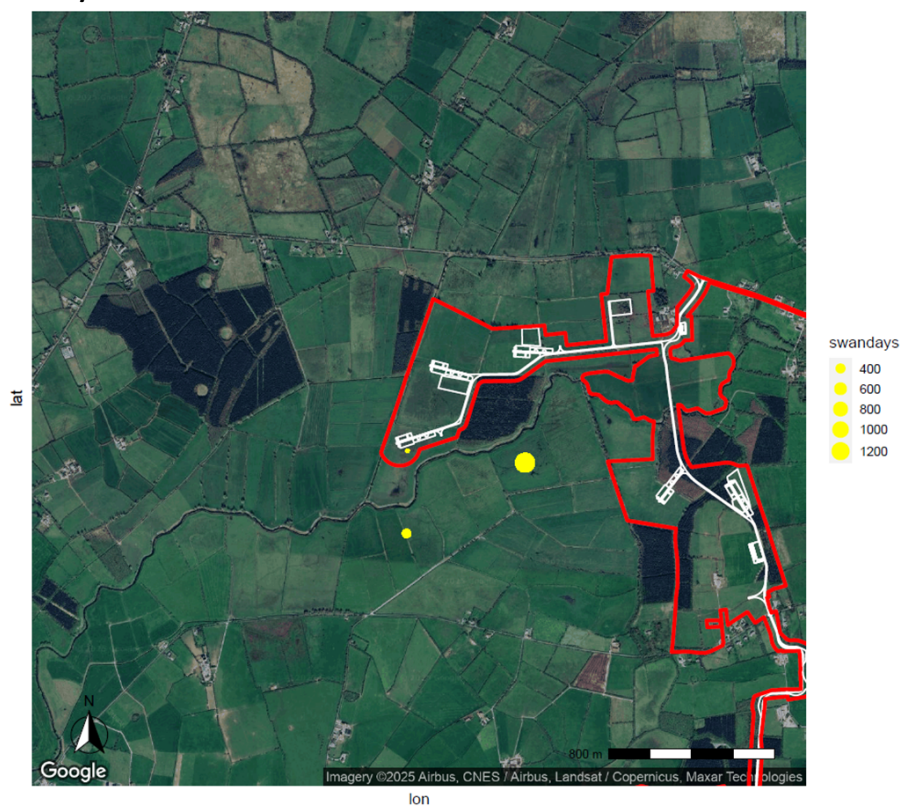


Figure A2, a-e. Annual site use at Camas South by whooper swans (swan-days (SDs)) in relation to proposed turbine array and project boundaries (red)

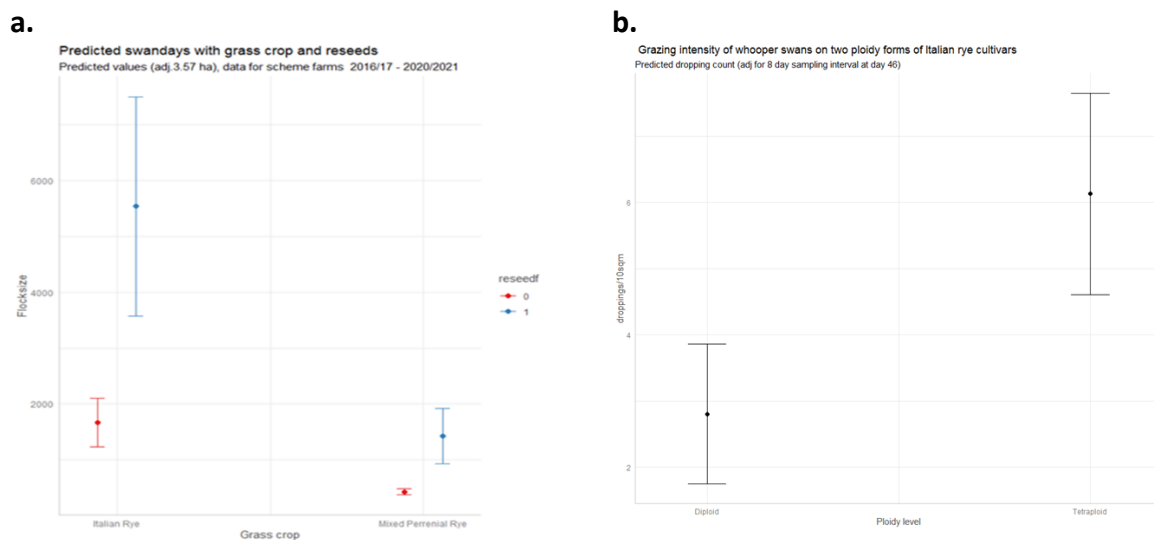


Figure A3 a. Whisker dot plots illustrating modelled abundance of whooper swans comparing Italian rye and perennial rye swards and reseed (Mackie, 2022), and **A3 b.** Grazing intensity field trial between tetraploid and diploid Italian rye cultivars (Mackie, 2022).

Appendix B. Technical note on potential impacts on whooper swans from onshore wind farms & supporting information for mitigation design

B.1 Background

Information within the scientific literature on the impact of wind farms on birds is often generalised to group level or weighted towards species that are particularly prone to collision - those that predominantly hunt for food while airborne such as raptors. Other groups and species therein are less well documented while specificity as to a wide range of possible effects and influences of turbines are undermined through the short duration of data collected, complexity of different landscapes, and ever-increasing scale of wind installations. In order to navigate a way to negate ecological impacts, mitigation often relies on pulling together and interpreting pieces of an incomplete jigsaw, with relevant case studies far and few between. This report draws from a number of studies, evolving science, impact prediction and underlying perceptions related to the potential impact of wind turbines and wind farms, focusing on large-bodied waterfowl and swans and geese in particular. The report draws from over 30 years of literature to provide context to mitigation design for a proposed turbine array juxtaposed to a small overwintering flock of Icelandic whooper swans (*Cygnus cygnus*) at Camas South, near Bruff, Co. Limerick, Ireland. The author recently completed a doctorate on whooper swans and their response to mitigation for a road development in Northern Ireland with research topics spanning habitat selection, disturbance and behavioural impacts of road and powerline infrastructure and collision risk, aspects of which are here repurposed within the context of the onshore wind industry and specifically to mitigation design for a wind farm proposal.

B.2 Introduction

Wind remains an important energy source for reducing fossil fuel emissions and their impact on climate change, regarded to be a future threat to both human and wildlife population resilience. However, wind energy installations can influence wildlife locally or regionally, across a range of taxa and notably birds, the extent of which can be highly variable and dependent and a multitude of factors (development scale, turbine size, topography, habitat) and not least the susceptibility of coincident species (ecology, morphology, seasonality, and behavioural traits). Direct impacts on birds can be through collision with turbine blades and habitat lost through the infrastructure footprint, or indirect, due to localised habitat degradation or displacement caused by disturbance (audiovisual effects of turbines or anthropogenic activity during maintenance), or to barrier effects, where displacement and habitat loss is more extensive and significant energetic costs can be incurred if birds have to make detours on migration or during daily foraging bouts.

As a guide to planning, species-specific collision probability metrics have been developed to model expected mortality rates given a number of metrics e.g. flight altitude, flight frequency, flight speed, coincidence to proposed turbine locations and extent of rotor sweep (Band et al. 2007). However, as mortality estimates between individual turbines and/or between different wind farms, can range widely, there appears to be considerable scope for reducing mortality by design and turbine placement with context to the landscape scales used by birds (De Lucas & Perrow, 2017). Similarly, displacement, although now becoming more extensively studied, is still at a level where current knowledge remains general across bird groups (Marques et al., 2021) and overall impacts are often simply classified (e.g.

negative/neutral/positive) and caveated as to the use of different experimental approaches or difficulties in accounting for confounding factors such as the distribution of habitat quality over the life time of a study. Furthermore, the length of post-construction monitoring is often limited and therefore less able to assess the extent of habituation of birds to turbines or its potential to increase collision risk. However, impact prediction and guidance for minimising risks to wildlife continues to be refined as the number of case studies grows, monitoring techniques become more advanced, and with the growing emphasis on experimental design and systematic data collection to address uncertainty.

The extent of any impact on a species will depend on its tolerance and ability to adapt to the perceived risk (May, 2017). Mitigation design to offset predicted impacts will reflect the likelihood of possible outcomes for any target species, redefined by May, (2015) by order of scale as “macro-avoidance” (barrier effects - wind farm avoidance), “meso-avoidance” (displacement - avoiding areas around individual turbines) and “micro-avoidance” (collision risk – the ability to avoid rotor sweep at close quarters). Mitigation design, therefore, needs to draw from species-specific case studies (or extended to similar species within a bird group if limited) within the energy industry or similar infrastructure developments, or occasionally from the collective expertise of professionals with ecological knowledge specific to a target species (McGuinness et al. 2015). As predicted risks for any one species may be influenced by a number of interacting variables (Marques et al. 2014) - weather, turbine operational state, changes in land use - mitigation design can encompass an element of adaptive management whereby decision-making reflects uncertainty and adjustments can be made once operational, ideally ensuring the integrity of any experimental design is maintained (Copping et al. 2019). Accomplished mitigation and improved access to its documentation may therefore enable future developments at sites where conflict levels were previously thought to be unacceptable and where, with limited data, planning would have defaulted to a more precautionary approach (May, 2017; Koppel et al. 2014).

B.3 Sensitivity of Anseriformes to wind farms (swans and geese)

B.3.1 Collision mortality

Perception

There are some similarities or common perceptions regarding species prone to energy infrastructure whether mortality risk from power line strikes or from collisions with turbine blades. The ratio of body mass to wing area of birds has been shown to dictate flight manoeuvrability (Rayner 1988) and as such bird groups with high wing loadings, including waterfowl, waders, cranes, bustards, and grebes, are least able to take avoiding action if unexpectedly, encountering an obstacle in flight (Bevanger, 1998; Janss, 2000; Barrientos, 2011). In addition, collision vulnerability has been linked to flight speeds and flocking behaviour (Alonso & Alonso, 1999; Drewitt & Langston, 2008) and to species with narrow visual fields (Bevanger, 1994; Martin & Shaw, 2010). Swans in particular, are regarded to be vulnerable with separate studies attributing high mortalities directly due to power lines; 19-38% mute swans in Sweden (Mathiasson 1992; Stolt et al. 1986); 44 % in the UK (Ogilvie, 1967); 25% and 27% for adult whooper and Bewick's swans respectively (Brown et al. 1992). In this regard ongoing efforts to highlight the spatial sensitivity of vulnerable species to energy infrastructure on migration, is an important guide for strategic planning (Gauld et al. 2022; McGuinness et al. 2015). However, as turbines are directly associated or coincident with transmission lines, they are often combined in risk analysis tables, illustrated in density grid cells with powerlines (Gauld et al. 2022), have been given the same avoidance

rates for modelling mortality (Wood et al. 2021) or adjoined in the same narrative and allows for a misconception that both turbines and powerlines pose equivalent risks in that they both represent three dimensional obstacles - albeit across a different range of flight heights. Collision risk probability of swans as a point in case remains emphasised as a species of high risk (McGuinness et al. 2015), in part given their over wintering habits of making daily foraging flights to and from nocturnal roosts, often in poor light conditions, and at flight heights susceptible to the rotor sweep of small to medium-sized turbines (Larsen & Clausen, 2002). However, recorded swan mortalities due to wind turbines appears to be very low with references that include; two confirmed fatalities for whooper swans in comparison to 25 mute swans and 38 geese (multiple sp.) registered across 15 wind farms in Germany over the period 2002-2020 (Dürr, 2020); between 0 and 2 Bewick's swans from 1,664 individuals (100 flocks) observed in flight on a Dutch wind farm (Fijn et al. 2007; 2012), and zero swans and 11 geese from 3605 fatality records from 73 studies in the US (Rees, 2012). Although the German fatality register is generally regarded to be a gross underestimate, as carcass surveys for the earliest years were largely undertaken for only one-year post-construction (Rees et al. 2012), systematic collection of data has been improving (Hötter & Dürr, 2017). While no geese or swan mortalities to turbines have been reported in Ireland, even if in part due to the confidential nature of such data (Rees, 2012), if assumed to be low, is in stark contrast to mortality recorded for powerlines with 490 electric outages in Northern Ireland alone attributed to whooper swans and low voltage lines between 1998 - 2007 (Preston, 2006).

Avoidance rate for swans

The avoidance rate for predicting swan collision with turbines has been repeatedly reviewed by Nature Scot (previously SNH) and increased from 95 % to 98% (SNH, 2010) and from 98% to 99.5% (SNH, 2018) in the light of growing evidence (Band, 2024; Whitfield & Urquhart, 2015; Whitfield, 2010). Whitfield & Urquhart (2015) recommended an even higher avoidance rate of 99.8 for swans if recalculating mortality risk with a 49% rate of macro-displacement for swan flights ~ 300m from turbines as observed by Fijn et al. (2012) but stopped short of advocating a further increase in avoidance rate to reflect an apparent reduction in post construction swan abundance, acknowledging the limitations of a single study and that year-effects on habitat quality could not be ruled out.

The prediction of collision mortality using the standard Band model (Band et al. 2007) and premise of using pre-construction field data, is subject to varying degrees of uncertainty not least due to the unknown extent to which a target species is likely to avoid individual turbines, or wind farms entirely, once turbines are operational. This conundrum has prompted attempts for alternative modelling methods (Everaert, 2014; Kleyheeg-Hartman et al. 2018) that draw upon individual case studies where mortality for a number of species has been quantified, incorporates turbine array metrics and the frequency (and abundance) for birds that continue to fly through and/or forage within the wind farm envelope. However, as the number of species-specific case studies for such models remains limited and the extent of displacement likely to vary with site, (habitat quality, topography, levels of habituation etc.), the Band model remains the common standard for many countries not least due to the issues of collecting reliable mortality data from offshore wind farms (Band, 2024). The likelihood or the extent of avoidance, however, still needs to be addressed or in some way quantified where proposed turbines are proximal to regular flightlines or foraging areas, and where mitigation measures need to be designed to reduce potential collision whether by manipulating landscape use through habitat enhancement or deterrence or creating habitat offsite if barrier effects are thought likely.

B.3.2 Displacement and avoidance

Anseriformes (the taxonomic order relating to waterfowl) are generally regarded to be particularly prone to displacement by wind turbines with meta-analyses finding 68.2 % and 69% of peer reviewed studies to have reported negative impacts from wind energy installations (Marques et al. 2021; Hötter, 2017). Anseriformes are thought to be particularly affected being coincident to open landscapes such as grasslands, farmland and wetlands, where wind energy is well-defined (Langston & Pullan, 2003; Hötter, 2017; 2006; Stewart et al. 2005), and their tendency to be more risk-averse compared to higher order bird groups such as raptors (Lima & Dill, 1990; Blumstein, 2006). Marques et al. (2012) reported mean displacement effects of 116m (+/- 64m), with up to 54% of studies indicating a lower abundance post-construction. However, sensitivity to disturbance varies among the family groups (geese, swans and ducks) and between species, attributed to a variety of characteristics e.g. body mass and aerodynamic ability to take flight (Blumstein, 2016; Morelli et al. 2019 *a & b*), brain size for cognitive perception (Samia et al., 2015), and to whether species are hunted and more fearful in certain settings (Elmberg et al. 2025; Madsen 1985; Fox & Madsen 1997; Laursen et al. 2009). Hötter (2017) in his review on wind farm impacts found 90% of all studies relating to geese (n=20), indicated displacement effects compared to 78% for swans (n=9) and 78% for ducks (n=54).

Perception of risk

Distribution and abundance is, invariably, influenced by an interplay between resource availability and a perception of risk (Lima & Dill, 1990; Gill et al. 1996) whether risk is the likelihood of predators, natural or human, (e.g. proximity to areas of cover or perches) or, as in the context of infrastructure, audiovisual disturbance from wind farms, roads, areas of human settlement or an awareness of collision-risk if venturing too close to turbines or powerlines. The distances at which birds can tolerate disturbance may also vary with season when colder weather or pre-migration preparation affects nutritional need (Elmberg et al. 2025), tolerance within larger flocks (Madsen, 1985; Beauchamp, 2017) or reduced by habituation (Hockin et al. 1992; Coetzer & Bouwman, 2017). May et al. (2015) put forward the use of flight initiation distances (FIDs) of different species (first described by Blumstein, 2005) as a metric of awareness that might guide species-specific mitigation measures to minimise collision risk with turbines for less aware species. However, established FID's may also provide context to guide displacement prediction given the limited number of case studies published for specific species i.e. swans, and that with caution, can be supplemented with findings from a similar wildfowl group - such as geese. A recent FID study by Elmberg et al., (2025) comparing single species flocks on agricultural crops found across three complete winters and in decreasing order of fearfulness recorded (with mean distances in metres and standard deviation in parentheses), bean goose (171.3m, 54.9) further than greylag goose (103.6m, 50.1) > whooper swan (101.9m, 42.4) > Canada goose (92.1m, 62.5) > barnacle goose (77.1m, 41.3) recorded at the closest distance. While FIDs broadly conformed to body mass as hypothesised by Blumstein (2006), with barnacle as the lightest goose likely to have to feed longer and prolong flight initiation as a predator response, whooper swans had shorter FIDs than expected than both bean and greylag geese with the disparity attributed to the former species being protected from hunting (Elmberg et al. 2025).

Avoidance metrics

Avoidance distances from turbines reported for overwintering geese and swans varies between and within species (Rees, 2012; Hötter, 2006; 2017) while direct comparisons of studies are hampered by

the use of different displacement metrics (minimum, median and mean minimum distances; distance at which 50% abundance occurs; zone of absence or reduction; distance from flock centre) reflecting partly the different methodologies used (bird counts, faecal density transects), and extent of experimental design from anecdotal to Before and After Construction Impact designs (BACIs) or Gradient Impact designs (GIs), but also as post-construction monitoring is frequently limited to one year.

Reported avoidance distances for overwintering swans and geese range from 200 – 560m and 30 - 600m respectively (Rees 2012), or as median and means of 125m and 150m (swans n=8)) and 300m and 347m (geese (n=15)), (Hötter 2017) which are broadly comparable to the FIDs reported for an approaching human by Elmberg et al. (2025). Swan flocks of mixed species were reported to continue their use of fields adjacent to a linear wind farm development at the edge of Lake IJsselmeer at Urk, Netherlands (Winkelman, 1989), a small proportion of which foraged within 50 metres of turbines although larger flocks appeared to cluster at between 200-400m from turbines compared to an adjacent control area with no turbines. Furthermore, the only apparent negative impact reported in regard to the distribution of whooper swans, was only found to be significant within the second year of operation, while for Bewick's swans, mute swans, bean geese, barnacle geese and greater white-fronted geese, there was no apparent wind farm impacts for the two years of post-construction monitoring. Another BACI-based study by Fijn et al. (2012) on Bewick's swans commuting 2 – 3 kms from Lake IJsselmeer (Netherlands), found swans continued to forage between two parallel lines of turbines 1.6 kms apart but in reduced numbers post-construction. However, having initially preferred to fly further to forage, swans returned to feed within the wind farm in greater numbers towards the end of the winter and to feed to within 125 m of turbines (average distance of 560m from flock centres). Fijn et al. (2012) further reported macro-avoidance where 16% of all swans surveyed, commuting from their nocturnal roost, flew through the middle of the wind farm while 49% adjusted flight direction on approach. No near-misses were witnessed and if swans approached turbine lines from the side, flight paths were adjusted within 300m of towers, regularly flying between turbines spaced 300-400 m apart and without any evidence of collision - even when flying in poor light conditions and when verified by radar > 30 minutes after sunset (ibid).

Habituation

Whether the seasonal increase reported within the wind farm by Fijn et al. (2012) could be regarded as habituation is debatable as by strict definition it would need marked individuals for assessing changes in behaviour and more than a single year of post-construction data. Percival (2005) on reporting much-reduced avoidance distances to within 30m of coastal turbines for barnacle geese using saltmarsh, suggested that close proximity to turbines was likely a response to limited resources. For comparison, barnacle geese were completely excluded within 300m (and 50% reduction of habitat use from 300 – 600m) in the Netherlands, foraging in mid-winter within more homogenous farmland where they had greater choice (Kruckenberg & Jaene, 1999).

Stronger evidence for apparent habituation has been demonstrated by Madsen & Boertman (2008) who after returning to resurvey displacement distances for spring-staging pink-footed geese after a decade of wind farm operation, discovered minimum distances at three different wind farms had more than halved from 60m to 20m (Velling cluster), 175m to 75m (Klim cluster) and 75m to 25m (Thorup line). Furthermore, the reluctance of geese to venture beyond 200m of the outer edge of the Velling

turbine cluster a year after construction (Larsen & Madsen, 2000) had progressed to geese foraging 20 m from turbines within the wind farm matrix (Madsen & Boertman, 2008). The likelihood of increased collision risk with reduced avoidance has of course been raised (Hötter, 2017; Larsen & Madsen, 2000). However, there is currently no evidence that this is the case, in fact, theoretical avoidance rates used for predicting collision rates have gradually been revised upwards for both geese and swans over the last decade (Whitfield & Urquhart, 2015; SNH, 2013; SNH, 2018).

Scale effects

Turbines have, however, gradually increased in size from small < 500kW turbines with hub heights and rotors ~30m (1980/90's) to medium turbines in late 1990's (500-1000 kW) with hub heights and rotor diameters ~ 50m to large turbines (1-5 MW) with hub heights 60-120 m and rotor diameters 66-160 m, as the industry expands and repowers existing wind farms with improved commercial and technical efficiencies (Enevoldsen & Xydis, 2019). Case studies examining how birds respond to a rapidly expanding wind industry - and the response of birds to larger turbines in particular – is struggling to keep pace (Madders & Whitfield, 2006; Rees, 2012). Hötter et al. (2005); Hötter (2017) demonstrated a positive correlation between avoidance distance and turbine hub heights with lapwing, golden plover and carrion crow while Madsen & Boertman, (2008) suggested that observed habituation of pink-footed geese may have been less progressive in one of the two wind farm clusters they studied due to its larger turbines with hub heights of 45m (Klim wind farm) as opposed to 21-31.5m at Velling. Increasing the distance between rotor tip and ground level has been suggested could reduce collision risk for commuting swans (Larsen & Clausen, 2002) where daily flight altitudes were found to be below 50m, while larger turbines with greater ground clearance have been demonstrated to reduce mortality per unit area of rotor sweep by one third (Krijgsveld et al. (2009). In a review by Hötter, (2017), taller turbines reduced displacement distance for more sensitive species groups, including wildfowl, and suggested that the slower speed of rotor tips and increased distance from the ground may be less disturbing while others have indicated that the increased distance between larger turbines helps to reduce barrier effects imposed by linear wind farms (Fijn et al, 2012). A more recent and ongoing long-term study on greater white-fronted geese and red-breasted geese in the Saint Nikola wind farm in Bulgaria (Zahtindjiev et al. 2017) have found minimal displacement effects for a wind farm with a matrix of 3.5 MW turbines (hub heights of 105m and rotor diameters of 90m with turbines 300-600m – 2000m apart) with an average minimum foraging distance from turbines of 80m (range 30-196m) and no recorded collisions during six years of systematic carcass monitoring. However, although the abundance of geese appears unchanged, there remains some debate as to whether an expansion in foraging range and a reduction in flock sizes, is a response to the wind farm or a combination of other factors such as field size contraction, habitat fragmentation (increasing linear infrastructure) and spatial variation of hunting disturbance (Harrison et al. 2018; Zahtindjiev et al. 2017). In contrast, post-construction monitoring (years 1 and 3) of the recently repowered Klim wind farm, after the installation of a reduced number of 3.5 MW turbines in 2015 (93m hub height, 113m rotor diameter), continues to have a significant macro-avoidance effect where a large proportion of ~24,000 thousand commuting pink-footed geese continue to flight above or around the wind farm periphery (Drachmann et al. 2021). However, turbines at the Klim wind farm are closer together than the Saint Nikola wind farm (~300m between turbines with two lines 500m apart compared to 300-600m-2000m), while turbines in the former also intercepts the flight path between roost and foraging areas. By comparison, collision mortality at Klim is also evident with an estimated collision mortality that increased in year 3

(est. avoidance at 99.92 – 99.95% in year 1 and 99.81-99.88% in year 3), coincident to a reported increase in the proportion of foraging geese (21% to 49%) - to those in flight - suggesting perhaps, habituation or alternatively just a response to local habitat quality. Common cranes (*Grus grus*) at the same wind farm, in contrast to pink-footed geese, displayed meso-displacement avoidance, flying between turbines but with no recorded mortalities over the same monitoring period (Drachmann et al. 2021).

Meeting net zero targets for decarbonisation remains an ongoing challenge even as wind energy technology continues to improve with an ability to generate power from ever lower windspeeds with larger turbines and rotors (Enevoldsen & Xydis, 2019). With turbine location issues ongoing with proximity to settlements, transportation logistics and increasing environmental concerns over species decline and biodiversity loss, the need for longer term monitoring and tailored experimental design remains essential. Improving the efficacy of impact prediction, expanding a portfolio of mitigation solutions, refined research, adaptive management and a legacy of robust analyses, can only help facilitate future planning proposals.

B.4 Icelandic whooper swan

B.4.1 Demography

The Icelandic whooper swan population was last censused in 2020 at 43,255 (Brides et al. 2021) 27.2% higher than the 2015 estimate and double that of the 2000 census (Hall et al., 2016) with largest change in numbers in England, where wintering numbers had increased by 32% to 15,927 compared with a 22.1% increase in the Republic of Ireland at 14,467 and which now holds 36.8 % and 33.4% of the population, respectively (Northern Ireland 4,644, 10.7%). This most recent increase in Ireland marks the end of a period of gradual stagnation (Burke et al. 2020) but still remains a reduction in the overall proportional share as the population expands at a greater rate in SE England (Brides et al. 2021). Productivity estimates typically range between 15% and 20% and brood size at between 2.0 and 2.5 cygnets. Accessibility to an abundance of wintering foraging resources provided by more intensive arable and livestock farming have been suggested as an explanation behind an increasing population trend. However, a recent capture-mark-recapture analysis covering a period of 30 years has also suggested that the increase may be partly due to an improved survival rate with whooper swans that choose to winter on nature reserves increasing their survival rates across all age classes; from 0.77 to 0.85 for adults, 0.73 to 0.86 for yearlings and 0.72 to 0.91 for juveniles (Soriano-Redondo et al. 2023). Reduced exposure to ingesting lead shot, supplementary feeding, managed roost sites, increased use of diverters on powerlines, and reduced disturbance have all been put forward as possible cause.

B.4.2 Ecology

Whooper swans in the UK and Ireland traditionally overwinter on freshwater habitats and agricultural land, with a gradual shift from the mid-20th century, from feeding predominantly on aquatic vegetation to arable crops and improved pasture (Robinson et al. 2004; Brides et al. 2021). However, whooper swans continue to exploit aquatic vegetation in early Autumn (Harding 2008; Rees et al. 1997) but once depleted or inaccessible, the majority of whooper swans in Ireland move to improved pasture, often with a preference for new grassland leys (Colhoun, 1998; Rees et al., 1997), or increasingly as is the case in southern England, winter cereal crops (Brides et al., 2021). In 2020 international whooper swan census, 71.6% of whooper swans in the Republic of Ireland were on

pasture of which 53.3% were recorded to be on improved dry grassland and 12% on improved wet grassland (Brides et al., 2021). However, the presence and importance of water when feeding on pasture may not be accurately portrayed under standard swan census methodology. Habitat selection analysis for a study on Whooper swans at Toome in Northern Ireland, (Mackie, 2025) demonstrated that water availability was a key driver for field selection, lying mostly in microtopographic depressions below the sward, on compacted areas at field gates or ruts made by agricultural machinery, and not necessarily visible when viewed obliquely from the edge of a field. More extensive flooding in agreement with Bowler (1996), had a small negative effect likely due to grass die-off if swards were inundated for long enough to degrade, while during a dry winter semi-permanent or permanent water was positively correlated with flock size.

Whooper swans once aquatic vegetation is depleted - or out of reach as water levels rise - behave as central foragers flying from lakes or rivers used as nocturnal roosts to nearby foraging fields usually within 1-3 kms but can be several kilometres away. The energetic constraints of flights can have a bearing on habitat selection and distances flown (Gill, 1996; Johnson et al, 2014) with shorter distances recorded at Toome in spring (Mackie 2025) thought to benefit weight gain in preparation for migration with a similar occurrence reported for barnacle geese in the Netherlands in spring (Si et al. 2011). Opportunities of reducing energetic costs are also occasionally taken when swans are able to remain within a few hundred metres of foraging fields by roosting in temporary floods but may need to be vacated during the night, demonstrated by telemetry at Toome (Mackie, 2025) as generally shallow and vulnerable to fox harassment.

B.4.3 Pasture quality

Forage quality has been demonstrated to decline (lower nitrogen content and increased fibre) as swards lengthen (Summers & Critchley, 1990; Owen et al. 1977) and is known to influence field selection of geese (Vickery & Gill, 1999), although longer swards may be exploited after the application of nitrogen fertilisers (Riddington et al. 1997; Hassell et al. 2001; Owen et al., 1977). The application of nitrogen fertiliser may alter a range of properties that affect habitat quality, improving digestibility by increasing protein and water content (Prop et al. 2005; Owen et al.1977) to reducing the levels of acid detergent fibre thereby enhancing metabolizable energy (Prop et al., 2005). Similarly different grass species will vary in quality (Fox & Abraham, 2017; Vickery & Gill,1999) and where wildfowl once had more specialised preferences for certain grass species there has been a shift to the more digestible and increasingly widespread monocultures, and perennial rye-dominated swards in particular (Fox et al. 2016; Owen et al. 1977). Mackie (2025) demonstrated that for whooper swans, fine scale field selection was indeed influenced by sward height with a greater probability of field use if perennial rye swards were less than 15 cms in height, had a high percentage of a medium leaf grade (4-6 mm blade width), and a higher percentage of grass cover. In the same study and as reported by others (Colhoun, 1998; Rees et al. 1997), whooper swans were attracted to reseeded fields but fields at Toome had an even higher intensity of swan use if sown with Italian rye (*Lolium multiflorum*). Furthermore, a 2 x 3 plot field trial monitoring faecal plots and two different ploidy levels of Italian rye, indicated an apparent preference at ploidy level in this case for tetraploid over a diploid cultivar (Mackie, 2025).

B.4.4 Habitat use and disturbance

Preferred habitats and foraging requirements can change in time as a function of thermoregulatory constraints, perception of predation pressure and demands of migration (Owen et al., 1992; Fox et al.,

2016; Fox & Abraham, 2017). The quality of foraging resources therefore plays a central role in habitat selection for most species (Forsman et al., 2008; Bock & Jones, 2004; Morris, 2003). In the case of herbivorous wildfowl with a limited ability to digest fibre (Prop & Vulink, 1992; Sedinger, 1997), there is a balance between selecting habitats offering high intake rates and the quality of vegetation they contain (Fox et al., 2016). The efficiency of feeding must also have a role in balancing energy budgets and influence field use with forage density (biomass) (Rees, 1990) and bitesize (Hassall et al., 2001) regarded as important components. Field selection will therefore not only be influenced by the cost of commuting distance from a roost, but the additional energy lost if repeatedly disturbed after arrival.

To mitigate the potential reduction in habitat quality through pervasive or indirect disturbance events it is important to know to what extent animal behaviour might be impacted and under what circumstances mitigation through landscape design or disturbance management might be appropriate and effective. Conventional methods of measuring disturbance (effects) on birds include “flight initiation distance” (Owen, 1977; Madsen, 1985; Blumstein, 2016; Coetzer & Bouwman, 2017), flight frequency (Norris & Wilson, 1988; Gill et al. 1996), “approach distance” (Madsen, 1998; Rees et al. 2005), displacement period (Madsen, 1998) and recording different behavioural states and activity budgets for flocks or focal individuals (Rees et al., 2005; Taylor et al. 2019; Yu et al. 2019). Alternatively, site specific impacts of disturbance can be analysed by correlating disturbance frequency with spatial depletion using a resource-use trade-off (Gill et al. 1996; Madsen, 1998; Gill, 2007; Wallis et al. 2019). Although disturbance is often associated with discrete events, the relevance of chronic disturbance (constant, low-level, pervasive, ambient, or gradual), with its role in modulating disturbance variation, has been recognised in classical disturbance studies (Fraterrigo & Rusak, 2008) and may be just as relevant in behavioural ecology. A recent assessment of disturbance gradients, habitat use, sensitivity to disturbance, and prevalence of disturbance events were all key objectives associated with mitigating impacts of a recent road development on whooper swans at Toome in Northern Ireland (Mackie, 2025). Although the standard three year period for post construction monitoring fell short of swans returning to certain fields at pre-construction levels (i.e. a period of neophobia) to complete a before and after comparison in behaviour, there was strong evidence to suggest swans which selected fields closer to a pre-existing road section, were able to forage more efficiently due a reduced vigilance. However, as to what extent this was due to masking by chronic disturbance from traffic, an absence of certain disturbance sources in proximity to the road (e.g. hunting) and/or to an element of habituation to cars and people, remains uncertain.

The extent of displacement of wildfowl from turbines as well as evidence of habituation has previously been assessed using faecal transects or bird counts to provide minimum distances and relative abundance as a gradient of habitat use (Larsen & Madsen, 2000; Madsen & Boertman, 2008; Harrison et al. 2018). However, a combination of abundance with behavioural response may be more informative in evaluating the effects of individual turbines and associated infrastructure, as well as context to settings and ever-increasing turbine size. A behavioural approach would also help refine and validate existing guidelines on buffer zones as prescribed by Goodship and Furness (2022) currently suggested for swans and geese species regarded to be of medium sensitivity, to be “200m-600m”. An improved understanding as to the interactions between habitat quality, wind farm effects, additional linear infrastructure and disturbance levels e.g. distribution/intensity of local hunting (Harrison et al. 2018, Madsen, 1985), would clarify mitigation efficacy and provide answers as to why certain wind farms are tolerated by geese over others and even possible benefits – as indicated might be the case

for red-breasted and greater white-fronted geese foraging within the Saint Nikola wind farm in Bulgaria (Zahtindjiev et al. 2017).

B.5 Mitigation

Ecological mitigation measures are designed to reduce the effects of environmental change on habitats or species of importance. With respect to infrastructure development, the Mitigation Hierarchy is an industry adopted, formalised planning tool used in Environmental Impact Assessments (EIAs) whereby broad mitigation concepts are sequentially explored or enacted in decreasing order of preference, namely to (1) avoid, (2) minimize, (3) remediate, or (4) offset the negative effects of change (zu Ermgassen et al., 2019; Arlidge et al., 2018).

Those impacts that cannot be avoided or minimised by design (1&2), may be successfully offset by habitat creation, restoration, or enhancement nearby (4). Although the effectiveness of any mitigation scheme can be enhanced by optimising ecological design (Madsen et al., 2014) the efficacy of mitigation measures may be linked to the evidence-base (or lack thereof) that underlies their design (Hunter et al., 2021). This can be further complicated by lag effects through delayed ecological response or additive post-development stresses, which may not be evident until after any requisite monitoring protocols have ceased to operate (Findlay & Bourdages 1999; Zhang & Fox, 2019).

Following the mitigation hierarchy (zu Ermgassen et al., 2019; Arlidge et al., 2018) direct, and occasionally indirect, habitat loss, that can only be remediated or offset (rather than avoided or minimised) requires a level of ecological understanding to ensure not only that the new habitat is likely to be used but should ideally provide at least a neutral gain without any obvious consequential or indirect increase in mortality risk. Mitigation design is rarely straightforward, however, being reliant partly on a combination of relevant case studies and field data often collected over a limited time frame from which year-effects may not be realised. Inevitably, where a suite of mitigation measures is introduced, the efficacy of each component, although difficult to assess, is secondary to whether a target threshold is ultimately matched within the post-development monitoring period. With a growing recognition of a gap between conservation research and mitigation practice (Hunter et al., 2021; McDonald et al., 2020) the need to improve the availability and systematic use of empirical evidence in conservation management is regarded as fundamental (Sutherland et al. 2019).

Mitigation design for wind farm development at Camas South is fortunately able to benefit not only from five years of monitoring, but also from a recent study specifically related to whooper swans and mitigation for a road development and associated risk of powerline collision at Toome, Northern Ireland. Where there may be many similarities between both development projects (species, infrastructure, habitat enhancement, potential disturbance), there is also opportunity to build knowledge on mitigation efficacy and how whooper swans may be successfully accommodated.

B.5.1 Displacement risk

Camas South although used less by whooper swans than a sister sub-site at Ballycullane, appears to be well established as a foraging site whether visited as a response to seasonal variations in habitat quality, when energetically efficient to reach against prevailing winds, or when displaced by disturbance. In any event, with a degree of tolerance by whooper swans reported from other wind farm studies (Winkleman 1989; Fijn et al. 2012; Scottishpower Renewables, 2019) and an expected

element of site philopatry, whooper swans will invariably attempt to continue using Camas South as a foraging site given appropriate design and the attraction of suitable habitat. With this in mind it has been proposed that turbines T1 and T4 are to be located 1km apart to provide clearance (flight divergence occurred at ~300m for Bewick's swans (Fijn et al. 2012)), either side of their main flightline from Lough Gur (Figure 1). The majority of recently used foraging fields remain within expected limits of tolerance (> 200m,) from the closest turbine (T3), and 500m from turbines T1-T5 to the centre of the 75% KDE isopleth which marks the most intensely used area for the last five winters. In addition, habitat enhancement will be directed to an amalgamation of fields encompassing 13.7 hectares of floodplain located on the flightline and peripheral to the turbine array (Figure 1).

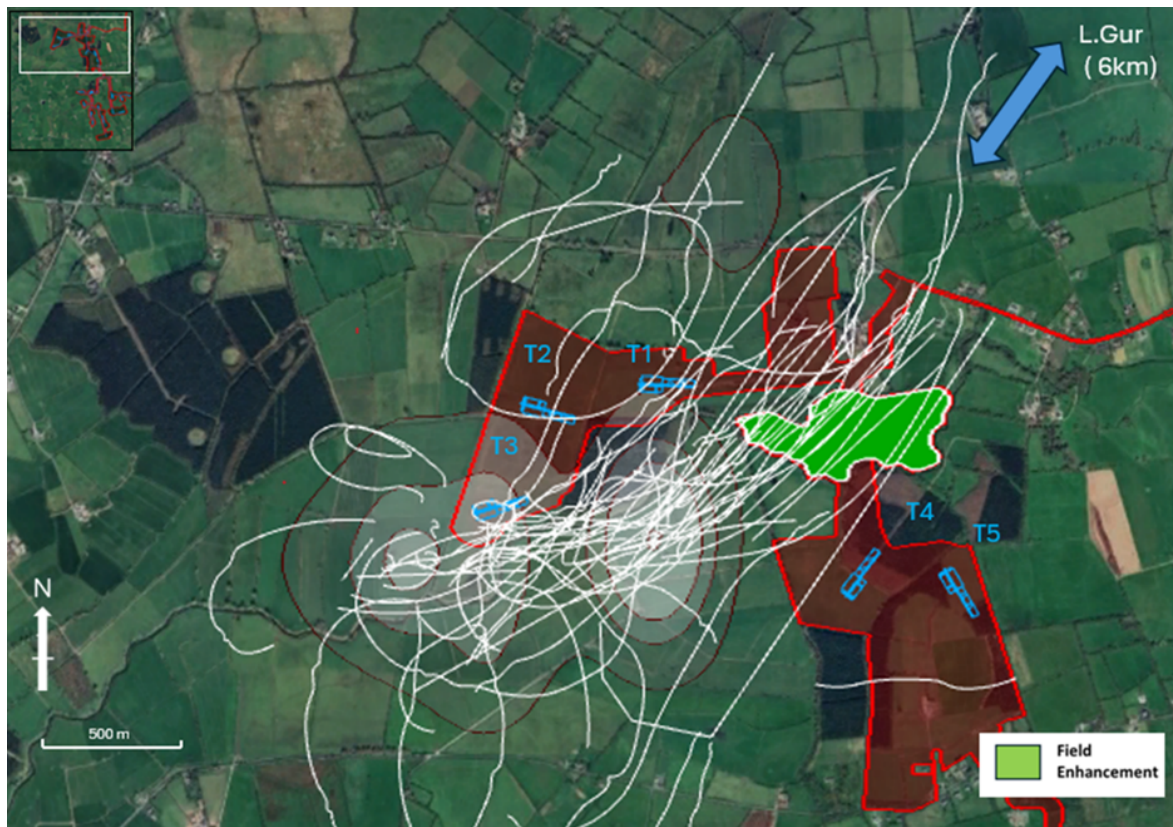


Figure 1. Projected flight lines from VP surveys illustrating SW-NE trend with proposed area for enhancement. KDE isopleth bands are used as a swan-day index for site use while here shading increases with intensity of use.

B.5.2 Collision risk

On the basis of literature reviewed, the risk of collisions with turbines for whooper swans is generally thought to be extremely low (Fijn et al 2012; Whitfield & Urquhart, 2015; Whitfield, 2010) and contrary to what might be indicated by the more precautionary position taken by Rees (2012) and McGuinness, (2015). The recent increased 99.5 % CRM avoidance rate (Band, 2024) has been commonly adopted until such time further case studies become available that would support the higher rate 99.8% (as for geese) proposed by Whitfield & Urquhart (2015). Quantifying levels of macro as well as meso-

displacement may increase avoidance rates even further (Fijn et al. 2012; Whitfield & Urquhart (2015)). Micro avoidance – regarded as the ability to avoid collision at close quarters (< 10m (Cook et al. 2014)), is not regarded to be high for a large-bodied bird such as a swan and hence the perceived susceptibility to collision mortality and reputation as a high-risk species, and with powerlines in particular. It is well established that collision risk to powerlines is influenced by an number of factors e.g. flocking behaviour, flight speeds, (Alonso & Alonso, 1999; Drewitt & Langston, 2008), species with narrow visual fields (Bevanger, 1994; Martin & Shaw, 2010), and fatalities more pronounced if coincident to migration corridors, between roost and foraging areas (Janss & Ferrer, 2000; Bevanger & Broseth, 2004) or when migrating at night (Bevanger, 1994; Bernardino, 2018). However, it also has been demonstrated that there is a contrasting mortality risk between migrant and sedentary birds of the same species e.g. Great Bustards (*Otis tarda*) (Palacin, 2016), indicative that risks are lower for local individuals which have an enhanced knowledge of their surroundings. This latter finding may also be argued is likely to be the case for overwintering whooper swans, where repeated daily flights along a regular route promotes a high degree of awareness to landscape obstacles. Evidence from the whooper swan study at Toome (Mackie, 2025) demonstrated exceptionally low mortality from commuting flights over powerlines with avoidance rates of 99.99 % estimated from carcass recovery and the number of individual flights inferred from field use. Avoidance rates were, however, slightly lower (99.98 %) in midwinter which might be expected if flying in poorer light conditions, as swans foraged longer after sunset with shorter daylengths and flew to roost significantly later. Incidentally, roost flight surveys observed line clearance to be minimal < 5 m, with flight altitude often dropping between line-spans supporting a high level of spatial awareness. Further anecdotal evidence would suggest an ability to assess risk with swans giving more clearance to powerlines when returning to roost in windy weather, or on one occasion in storm conditions returned to roost an hour early in good light. Although this may suggest a high level of visual acuity and awareness of static obstacles by whooper swans – their ability to negotiate moving turbine blades if habituated and flying in close proximity to turbine towers, may be challenged. The extent of turbine avoidance by large-bodied birds (including swans) has been recently quantified in a Danish case study (Therkildsen et al. 2021) and partly explains the low collision incidence reported in the same study, in that birds flying through the RSA or at collision height, reduced as the distribution of flying birds both condensed between turbines (> 150m), or either climbed above or dropped below collision height once turbines were operational - effectively halving relative proportions of flights within the rotor swept zone. It is worth noting, however, that the Danish study also recorded a small percentage of total flights below the RSA (< 45m) but within 0-50 m (<5%) and 50-100 m (~5%) increments from turbine towers. Given that the altitude range of whoopers swans' commuting flights are between 10 - 45m (Larsen & Clausen, 2002) larger rotor diameters as proposed for Camas South (currently giving a ground displacement of 24m) could increase collision risk if swans are prepared to fly in close proximity to turbines. To minimise risks to whooper swans, turbines that are closest to a potential foraging area could either carry smaller rotors i.e. 100 m as used in the Saint Nikola wind farm in Bulgaria with negligible reported collisions for geese, or if necessary, be subject to curtailment periods to cover daily flight routines moving to and from roost. An exception to this is at T6 where turbine dimensions are different, and has a ground clearance of 14 m, however T6 is located sufficiently far from the main whooper swan activity area, such that it is not expected to pose a collision risk. Painting a single blade black (or red) is currently being trialled in the Netherlands, Spain, South Africa and is planned for an offshore UK wind farm, after a ground breaking trial on a Norwegian wind farm found reduced collision mortality of White-tailed Eagles (May

et al. 2020), However, first year results using a BACI design and 14 turbines at Eemshaven, Netherlands, to reduce of high mortality observed during migration months (gulls, waders and passerines), have so far been inconclusive but another final year of the study is still to be published (Klop et al. 2024).

The use of both visual (e.g. flashing lights, strobes, giant eye transfers) or acoustic deterrents have been trialled in the past to discourage bird groups exhibiting the least avoidance from turbines e.g. raptors but with a mixed effects in the literature not least due to the longer-term issues of habitation (Dooling, 2002; Smith et al. 2011). Habitat manipulation can be used as a deterrent either on its own or in conjunction to habitat enhancement in order to lure target species away from turbines and has been attempted for eagles (Walker et al., 2005), planting scrub to deter kestrels from hunting at turbine bases (Cordeiro et al. 2013) and clearance of nesting habitat for European nightjars (Shewring & Vafidis, 2017) and for geese (Percival et al. 2020; 2021). For grasslands, specific sward heights and seed mixes are commonly used in airports to reduce risks of bird strikes from aircraft (Bradbeer et al. 2017) and target an assemblage of bird groups, wildfowl, gulls, waders and even small mammals - so not to encourage raptors - and possibly more feasible within the confines of a closely managed airport and where daily observations can input into adaptive management. Larger scale land-use management of wind turbine surroundings, however, requires close cooperation among all stakeholders to enable successful and uninterrupted operation (Gartman et al. 2017). If this is not possible through land agreements it may be that turbine specifications need to be reviewed or a requirement for turbine curtailment, if risks of collision in poor visibility remains such as when flying in fog or later at dusk during mid-winter. If management control of surrounding land is a possibility, field reduction by fencing/hedges to ~ 2 ha and/or reducing grass sward quality using a native multi-species seed mix of finer grasses (e.g. Meadow Fescue (*Festuca pratensis*), Timothy (*Phleum pratense*), Meadow Foxtail (*Alopecurus pratensis*), reduced fertility and winter grazing, will independently (but ideally combined), minimise field-use by swans. Allowing the sward to lengthen, although also likely to be a deterrent to foraging swans, may inadvertently attract hunting kestrels and buzzards close to a turbine. As the opportunity to design a fully comprehensive mitigation program may have limitations, adaptive management in the form of monitoring and review of clearly defined criteria and curtailment protocols, inevitably remains an important safeguard.

B.6 Summary

Impacts on birds from onshore wind turbines and wind farms generally fall into the two main categories of collision and displacement risk. The vulnerability of different bird species varies by group and is broadly related to ecology, with those that rely on being airborne to hunt being more vulnerable to turbine collision than those that spend the larger part of their daily activities foraging on the ground. Wind farms have, however, the potential to impact on a wider range of bird groups when turbine arrays intersect migratory corridors or daily flight lines. Large-bodied birds, with a high wing loading, are regarded to lack flight manoeuvrability and to be less able to take avoidance action when unexpected obstacles are encountered (Bevanger, 1998; Janss, 2000; Barrientos, 2011). While swans are well known to be regular victims to powerline collision the perception that swans suffer the same mortality risk from turbines is not supported by case studies (Dürr, 2020; Fjin et al. 2012). However, while predicted fatalities in the past may have appeared to have been overestimated, this may in part be due to the initial displacement of birds after construction and a limited duration of monitoring typical of the early years of wind industry development. Nevertheless, both displacement and collision risk of swans to turbines appear to be limited (Winkleman et al. 1989; Fjin et al. 2012), while geese, which

appear to be more prone to displacement effects, have been reported to habituate to turbines over time (Madsen & Boertman, 2008). The extent of meso-displacement may also have reduced over the lifetime of the industry as the scale of turbines has increased requiring greater distances between towers and ground clearance of rotors, while slower revolutions enable transient birds to adjust flight direction or altitude to avoid collision (Krijgsveld et al. 2009; Hötter, 2017; Zajtindjiev et al. 2017; Therkildsen et al. 2021). Recommendations to re-evaluate the collision risk for swans and turbines (Whitfield, 2010; Whitfield & Urquhart, 2015) is now reflected in collision risk modelling with avoidance rates raised from 95.0 % to 99.5% (Band, 2024; SNH, 2018).

The Icelandic whooper swan population has increased steadily over the last three decades with the most recent estimate of 43,255 in 2020 (Bridges et al. 2021) representing a two-fold increase from the 2000 census year (Hall et al. 2016). While an increasing abundance of high quality winter forage (winter cereals and intensive grass production) has been put forward as one possible reason, a more recent study looking at ring re-sightings, suggests the increase in Great Britain is due to whooper swans using nature reserves where supplementary feeding, reduced exposure to lead shot, and less risk of powerline collision have improved survival rates (Soriano-Redondo et al. 2023).

Whooper swan ecology has changed over recent decades with a gradual switching from feeding on freshwater aquatics to agricultural grassland (Colhoun, 1998; Rees et al., 1997) and now, as central foragers, make daily commuting flights to and from traditional wetland roosts. Although attracted to high quality monocultures and the benefits of grass cultivars genetically engineered for intensive livestock farming, the presence of water remains important for field selection (Rees et al., 1990, Mackie, 2025). This limits the number of suitable foraging sites to areas where fields are large, flat and low-lying - typical of river floodplains and to within a commuting distance of several kilometres. As large-bodied birds, the energy expended in taking flight is costly and large, open fields provide security from predation and risk of disturbance. With a move away from natural wetland habitats to forage within rural and often semi-urban environments, whooper swans need to balance foraging efficiency with an innate perception of fear or risk within new surroundings. Proportional differences in how swans behave in different settings and to different levels and types of disturbance, can provide insight into what influences site selection, flock resilience and the spatial-temporal extent of sensitivity towards novel developments such as wind turbines.

In understanding the ecological needs and landscape-use of whooper swans, the potential impacts of wind energy development can therefore be minimised through design and careful location of turbines to avoid barrier effects. Further mitigation to manipulate swans' foraging distribution can use a combination of enhancement and deterrence measures, in part precautionary, to further minimise displacement and collision risk, and in part to maintain foraging capacity. While the visual acuity and landscape awareness of whooper swans is reasoned as proficient, post-construction monitoring of whooper swans' distribution, flight profiles and extent of collision fatality will verify whether turbine curtailment measures may be required as well as to refine and demonstrate the extent of mitigation efficacy.

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