OWSMRF Scope of Work

Feasibility study for large-scale deployment of mark-recapture systems

(Research Opportunity 2.3a)

This document should be cited as: JNCC. 2022. OWSMRF Research Opportunity 2.3: Feasibility study of large-scale deployment of mark-recapture systems. Joint Nature Conservation Committee, Peterborough.

Contents

1 Background

Offshore wind farms (OWF) are seen as a key part of efforts to combat climate change (Snyder & Kaiser 2009). However, there are a number of significant concerns about the potential of offshore wind to have a negative impact on wildlife and biodiversity, particularly in relation to birds (Drewitt & Langston 2006; Gibson et al. 2017). Understanding the potential effects of offshore wind development on protected bird populations is required as part of Environmental Impact Assessments (EIAs) and Habitats Regulations Assessment/Appraisal (HRA). EIAs assess impacts to the wider environment, whilst HRAs assess whether a plan or project will have an adverse effect on a site protected under The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019, The Conservation (Natural Habitats, &c.) Amendment (Scotland) Regulations 2019, the Conservation (Natural Habitats, &c.) (Northern Ireland) Regulations 1995 (as amended), and/or The Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended). As the scale of offshore windfarm development expands, the risk of reaching unacceptable levels of cumulative impacts to protected bird populations increases. In order to undertake meaningful cumulative impact assessments, there is a need for improved understanding of how birds respond to offshore windfarms and how to better quantify the risk to populations of concern. Without such information, there is a legal requirement that decision making is necessarily precautionary, and there is a risk that offshore windfarms may not be deployed at sufficient scale to contribute fully to emission reductions targets and ambitions.

As part of the impact assessment process, the likely effects (e.g. collision, barrier effects and/or displacement effects) of a planned offshore windfarm on marine birds are estimated. Once the magnitude of these effects has been estimated, it is necessary to understand which SPA colonies (if any) and wider populations these affected birds originate from. Finally, the potential population response to these OWF effects (i.e. reduced productivity or increased mortality) is assessed using population modelling. Data to inform this process are frequently scant, leading to high uncertainty in magnitude of effects and a lack of confidence in predicted population response to effects.

This scope of work aims to collect new empirical evidence that will reduce uncertainty in two parts of the assessment process:

- Connectivity between OWF and SPA populations in both the breeding and non-breeding season, i.e. acquiring a better understanding of the extent to which predicted mortality from an OWF can be attributed to an SPA population;
- Population modelling through acquiring better evidence on demographic rates, including survival, immigration/emigration, natal dispersal, and potentially, age at first breeding and frequency of non-breeding among adults, thereby increasing confidence in population model predictions.

Both these evidence needs can be addressed using the same approach: large-scale deployment of a mark-recapture system. In its simplest form, this requires marking birds with a unique individual mark and then, at a later date and potentially different location, recapturing them. (Note, the term ‘recapture’ refers to detecting the presence of an individually marked bird through some means and doesn’t necessarily mean physically recapturing an individual, e.g. ‘recapture’ includes resighting of marked individuals by human observers and automated detection of a tagged bird.) If individual birds are marked at an OWF and are then subsequently recaptured breeding at an SPA colony, this provides information on connectivity between SPA populations and OWF. If adults are marked when breeding at an SPA colony one year and are subsequently recaptured in a subsequent year when breeding at a different colony, this provides demographic information on immigration and emigration. With a sufficient number of marked adult individuals and frequent recaptures, adult annual survival rates can be determined. With high quality recapture data from many colonies, it may be possible to estimate frequency of non-breeding, i.e. if a bird is not seen at a given SPA, recapture data will allow estimation of whether it has moved or died, and if it has moved, whether it is likely to be breeding or non-breeding. Finally, marking many chicks and, years later, observing when and where those individuals return to breed provides information on juvenile and immature survival, age at first breeding and natal dispersal.

The OWSMRF (Offshore Wind Strategic Monitoring and Research Forum) identified black-legged kittiwakes to be one of the species currently posing greatest consent risk to offshore wind deployment (https://jncc.gov.uk/our-work/owsmrf/). Better evidence on OWF-SPA connectivity and demographic rates are required to reduce uncertainty around impact assessments for kittiwakes. Detailed information on knowledge gaps, evidence required to fill those gaps and research opportunities for obtaining evidence is reviewed in two JNCC reports: Black *et al.* (2019) and Black & Ruffino (2020). The specific data requirements and evidence needs to improve confidence in kittiwake impact assessments are as follows.

1.1 Connectivity between OWF and SPA populations

Given the wide-ranging pelagic nature of kittiwakes, it is not always clear how many of the individuals interacting with a particular windfarm are from which SPA population. Better empirical evidence regarding the provenance of kittiwakes in and around OWFs is needed to inform approaches to apportioning effects on individuals observed using a windfarm footprint to appropriate SPAs (and wider populations). This is important both during the breeding and non-breeding season. For example, if kittiwakes from an SPA regularly forage in an OWF during the breeding season and then encounter multiple OWF during the non-breeding season, their risk of collision mortality and consequent population decline could be high. However, evidence on the origin of kittiwakes occurring within an OWF and marine areas used by individuals from SPAs is lacking. In particular, evidence is needed on movement behaviour of a large number of individuals over long time periods. Consequently, there is a need to identify and assess the effectiveness of systems for establishing connectivity between OWF and SPAs. By improving evidence of connectivity (or a lack of it) with SPA populations for kittiwakes using OWFs, confidence in apportioning of OWF mortality to SPA populations will be increased.

1.2 Better demographic information

Long-term studies of kittiwakes at colonies such as the Isle of May mean that there is a good understanding of population biology and demographic rates of kittiwakes, compared with other species (e.g. see Horswill & Robinson, 2015). However, key demographic parameters are still poorly quantified and uncertainty in these parameters generates a lack of confidence in predicted population response to OWF mortality.

Currently population modelling approaches, such as Population Viability Analysis (PVA) treat an SPA colony as a closed population, i.e. there is no immigration or emigration. However, immigration could be an important mechanism for maintaining SPA population size and could provide resilience to additional mortality for the population. Equally, for a declining population, emigration could accelerate population decline, e.g. through failed breeders prospecting and subsequently moving to alternative sites (Ponchon *et al*., 2015). Obtaining evidence on immigration and emigration rates for colonies will enable greater biological realism to be incorporated into assessments of how populations will respond to additional mortality.

Age at first breeding in kittiwake populations is not well known, despite this being a potential mechanism through which density dependence could operate on population growth. For example, at high population densities, individuals may have to start breeding at a later age due to a lack of suitable nest sites. Whilst age at first breeding by itself doesn't confirm presence of a density dependent process operating on a population, when considered alongside other information such as immigration/emigration, it does provide insight into potential density-dependent mechanisms. It can also be an indication of whether a population is sitting above or below carrying capacity, e.g. delayed age at first breeding implies an abundance of breeding-aged birds and a shortage of nest sites or other resources as occurs for a population sitting above carrying capacity.

There is evidence that adult kittiwakes take sabbaticals, i.e. do not breed every year. Information on frequency of sabbaticals and proportion of the population that are mature but not breeding each year gives valuable insight into population dynamics. When considered alongside other variables such as survival rates and population growth rate, high sabbatical frequency can indicate a population in dire straits that is unable to find sufficient prey for most adults to get into breeding condition or can indicate a healthy population with 'floater' individuals enabling the population to buffer itself against additional mortality, for example, through rescue effects.

Finally, annual adult survival estimates tend to be not up to date and derived from a small number of intensively monitored colonies or populations only. In addition, estimates of annual survival rates for younger age classes have very high uncertainty. Combining information on demography (e.g. survival rates) and connectivity (i.e. immigration and emigration rates) will give insights into source and sink dynamics at the scale of the wider meta-population. From this, we can infer what is maintaining population size at SPA colonies; is it immigration from other colonies or survival and recruitment from within the SPA colony? This understanding will greatly improve our ability to predict how an SPA population might respond to offshore wind mortality.

The principle of mark-recapture methods involves marking an individual with a unique mark, enabling that individual to be identified again, then releasing that individual back into the population. Normally, many individuals in a population are marked and efforts are made to recapture marked individuals. Mark-recapture methods are frequently used to estimate the size of a population, as recapture rate gives information about the proportion of the total population that is marked. If recapture rate is sufficiently high, it is possible to estimate the likelihood of an unseen individual having died or just not being sighted on that occasion. The higher the recapture rate and the more individuals that are marked, the higher the certainty in the estimated annual survival rates. For long-lived species, such as kittiwake, with high adult survival and with most adults returning to colonies to breed each year, mark-recapture methods can be successfully used to estimate adult survival. However, juvenile and immature survival is likely to be lower and more variable through time as immature birds tend to disperse away from their natal colony and to only return to the colony when they are close to maturity. Consequently, estimating juvenile and immature survival rate is more difficult, due to much lower recapture rates for these age classes. To compensate for this, a very large number of chicks would need to be marked to derive a reliable estimate of immature survival rate.

More up to date and better quality (more accurate and precise) data on survival of all age classes, immigration/emigration, natal dispersal, age at first breeding and sabbatical frequency will greatly improve confidence in modelling population response to predicted OWF mortality. Importantly, this type of information will show whether colonies of interest with respect to offshore wind development are acting as source or sink populations, with population size being maintained by productivity and survival at the focal colony or reliant on immigration from another colony. This will strongly influence predicted population resilience to additional mortality from offshore wind developments.

2 Aims and objectives

The aim of this Scope of Works is to review and identify the best mark-recapture systems that, when deployed at large-scale, will enable acquisition of new evidence leading to reduced uncertainty in apportioning OWF mortality to kittiwake SPAs and increased confidence in predicted kittiwake population response to additional mortality.

2.1 Objective 1: Review of potential mark-recapture systems

What mark-recapture systems are currently being used? Review of mark-recapture systems both in development and already deployed in other species/locations/contexts. Identification and description of available systems.

2.2 Objective 2: Evaluation of scale of deployment required to address key ecological questions

At what scale would a mark-recapture system need to be deployed to be confident of obtaining data of sufficient quantity and quality to address key ecological questions? Assessment of scale of deployment, i.e. numbers of kittiwakes to be marked and recapture effort (number of receivers/observers over what time period and spatial scale) required under a series of scenarios to be confident of obtaining reliable data to address key ecological questions around kittiwake movements and demography.

2.3 Objective 3: Deployment Considerations

Is it feasible to deploy these mark-recapture systems at sufficient scale on kittiwakes? What are the issues to consider for deploying systems identified under Objective 1, at sufficient scale to address the key ecological questions identified under Objective 2. This includes technical considerations, logistical constraints, resource requirements, Health & Safety and ethical/welfare issues.

2.4 OPTIONAL: Objective 4: Recommendations and deployment plan

How should these mark-recapture systems be deployed? Recommendations for the system(s) that would be the best to deploy, given the systems that are available (Objective 1), the data requirements of this work (Objective 2) and deployment considerations (Objective 3). Work under this objective can only take place after information from Objectives 1-3 has been reviewed and the scope of deployment has been defined. Scope will include considerations such as: which ecological questions are of highest priority, how accurate and precise do data need to be, what budget is available for deployment, etc. This objective will include a deployment plan for the optimal mark-recapture system(s) as well as information on what would be needed to undertake a pilot testing phase of the best system(s).

3 Detailed tasks

For the purposes of this Scope of Works, we are interested in any mark-recapture system that includes applying some sort of unique mark to an individual followed by some form of ‘recapture’. This includes any technology that can detect when an individual is in a particular location and identify that individual. Traditionally recapture is dependent on catching birds or visual recording of colour-ringed individuals, both of which are observer biased and observer limited systems. The review should include and evaluate the potential for new technologies and approaches that allow for remote detection, detection away from colony settings and which have multi-annual potential to obtain new data to address key ecological questions.

3.1 Objective 1: Review of available mark-recapture systems

This work will require searching the literature and other sources of information to identify and review different mark-recapture systems that are currently or will be imminently deployed on birds. Systems should be capable of addressing the ecological questions identified in Objective 2 below.

There will be several types of systems that could potentially deliver useful data:

- Attaching colour rings with a unique combination of alphanumeric codes or metal rings to each individual kittiwake on land or at sea and then manually visually or physically recapturing them at another point in time and, in some cases, space. E.g. colour ringing kittiwakes (http://cr-birding.org/nl/taxonomy/term/2445) and the BTO Retrapping Adults for Survival (RAS) scheme (https://www.bto.org/our-science/projects/ringing/surveys/ras/taking-part/scheme-downloads). This type of system has been deployed on kittiwakes so the review should cover only deployments on black-legged kittiwakes. It should include deployments in any country, not just the UK;
- Attaching unique tags to birds followed by automated recapture of individuals using receivers that can detect when a tag is in the vicinity. An example of such a system includes the MOTUS Wildlife Tracking System (https://motus.org/). These types of systems will not have been deployed extensively on black-legged kittiwakes, if at all, and so the review should include deployment on any birds (terrestrial, coastal or marine), anywhere in the world.
- Attaching remote download tags, e.g. the ICARUS Global Monitoring with Animals (https://www.icarus.mpg.de/en) and GPS devices provide detailed and accurate information on animal movements. Potential limitations of remote download GPS tags include cost, which means that only a small number of birds can be followed, and size which, for small animals such as kittiwakes, means that they should not be deployed for long periods due to potential effects on animal behaviour and welfare (Chivers *et al*. 2016; Geen *et al.* 2019).
- Attaching archival tags, e.g. GLS and archival GPS tags. Other tracking devices are available which are much smaller, lighter and less expensive, e.g. light-sensitive geolocator tags. These devices give only a very coarse indication of a bird’s location to +/- 150km although accuracy can be improved by use of additional information (e.g. Livoski *et al.* 2019; Merkel *et al.* 2016).

It is very likely there are other types of mark-recapture systems available, which should be included in the review. For example, could cameras work as part of a mark-recapture study? Could they reliably identify unique marks on birds? The review should present a list of all systems identified and a short paragraph describing each system. Many of these systems will not be able to deliver relevant data on kittiwakes. To be able to do this, a system needs to be able to (i) be deployed over large spatial scales, (ii) support marking and recapturing lots (100s-10,000s) of individuals, (iii) not be prohibitively expensive, (iv) be suitable for deployment in the marine environment and, (v) be deployed over many years. For those systems not capable of meeting these requirements, briefly indicate why and on which aspect the system will fail to deliver. This review should demonstrate that a thorough search for mark-recapture systems was undertaken (e.g. search terms used) and why any systems were found to not be suitable for deployment on kittiwakes, but it does not need to be lengthy and detailed.

For those systems that theoretically could be capable of meeting the five requirements listed above, a more detailed review of the system is required.

3.1.1 Technical review for each of the more promising systems

For each system that meets the five requirements above, a detailed technical description of how the system works should be provided. This should include the following information:

- How mature is the technology or, for those systems in development, when they will be available at commercial scales and will they have undergone sufficient and relevant testing?
- A list of all species on which this system has been successfully deployed.
- How the unique mark is attached to the bird, e.g. leg rings, tag mounted on leg rings, on the back of a bird with a harness?
- Mass of the mark (e.g. tag or device) and other considerations to do with attachment and size/shape of the mark;
- Mark duration before it fades/is lost/stops emitting a signal;
- Any reported device effects;
- Geographic area covered by each deployment of the system, both in terms of total spatial area covered and where in the world, e.g. how many receivers are already deployed around the UK/Europe which could recapture marked birds; how many kittiwake colour-ringed projects are active in the UK and overseas and at which colonies have they been deployed;
- Timescale over which the system has been in operation and how long studies on different species have been running;
- Whether individuals were caught and marked at sea or on land or both;
- Type of recapture (automated/manual) and technical information on how recapture works.
- What technology do the receivers use to detect the mark, e.g. VHF? What is the size and shape of the receivers? Were there any logistical issues or constraints with either tags or receivers, e.g. radio frequency used? What range do receivers have? Are they line-of-sight, e.g. would land act as a barrier to detecting a tag?
- Whether recapture, including automated (e.g. receiver deployment) and manual (e.g. visual observations of marked individuals) occurred at sea or on land. Where receivers have been deployed at sea, provide as much detail as possible, e.g. type of structure used, was the structure in current use or decommissioned, how was the receiver deployed, what maintenance is required and how is that undertaken?
- What information the system delivers during each recapture, e.g. how accurate and precise is the record in time and space? Can the system give any information on flight heights and/or behaviour of the individual?
- Any issues or detrimental effects from the system. Were there any examples of the system failing and if so, why? Are there inherent known biases in the system? E.g. detection ranges, battery life constraints, need for solar recharging which can affect detection at times of year, periods of the year when environmental conditions limit the system such as for GLS tags.

Any other relevant technical information on that system should also be presented. Note, under this objective, we are only interested in understanding how these systems are currently being used. Under Objective 3, we wish to understand the feasibility of using these systems for kittiwakes. Therefore, this section should simply document current deployments of each system and does not need to consider how the system could be deployed on kittiwakes. The contractor should also document ecological questions that have been addressed using data collected by this system and an indication of the quality and quantity of data acquired/ability of the system to address these questions.

3.1.2 Review of scale of deployment and recapture rate

The contractor should provide a detailed review of the scale of deployment and recapture rate achieved for all black-legged kittiwake mark-recapture studies, including other reviews, such as Horswill *et al.* (2016). The review under this objective should include:

- Numerical scale of deployment (e.g. the number of individuals marked and section of the population that was marked (chicks, adults));
- Recapture effort through time (i.e. duration of the study, number of person-hours spent searching for marked birds);
- Recapture effort through space (i.e. number of observers/receivers deployed, spatial area covered by recapture effort);
- Recapture rates achieved;
- Any other factors that influenced the observed recapture rates should also be reported.

Recapture rates obtained from a given number of marked individuals and recapture effort deployed will be used in Objective 2 to inform recommended scales of deployment.

3.2 Objective 2: Evaluation of scale of deployment required to address key ecological questions

This objective should assess the scale of deployment, i.e. how many birds to mark and how much recapture effort would be required to address the ecological questions listed below, for the mark-recapture systems identified under Objective 1. This is to inform Objective 3, which looks at the feasibility of deploying these systems at the scale required, as determined under this objective (Objective 2). At this stage, the scale of deployment should be a hypothetical indication of the number of individuals that would need to be marked and recapture effort required in order to effectively address our ecological questions. A detailed deployment plan that includes information such as where to mark birds, should be provided under Objective 4. Given the complex nature of this evaluation of scale of deployment and large number of uncertainties and assumptions required, the Contractor will advised on how best to tackle and present this work, informed by the information provided under Objective 1.
Marking more birds and deploying lots of recapture effort will result in better quality demographic estimates and reduced uncertainty in the impact assessment process. However, larger scale deployment will also be more financially expensive and/or will take longer to deliver key evidence. Therefore, there is a trade-off in resource investment and quality of evidence arising from a mark-recapture study. Under this objective, the contractor should provide information to assist with resolving this trade-off.

3.2.1 Key Ecological Questions

The key ecological questions to be addressed by deployment of one or more large-scale strategic mark-recapture systems are:

OWF-SPA connectivity:

- During the breeding season, what proportion of kittiwakes observed using an OWF development area (planned or operational) are from an SPA population and how does this vary through different parts of the breeding cycle, e.g. during incubation vs chick-rearing?
- Do kittiwakes from a particular SPA use one or more OWFs?
- To what extent do kittiwakes from SPAs use offshore wind farm areas in the non-breeding season?
- How far do birds range during different parts of the breeding cycle? Where are birds from particular colonies when not breeding? When do they migrate? Is there non-breeding segregation of populations?
- How does 'sabbatical' bird distribution in the breeding season vary from breeding birds? Are breeding or sabbatical birds more likely to be using OWF areas?

Demographic information*:*

- How frequently do adult kittiwakes change breeding colony, i.e. evidence for immigration/emigration? Is there evidence of systematic directional movements? Are there any covariates which could explain variation in where kittiwakes move from and to, e.g. colony size, nest density, productivity?
- How frequently do adult kittiwakes take a sabbatical from breeding, i.e. have a non-breeding year? Can we be certain that they are not breeding at another colony?
- Which colonies do young kittiwakes recruit into and how far are these from their natal colony?
- At what age do young kittiwakes start breeding?
- What are annual survival rates for adult kittiwakes? Is it possible to get separate estimates for different colonies, or for those using different regions of sea during different seasons? Are there any differences in survival rates for individuals using OWF areas compared with those that forage elsewhere, and can any differences be attributed to OWF?
- What are annual survival rates for juvenile and/or immature kittiwakes? Is it possible to get separate estimates for each sub-adult age class or is it only possible to get a single estimate of survival from fledging to recruiting into a breeding population?

Some systems may be able to address additional ecological questions. For example, an automated tag-receiver system and/or camera system may be able to acquire information on provisioning rates and foraging trip duration by recording when an individual returns to the colony. Whilst collecting this type of information is not the primary aim of this work, this is still useful information and should be noted in the contractor's report. Also, any ability of the system to address similar ecological questions for other species of interest with respect to offshore wind development should be noted.

3.2.2 Scale of deployment

How many individuals would need to be marked and how much recapture effort is needed to be able to address these ecological questions with sufficient power to substantially reduce uncertainty around these key evidence needs? The scale of deployment will depend on several inter-related factors:

- How much **certainty/confidence** is required in evidence/**estimates** for the above ecological questions? E.g. what confidence interval is desired for an estimate of adult survival? Is a single survival estimate sufficient or is information on how survival varies across individuals (e.g. those foraging inside vs outside OWF) or through time needed? This will be determined by, among other things, sample size and recapture rate.

- What is the likely **recapture rate**? Recapture rate is the likelihood of encountering a marked individual in a particular year; a higher recapture rate will generate more confidence in estimates of kittiwake movement and demography. Recapture rate is determined by the following variables.
- **Survival probability**, i.e. the probability that an individual is still alive and has not emigrated out of the study population and so is available to be recaptured. If all marked individuals were seen each year they were still alive, recapture rate would be 1 and all individuals that were not seen could be assumed to have died or left the population. This would give 100% confidence in the derived annual survival rate. However, not all marked individuals are recaptured each year.
- **Species behaviour**. The behaviour of a species influences the probability of it being recaptured. For example, kittiwakes nesting on inaccessible ledges may make sighting of colour rings very difficult, thereby reducing recapture rate. Automated recapture, e.g. using a tag-receiver system, might increase probability of a marked bird being recaptured.
- **Number of marked individuals**. Marking more individuals increases recapture rate. When survival is highly variable across individuals and time, and/or behaviour varies among individuals and time, recapture rate will also be highly variable among individuals and through time. The more individuals that are marked, the more information (extent of variation) on recapture rate can be obtained, leading to more certainty around whether an individual was not seen because it had died or because it was not recaptured in that particular year.
- **Recapture effort through time**. Looking for marked individuals over a longer period will increase the recapture rate. An individual could go many years without being seen, before eventually being recaptured. This low recapture rate would increase uncertainty around survival estimates (if a bird is not seen it would not be known whether it had died or was just not seen that year) but is important for long-lived species as a short duration study would conclude individuals had died, leading to biased underestimates of annual survival. However, if recapture rate is increased through other means (e.g. by increasing area where marked birds are looked for), recapture effort through time could be reduced (i.e. there is a trade-off in number of birds marked, recapture effort through time and recapture effort through space). For manual systems, person-hours spent searching for marked birds each year will also influence recapture rate. Automated systems are presumed to operate constantly. As well as total duration of the study, recapture rate might vary a lot among years. A highly variable recapture rate through time also requires more years of study to capture the full range of variation and therefore obtain reliable estimates of survival.
- **Recapture effort through space**. This is the spatial extent over which marked individuals are looked for. This includes the total number of receivers or human observers deployed and spatial coverage achieved. As more recapture effort is deployed, so recapture rate moves closer to 1 and survival probability becomes more certain (i.e. recapture effort and certainty in demographic estimates are positively correlated).

The above shows that scale of deployment (number of birds marked and recapture effort), along with a species' survival probability and behaviour, determine recapture rate and confidence in demographic rates derived from a mark-recapture study. See Horswill *et al.* (2016) for more information. The contractor should use this information to indicate the potential scale of deployment required to obtain reliable demographic estimates for black-legged kittiwakes breeding in the UK. A series of scenarios should be presented in which the contractor identifies the scale of deployment (a coarse indication of the number of individuals to be marked and recapture effort required) that theoretically would deliver reliable demographic estimates, given plausible recapture rates from the literature (from Objective 1), the ecological question to be addressed (from Objective 2), and the mark-recapture systems under consideration (from Objective 1). Each ecological question will require different scales of deployment to achieve desired recapture probabilities and consequent reliable demographic estimates. For example, more kittiwake chicks will need to be marked to obtain a good estimate of juvenile/immature survival, compared with number of adults to be marked, when estimating adult survival. Some mark-recapture systems may not be able to address all ecological questions.

3.3 Objective 3: Deployment Considerations – feasibility, logistical constraints, cost and welfare issues associated with each mark-recapture system

The purpose of this objective is to provide information on the feasibility of deploying the mark-recapture systems identified in the review under Objective 1, on kittiwakes in the UK in the context of OWF development, taking into account potential scales of deployment required, as outlined under Objective 2.

Under Objective 1, an account of current deployment of each plausible mark-recapture system was given, irrespective of species and scale of deployment. Here, the feasibility and issues around deploying these systems on kittiwakes and at OWF in the UK, at the scales suggested under Objective 2, should be described. For each plausible mark-recapture system, the contractor should describe considerations and issues around deployment of each system. The following information should be documented. Where appropriate, reference should be made throughout this section of the report to the ecological questions of interest. It might be necessary to contact experts such as practitioners or technology developers to acquire the information that is required under this task. A clear audit of who was contacted and the information they provided would need to be kept if this is the case.

3.3.1 Considerations around the marking and recapture of kittiwakes including ethical/welfare issues

- Generic considerations around catching and marking kittiwakes, that apply to all mark-recapture systems, should be briefly summarised, e.g. the process required to obtain permission to catch and mark birds from the BTO/Home Office as well as considerations around catching birds on land (access to nest sites, etc), and at sea (this is covered in a separate Scope of Works, OWSMRF RO2.4). Any ethical/welfare issues or information of relevance to a particular mark-recapture system should be reported here (e.g. potential challenges of harness tag attachment for kittiwakes).
- Tagging/marking of birds:
    - Tag specification and attachment method: give size, mass and shape of tag are there any issues with deploying this technique on kittiwakes? Where is the site of attachment on the bird and is there any potential for tag effects on kittiwakes? What scope is there for adapting the tag/device, e.g. for leg-attachment rather than harness-attachment? Are there multiple types of tag that would work under this system? If yes, provide details on all of them.
    - What is the maximum number of unique marks that can be deployed (e.g. unique alpha-numeric combinations of colour rings or unique electronic or radio signatures)? Combinations that have already been used should be reported, where known, if this is likely to significantly reduce the number of unique marks still remaining.

    - Lifespan of mark, e.g. battery life, colour fading, any other considerations about mark method in terms of durability at sea for many years? Any issues of particular relevance to kittiwake life history, e.g. cliff nesting (would this cause abrasion to tag?), highly pelagic nature in the non-breeding season, etc.
    - Risk of loss of mark for kittiwakes and how this could be mitigated. How likely is loss of mark?

- Recapture of marked birds:
    - Manual recapture by observers:
        - Can they access appropriate places to achieve enough recapture effort, how to control and record effort by volunteers to ensure quantified search effort is deployed among colonies and years, e.g. to be sure that all absences are recorded and that a recorded absence is due to a marked bird not being present rather than variation among observers? See Horswill *et al*. (2016).
        - Any benefit from opportunistic sightings from OWF service vessels or other vessels, e.g. ferries, wildlife tourism operators, or from land, e.g. sea watching programmes?
        - Can volunteers/citizen science alone deliver sufficient effort to produce an adequate recapture probability or is the system likely to need dedicated professional effort? What resources/support are needed to ensure consistent observer effort is maintained?

    - Automated recapture by receiver stations:
        - Over what distances can the system detect a PIT tag or a VHF radio transmitter? What influences this, e.g. under what conditions could this distance be reduced? How variable is it (this should be based on validated distance capabilities in the field rather than rely on manufacturers claims)?
        - Are recaptures directional? E.g. how accurate are fixes and can they provide any 3D information such as flight height? Or does the receiver simply record the tag presence somewhere within the receiver's detection range? Can an array of receivers improve spatial accuracy of fixes, e.g. within an OWF?
        - Could an automated recapture provide any information on behaviour of a bird, e.g. whether foraging or commuting, whether provisioning a chick or not, etc? Give details on any additional information, aside from location at a point in time, that the system can provide.
        - Where should receivers be deployed to maximise collection of the most beneficial data? How far apart should they be spaced? What is needed to inform a strategic placement of receivers?
        - Where are receivers already deployed that could be used?
        - Where should receivers be mounted for optimal detection rates? If mounted offshore, should the receiver ideally be on the transition piece or on the nacelle? (It would be helpful to know the theoretically ideal location for the receiver and further down to document what is actually feasible, e.g. it might be ideal to place the receiver on the nacelle but not technically feasible.)
        - What infrastructure is available in the North Sea for deployment of a network of receivers, besides OWF? Is current/planned infrastructure likely to be sufficient to adequately monitor movements of marked birds, particularly in the non-breeding season? Note, the deployment plan (Objective 4) will describe where receivers should ideally be placed; here there should be a description of coverage by a receiver

and how many receivers would be needed at a colony/OWF, in theory, to provide adequate coverage.

- If it is possible to concurrently collect data on other species, this should be documented.

3.3.2 Technical considerations around receiver deployment

- Technical considerations around deployment of receivers on operational offshore wind farms and other infrastructure in the marine environment, including mobile platforms such as ships. Note some of this information will have been documented under Objective 1; here it should be reported with reference to deployment at kittiwake colonies in the UK and/or offshore wind farms and other marine infrastructure in UK waters. A range of sources should be consulted to gather the necessary information for this objective, including mark-recapture system providers, offshore wind farm companies, other owners of marine assets:
  - Mass and dimensions of receiver and how does it attach to structure – where/how/loading, other engineering considerations;
  - Power supply to receiver;
  - Maintenance requirements, including downtime when receiver is not operating;
  - Quantity of replacement receivers/other parts needed and frequency of replacement needed (historic data on failure rates would be useful)
  - How are data collected and stored?
  - How are data downloaded and transmitted/transported to where data analysis will occur? Do they need to be collected in person or can they be transmitted remotely? How often does data download need to take place?
  - Can receivers be retrofitted to wind turbines and/or other existing structures at sea? How difficult is this and does it vary (e.g. by turbine size or model)?
  - What are the other issues associated with putting novel structures on offshore wind farms?
  - What are issues with deploying novel structures on other types of marine assets (e.g. oil and gas platforms)? Has this system been proven, tried and tested for deployment over long periods at sea?
  - Will turbine interfere with system's ability to detect marks or to store and access data?
  - Will system interfere with turbine at all, including communications between turbine and surveillance centre?
  - What are issues to be considered with decommissioning of receivers deployed at sea?
- Technical considerations around deployment of receivers on land
  - What are the technical challenges to deploying receivers at remote locations on land, e.g. on a cliff adjacent to a seabird colony?
  - Power supply?
  - Maintenance requirements?
  - How are data collected and stored?
  - How are data downloaded and transmitted/transported to where data analysis will occur? Do they need to be collected in person or can they be transmitted remotely?
  - What are issues to be considered with decommissioning of receivers deployed on land
- General technical considerations
  - What technical support is available for installation and maintenance of receivers? Is high quality technical support readily available at all times?

    - What kind of signal is transmitted by marks (tags) and are there any legal constraints on using this type of signal in the UK?
    - Are receivers that are already operational in other countries capable of detecting tags fitted to UK birds? If yes, how would information on when a tagged kittiwake was recorded near a receiver be obtained?

3.3.3 Data considerations

- Are data likely to be biased, e.g. due to only being able to mark individuals breeding at accessible nest sites? What other biases could there be in the data? What can be done to mitigate extent of bias or at least to check for it?
- Data collation, storage, processing and analysis requirements including any risks, e.g. novel methods, specialist skills required to model and analyse the data, computing power required to process the data.
- Who will collate, store and analyse the data for a long-term study? How will they be funded?
- Will the system enable collection of sufficient data to address the ecological questions identified under Objective 2. Will the system deliver what is needed?
- How do different scenarios of scale of deployment, identified under Objective 2, influence these feasibility considerations?
- Data ownership – does the data belong to whoever deploys the system? Is there any obligation to share data freely?

3.3.4 Resource considerations

- Timescales from initial project planning to obtaining useful relevant data of sufficient quality, e.g. how long would it take before useful estimates of survival could be obtained for adults and for juveniles/immatures? How would this vary with data quality, e.g. what is the minimum time for a first estimate, how long would it take to get a high-quality estimate?
- Estimated cost of marking and recapture. Costings should be provided for each of the scenarios of different scales of deployment, presented under Objective 2. Costs should be broken down by ecological question, e.g. assessing adult survival may require smaller scale deployment, at least in terms of study duration, than estimating juvenile/immature survival and so may be cheaper. Costs should also be broken down across years of deployment and by costs for marking (total cost and cost per bird) and costs for recapture. As much information as possible on costs should be provided.
- For some systems, there may be options for collaboration to reduce total funding costs, e.g. others may have interest in wide scale deployment of MOTUS receivers. Where there may be opportunities for collaboration to reduce costs, this should be indicated but potential collaborators do not need to be identified at this stage.

3.3.5 Risk analysis

- Identify and evaluate risks to deploying this system on kittiwakes, on land and at sea, in the UK, e.g. if an element of the system fails, does the whole mark-recapture study fail? What are the key points at which system failure is a possibility and what would the consequences be?
- What are the risks associated with each type of system? E.g. how should risk of volunteers failing to put effort into recapture colour-ringed kittiwakes be mitigated? Would volunteers need incentives to ensure necessary effort is achieved?

- Where are the uncertainties in performance and/or delivery? What sample sizes can we be certain of achieving? Where should redundancies be built into system deployment?
- What are the issues and considerations of needing to deploy at such a large scale? If it subsequently becomes unfeasible to deploy at the planned scale and deployment occurs only at a smaller scale, will useful results still be obtained? Could a modular deployment approach work? E.g. could larger scale deployment be divided into components which would each deliver something useful as standalone projects?
- Ability of system to be future-proofed, e.g. potential to increase scale of deployment in the future, confidence that receivers will continue to operate given future development of tags, e.g. will receivers continue to pick up signal of future tags?
- Provide a brief risk assessment for deployment of each system indicating where the risks lie, the likelihood of it occurring, the severity of the risk and mitigation that can be used to minimise the risk.

3.3.6 Health & Safety considerations

- What are the Health & Safety considerations associated with marking and/or recapture on land and at sea?
- Note, there is another Scope of Works (OWSMRF RO2.4) that reviews issues associated with physically catching birds at sea, i.e. the contractor does not need to identify and review issues around this. The Contractor will be provided with this scope so they are clear what is outside requirements under this objective. Therefore, this section should consider health and safety aspects specifically related to marking and/or recapture (resighting) of birds at sea.

It would also be helpful to summarise information in a way that facilitates comparison across mark-recapture systems. The contractor should produce a comparison spreadsheet showing benefits and limitations of each system, including predicted approximate costs of deployment at scales defined under Objective 2.

3.4 OPTIONAL Objective 4: Recommendations and Deployment Plan

This objective is an optional addition to the work and can only go ahead once the results of Objectives 1-3 have been considered. Under this objective, recommendations should be made on which system(s) offer the most effective approach for delivering sufficient data on kittiwake movements and demography. However, before being able to make recommendations, the contractor would need to know the approximate budget available, which ecological questions are of highest priority, an indication of spatial scale of deployment (e.g. regional or UK) and what quality of evidence is required from the mark-recapture system. Given the information in Objectives 1-3, project funders would need to decide how they wish to resolve the trade-off between quality of evidence, scale of deployment and resources required to deliver that.

We also recommend that, if available, information from Research Opportunity 3.1 is considered alongside Objectives 1-3. RO3.1 involves developing a meta-population modelling framework for kittiwake colonies in the UK. Part of the work (RO3.1b) would be to undertake a sensitivity analysis to identify where new empirical data would be of most benefit in the model. Developing a Deployment Plan using information from the meta-population model sensitivity analysis would ensure the right data is collected in the right way to assist with model parameterisation, thereby significantly improving our understanding of kittiwake population dynamics. For example, should deployment be focused on colonies currently predicted to be subject to offshore wind mortality, such as Flamborough & Filey Coast SPA and Forth Islands SPA? Will focussing effort on these colonies provide the necessary information at sufficient quantity and quality to substantially reduce uncertainty during the impact assessment process? Or should effort be focussed on other colonies that could potentially be acting as sources for the SPAs of interest? Information from RO3.1 would help inform this judgement, along with other considerations, such as which ecological questions are of primary interest.

Development of recommendations and a deployment plan should include considerations of systems that are already operational or imminently available at commercial scales (Objective 1), the ability of the system to be deployed at sufficient scale (Objective 2) and feasibility of deploying such a system at sufficient scale (Objective 3). Deployment of more than one system concurrently may be the most effective approach and work under this objective should include consideration of this option.

The review should include a detailed deployment plan of the steps to be undertaken to achieve a large-scale deployment. This might include, for example, a pilot testing phase, a power analysis, followed by full deployment. The deployment plan should provide information on where to deploy, including where marking of kittiwakes should ideally take place, i.e. which kittiwake colonies and OWF. It should specify the number of kittiwakes to mark (adults and/or chicks) at each location each year, including the minimum number of individuals to be marked to ensure data of sufficient quality are acquired. Issues with access to kittiwake nests at colonies should be described. Also, recapture effort including number and location of receiver stations and/or observers should be described. For example, under ideal circumstances, at which points on land and at sea should receiver stations be deployed, if a tag-receiver system is found to be a viable plausible mark-recapture system? Should mark and recapture effort be focused at colonies or at sea in an offshore wind farm area (planned or operational) or both? Note, this might depend on the primary objective of data collection – if understanding OWF-SPA connectivity is of primary interest, then marking at the OWF may be more useful whereas if understanding inter-colony movements is more important then marking at SPAs will be a priority. The deployment plan should also provide information on study duration; over how many years should marking occur and how long should recapture effort be deployed. The deployment plan should also include a risk analysis and mitigation measures around deployment, as well as all other considerations listed under Objective 3 (e.g. an experimental design to check for device effects).

Under this objective, it may also be useful to make recommendations on how to conduct a pilot testing phase for the system(s) recommended above. What is the minimum scale of deployment for a pilot testing phase? Where would this ideally be undertaken? What are the likely costs associated with this? What specifically should the pilot phase test? What questions should it address? How long would a testing phase take? During a test phase, ideally novel marks should be deployed along with tried and tested tags, such as GPS, to validate novel tags. What are the issues with this (e.g. combined tag weight)? What is the method for validating novel tags?

4 Outputs and Deliverables

It is envisaged that the main output under this contract will be a **detailed report** presenting the work under the Objectives 1–3, as described above. The report should include the following:

Objective 1: a brief review of all mark-recapture systems identified and an explanation of why systems were considered unsuitable for addressing our ecological questions. Given that there are five criteria the mark-recapture system needs to fulfil, a table indicating which criteria are met for each system would be useful. For those systems that were considered suitable, a detailed account of how the system works and current deployment should be provided. This section of the report should also include a review of recapture rates and associated recapture effort, from the literature.

Objective 2: a detailed assessment of scale of deployment required (i.e. numbers of birds to mark, recapture effort required) to address the ecological questions of interest. This will include a range of scenarios for each mark-recapture system.

Objective 3: a detailed review, for the most plausible mark-recapture systems, of all the issues and considerations around deployment, as listed above.

Objective 4 is an optional additional component of this work. Before this can be undertaken, the Project Funders would need to review all information from Objectives 1-3 and make decisions to inform a deployment plan and recommendations.

Objective 4: a detailed deployment plan, recommending which mark-recapture systems to deploy, where deployment would ideally take place, how many birds need to be marked and where/when/how recapture should take place. The deployment plan should also describe phases of deployment, e.g. pilot testing followed by full deployment.

Alongside the report, the contractor should provide a **comparison spreadsheet** which would provide information on each of the most plausible systems. This would capture a lot of the same information as in the report under Objective 3, but in a format allowing easy comparison and cross-reference across systems.

5 Dissemination

Dissemination to be decided by project funder but might include, for example, a presentation by the contractor and/or publishing the report.

6 Timescale

The contractor should provide a detailed Gantt chart, showing how long each objective will take to deliver and when delivery will take place. The key objectives, milestones and deliverables of this contract are:

- Objective 1: review of current mark-recapture systems.
- Discussion with Project Funders on which systems are of most interest and how scale of deployment should be assessed/reported on.
- Objective 2: assessment of scale of deployment required to deliver data capable of addressing the key ecological questions.
- Objective 3: review of deployment considerations: feasibility, logistical constraints, cost and welfare issues associated with each mark-recapture system
- Draft report and presentation to Project Funders
- Final report and comparison spreadsheet delivered to project funders.

Objective 4, if undertaken, should be delivered under a separate timetable as it has dependencies beyond the scope of work under this contract.

7 Health and safety

Not applicable as this is a desk-based study.

8 Evidence Quality Assurance

Contractor should demonstrate their own Evidence Quality Assurance process.

9 Contractor requirements

The contractor(s) would need to demonstrate the following expertise and experience:

- knowledge of black-legged kittiwake ecology
- experience in deploying and analysing data from mark-recapture studies
- understanding of best practice and issues around catching, handling, ringing and attaching devices to kittiwakes
- quantitative ecological modelling, including population dynamics and mark-recapture analysis (to be able to understand the types of data required and issues around data quality)
- general understanding of marine industries and infrastructure to appreciate opportunities and issues around deploying receivers on marine infrastructure
- demonstrated network of contacts/expertise and ability to access expertise for e.g. understanding the details of system performance and feasibility

10 References

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