OWSMRF Pilot Year

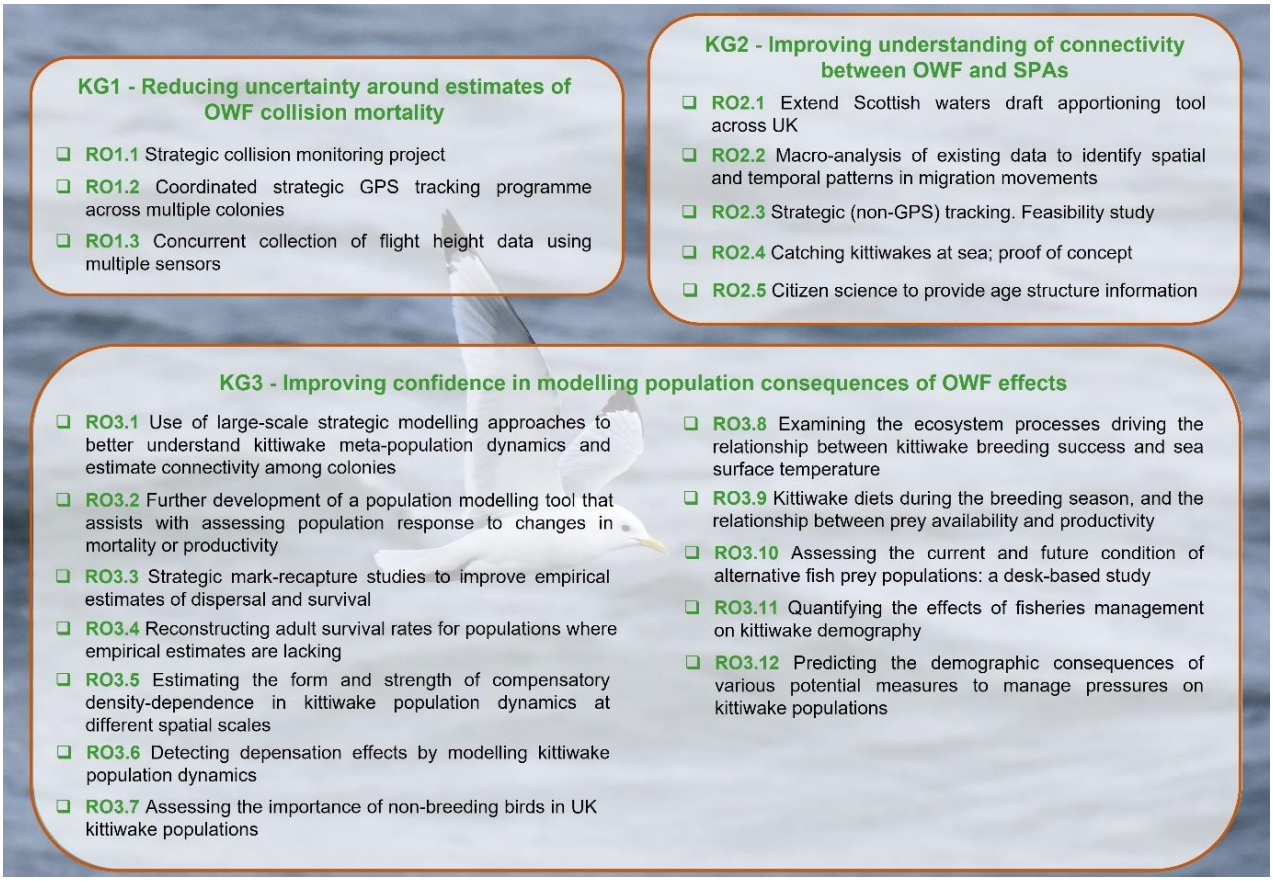
Research Opportunities on Black-legged kittiwake

The Offshore Wind Strategic Monitoring and Research Forum (OWSMRF) is an industry-led collaborative forum that aims to identify and develop research to fill critical knowledge gaps in our understanding of the impact of offshore wind development on the marine environment. At a workshop in May 2019, the black-legged kittiwake (*Rissa tridactyla)* was identified as posing the greatest consent risk to offshore wind development in UK waters.

Three priority Knowledge Gaps (KG) to inform cumulative/in-combination assessments were identified:

- KG1: reducing uncertainty around estimates of windfarm collision mortality
- KG2: improving understanding of connectivity between OWF and SPAs
- KG3: improving confidence in modelling population consequences of wind farm effects

The Joint Nature Conservation Committee (JNCC) has collaborated with nature conservation agencies, researchers and academics to identify a summary of potential research that might help address Knowledge Gaps 1, 2 and 3. The list of 20 Research Opportunities (RO) is presented as short concept notes. For each RO, some indication about applicability of research question(s) to species other than kittiwake is provided.



Knowledge Gap 1 -
Reducing uncertainty around estimates of wind farm collision mortality (Black *et al*. 2019*)

RO1.1 Strategic collision monitoring

Short summary of proposed research

This project would involve the deployment of turbine monitoring systems across a range of turbines and wind farms to collect empirical data on kittiwake collision rates. This would allow validation of the Collision Risk Model approach and empirical cumulative effects assessment.

RO1.1a Updated review of technology to detect collisions with turbines. This may need to include a field test if promising technology has not yet been deployed in offshore situation.

RO1.1b Power analysis and strategic framework for deployment of monitoring systems.

RO1.1c Deployment of systems.

Applicability to other species

This is an overarching project theme (i.e. covers potentially all flying species) and so would seem to be both applicable to other species vulnerable to collision risk.

ORJIP recently tendered for a review of collision detection technologies (brief description here). This would include power analysis of 'promising' systems to understand scale of deployment required to reduce uncertainty in collision risk. The now-completed two-year (radar) study at the European Offshore Wind Deployment Centre (EOWDC) will also provide some useful evidence for a range of species.

Therefore, a gap analysis would be required as a first step to determine what added value applying this RO to other species would bring.

Reference and contact

*Black, J., Cook, A.S.P.C. & Anderson, O.R. 2019. Better estimates of collision mortality to black-legged kittiwakes at offshore windfarms. *JNCC Report No. 644.* JNCC, Peterborough, ISSN 0963-8091.

See also OWSMRF Scope of Work RO1.1 'Review of systems for monitoring bird collisions at offshore wind farms'.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 1 -
Reducing uncertainty around estimates of wind farm collision mortality (Black *et al*. 2019*)

RO1.2 Coordinated strategic GPS tracking programme across multiple colonies

Short summary of proposed research

The aim of this project is to improve the understanding of spatial and temporal patterns in kittiwake at-sea distribution and behaviour and how this may influence collision risk. Validation of modelled collisions will inform cumulative collision estimates across existing wind farms.

RO1.2a Trial of harness attachment methods to assess feasibility and suitability for kittiwakes.

RO1.2b Review of existing tagging works and strategic plan for complementary studies.

RO1.2c UK roll-out, over multiple colonies and years.

Applicability to other species

Tracking studies have already been conducted for some species at some colonies. OWEER lists those projects in progress or recently completed. BirdLife Seabird Tracking Database details projects but seems incomplete. Similarly, SOSS collated seabird tracking studies but only up to 2011/12.

OWEER identified several evidence gaps in understanding of seabird movements in both the breeding and nonbreeding seasons that could be filled through tagging studies. A study published in 2015 simultaneously tracked Manx shearwaters from 4 colonies over 3 years, including GLS deployment (Dean *et al.* 2015). There does not appear to be any other current coordinated strategic GPS tracking programme across multiple colonies for any seabird species.

Coordinated strategic tracking of species would be possible in the same way as proposed for kittiwake. There may be some constraints on deployment such as accessibility of birds and consequent health and safety implications, ethical considerations, minimum size limit of the species, and potentially attachment trials before wider deployment could be considered. That may limit the strategic nature achievable. Accelerometers may not be appropriate for some species, however sensors to measure dive time/depth etc may be useful for some species.

Reference and contact

*Black, J., Cook, A.S.P.C. & Anderson, O.R. 2019. Better estimates of collision mortality to black-legged kittiwakes at offshore windfarms. *JNCC Report No. 644.* JNCC, Peterborough, ISSN 0963-8091.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 1 -
Reducing uncertainty around estimates of wind farm collision mortality (Black *et al*. 2019*)

RO1.3 Concurrent collection of flight height data using multiple sensors

Short summary of proposed research

This project would improve understanding of accuracies, biases, and comparability of flight height information collected by a variety of different methods. It would help us to understand the extent to which individual measurements, and resulting flight height distributions, may differ between different sensors and, consequently, the extent to which it may be possible to use data collected from one sensor alongside data collected from another when assessing collision risk. This would help reduce some of the uncertainty associated with the estimates of species flight heights, and therefore resulting collision risk estimates, used as part of the consenting process.

Applicability to other species

It may be that the comparison of flight height estimations from different platforms made for kittiwake would be applicable to other species. However, if there is concern that this is not the case, then projects involving for example Digital Aerial Survey and LiDAR could be reanalysed for other species of interest (as these platforms typically record all birds). There are several ongoing flight height estimation research projects identified in OWEER that could offer the opportunity to collect concurrent data from other sensors. Flight height data are also being collected at Sofia pre-construction surveys for kittiwake and other species using LiDAR (final pre-construction report expected early/mid 2023).

Reference and contact

*Black, J., Cook, A.S.P.C. & Anderson, O.R. 2019. Better estimates of collision mortality to black-legged kittiwakes at offshore windfarms. *JNCC Report No. 644.* JNCC, Peterborough, ISSN 0963-8091.

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Knowledge Gap 2 -
Improving understanding of connectivity between offshore wind farm and SPAs
(Black & Ruffino 2019*)

RO2.1 Extend Scottish waters draft apportioning tool across UK

Short summary of proposed research

The existing tool, developed by UKCEH and RSPB, uses species distribution predictions based on GPS tracking data presented in Wakefield *et al*. (2017) to provide quantitative apportioning of birds seen within a wind farm footprint to source colonies (for four species including kittiwake). This project would use the code developed for the existing (Scottish waters) tool and the UK-wide work of Wakefield *et al*. (2017) to extend the tool across UK waters.

Applicability to other species

This RO can be applicable to other species, but is dependent on availability of breeding season tracking data. To note, this RO has been progressed under ORJIP Stage 2 (Bird Sensitivity Mapping Phased II); however the full species list would need to be confirmed. In addition, there is a current ORJIP project (OWEER Ref: RE.OR.25) looking at updating and expanding an apportioning tool across UK, including the non-breeding season, and using recent tracking data to validate the model.

Reference and contact

*Black, J. & Ruffino L. 2019. Better linking effects of offshore windfarms on black-legged kittiwakes to populations, *JNCC Report No. 645*. JNCC, Peterborough, ISSN 0963-8091.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 2 -
Improving understanding of connectivity between offshore wind farm and SPAs
(Black & Ruffino 2019*)

RO2.2 Macro-analysis of existing data to identify spatial and temporal patterns in migratory movements

Short summary of proposed research

This project uses a collation of currently available data and products from various sources (both at-sea and tracking data types, and distribution map products). These data would be analysed to assess broad latitudinal movements and timings of migration, to indicate the extent at which cumulatively, kittiwakes are interacting with multiple wind farm zones and footprints during different seasons.

Applicability to other species

In principle, similar analysis could be performed for any species of interest, although a gap analysis to establish data sufficiency would need to be performed first. Several tracking studies identified in OWEER could contribute data, and to note that the Marine Scotland project on Strategic Review of Migratory Routes (OWEER Ref: RE.OR.33) may fulfil some or all of this RO for seabird species.

Reference and contact

*Black, J. & Ruffino L. 2019. Better linking effects of offshore windfarms on black-legged kittiwakes to populations, *JNCC Report No. 645.* JNCC, Peterborough, ISSN 0963-8091.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 2 -
Improving understanding of connectivity between offshore wind farm and SPAs
(Black & Ruffino 2019*)

RO2.3 Strategic (non-GPS) tracking; feasibility study

Short summary of proposed research

This project would explore the feasibility of, and practicalities around, using smaller lighter and less expensive means of tracking than GPS devices. This would include consideration of VHF radio tracking, Passive Integrated Transponder (PIT) devices and/or colour ringing. If deployed at scale across the UK, this would provide information on linkages between multiple wind farms and colonies and between colonies over time. This RO would also provide synergies with improved understanding of wind farm-induced mortality, and demographic rates for estimating population impacts of wind farm effects.

RO2.3a Desk-based feasibility study leading to recommendations for RO2.3b.

RO2.3b Pilot deployment to check assumptions and conclusions around logistics, costs, scale of deployment required, infrastructure requirements, data retrieval.

RO2.3c UK-wide deployment.

Applicability to other species

Similar constraints would apply as per GPS tags, e.g. minimum body sizes, attachment, accessibility. However, in principle, establishment of strategic non-GPS tracking for other species could be established in a similar manner to that proposed for kittiwake. Indeed, tag deployment on other species could be 'piggybacked' on a receiver network established for kittiwake. Further work on spatial extent of receiver network required and resolution (spacing of receivers) would be needed.

Reference and contact

*Black, J. & Ruffino L. 2019. Better linking effects of offshore windfarms on black-legged kittiwakes to populations, *JNCC Report No. 645.* JNCC, Peterborough, ISSN 0963-8091.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 2 -
Improving understanding of connectivity between offshore wind farm and SPAs
(Black & Ruffino 2019*)

RO2.4 Catching kittiwakes at sea; proof of concept

Short summary of proposed research

This project is a combination of desk-based and at-sea studies which would explore approaches and methods for catching kittiwakes at sea, sampling/device attachment/data collection options, potential biases and other issues to be aware of. The outcomes of this project would facilitate a more wind farm focussed approach to collection of movement/linkage data, leading to efficiencies and reduced uncertainty in linking wind farm effects to relevant populations.

RO2.4a Desk-based review of the feasibility of catching kittiwakes at sea.

RO2.4b Exploratory catching at sea.

Applicability to other species

Desk-based review should be feasible for other species. However, some species may not occur at sufficient densities that a statistically robust sample size could be marked. Therefore, there may be ethical considerations of including such species in exploratory catching when the likelihood is larger scale tagging would not proceed. In addition, purpose of tagging would need to be clearly addressed. For example, if non-breeding populations were the key consideration, then capture and tag deployment in the breeding season may not yield the desired information. Longevity and retrieval of tags would also need to be considered.

OWEER identifies a number of gaps in knowledge about connectivity of birds at sea with breeding colonies, including outside the UK. MFRAG are currently looking into feasibility for larger gulls to establish the breeding colony(ies) of origin.

Reference and contact

*Black, J. & Ruffino L. 2019. Better linking effects of offshore windfarms on black-legged kittiwakes to populations, *JNCC Report No. 645*. JNCC, Peterborough, ISSN 0963-8091.

See also OWSMRF Scope of Work RO2.4 ‘Feasibility review of catching black-legged kittiwakes at sea’.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 2 -
Improving understanding of connectivity between offshore wind farm and SPAs
(Black & Ruffino 2019*)

RO2.5 Citizen science to provide age structure information

Short summary of proposed research

This RO would use citizen science to improve evidence for assessing what proportion of birds seen at a wind farm footprint (and/or potentially affected by a wind farm) are adults. This would allow potential wind farm effects to not only be apportioned to the appropriate population (e.g. colony) but also to the appropriate age-class within each population.

RO2.5a Programmed trawl of online photograph libraries to pick out photographs of kittiwake, which could be assessed to identify age class.

RO2.5b Active 'upload' system of photographs taken by volunteers from coast and vessels of opportunity. These could then be assessed for age of kittiwake.

RO2.5c Pushing kittiwake aging as part of the survey agenda for volunteer surveyors taking part in JNCC's Volunteer Surveyors At Sea programme. This currently operates on routes off western Scotland with plans to extend to eastern Scotland and beyond.

Applicability to other species

Extension of this RO to other species would only be feasible for those species that show age-class plumage characteristics. Potentially restricted to gannet and gull species for differentiation of age classes, and mature/immature for other species. The architecture of a kittiwake Citizen Science programme could be used for other species where age-class information was collectable (i.e. determinable in the field) and desirable. JNCC Report 677 identifies collection of age class information as having the potential to improve estimates for productivity, adult and immature survival in Population Viability Analysis (PVA), and quantifying the effects of displacement on different age classes, e.g. immatures and non-breeders.

Sensitivity analysis of PVA models and any emerging displacement models would establish if age-class data is one of the key sources of uncertainly for each species in these assessments.

Reference and contact

*Black, J. & Ruffino L. 2019. Better linking effects of offshore windfarms on black-legged kittiwakes to populations, *JNCC Report No. 645.* JNCC, Peterborough, ISSN 0963-8091.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.1 Use of large-scale strategic modelling approaches to better understand kittiwake meta-population dynamics and estimate connectivity among colonies

Short summary of proposed research

This project makes use of an existing meta-population modelling framework, which has been developed by the University of Glasgow, to estimate the strength of connectivity among kittiwake colonies in key areas of Britain and Ireland. This would provide a better understanding of the wider population context in which individual kittiwake SPA colony dynamics operate.

RO3.1a Application of the model in UK/regional context using currently available data.

RO3.1b Perform model sensitivity analyses to identify which data gaps most strongly affect model performance.

RO3.1c Undertake targeted empirical data collection as informed RO3.1b.

RO3.1d Re-run meta-population model with new empirical data to generate improved estimates of connectivity.

Applicability to other species

The model can be used with data-limited populations (within limits) so it is potentially feasible to model a greater range of species and populations. A gap analysis would be required to understand for which species sufficient data is available to run at UK/regional scale.

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

See also OWSMRF Scope of Work RO3.1 'Modelling of kittiwake meta-population dynamics'.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.2 Further development of a population modelling tool that assists with assessing population response to changes in mortality or productivity

Short summary of proposed research

This project will add additional functionality to an existing on-line "PVA Tool", specifically a meta-population function that allows emigration and immigration to be incorporated into the population models. Movement rates will be informed by the outputs of RO3.1. This would improve confidence in predicted population response to estimated mortality from a planned offshore wind development by bringing more biological realism to current PVA approaches. It would also enable better modelling of other management measures that could increase productivity and survival, thereby informing evaluation of conservation measures.

Applicability to other species

The NE PVA Tool currently models: Arctic skua, puffin, guillemot, razorbill, little tern, common tern, Sandwich tern, kittiwake, herring gull, lesser black-backed gull, greater black-backed gull, fulmar, gannet, fulmar, shag and cormorant. Expansion of the Tool to model meta-populations (immigration/emigration) has been discussed but thus far not progressed. Outputs from RO3.1, if extended to other species, could enable this expansion.

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.3 Strategic mark-recapture studies to improve empirical estimates of dispersal and survival

Short summary of proposed research

This project will assess the feasibility of a large-scale kittiwake mark-recapture study, such as colour-ringing, in the UK to improve empirical estimates of key demographic rates such as survival and dispersal rates. Better estimates of these parameters are needed to improve the parameterisation of PVA and meta-population models, leading to improved confidence in predictions of how kittiwake populations are likely to respond to offshore wind farm mortality.

RO3.3a Feasibility of a coordinated large-scale mark-recapture programme of adult kittiwakes: desk-based review.

RO3.3b Feasibility of a coordinated large-scale mark-recapture programme of immature kittiwakes: desk-based review.

RO3.3c Deploying strategic adult mark-recapture at multiple colonies, and analyses of re-sighting data.

RO3.3d Deploying strategic chick mark-recapture at multiple colonies, and analyses of re-sighting data.

Applicability to other species

JNCC Report 684 on the feasibility of a kittiwake colour-ringing study concluded colour-ringing studies of 10 years could provide high levels of precision (within 2% of true values) of adult survival estimates and moderate levels (±10%) for juvenile/immature. Colour-ringing studies could be extended to other species but would probably require similar timescales/ringing effort. It would also be highly dependent on the strength of existing demographic data to inform power analysis. Therefore, while extension to some other species may logistically be feasible, it would be unlikely to provide useful information within the timeframe under consideration (3-5 years). Long-term mark-recapture adult survival studies of Manx shearwater breeding at Skomer and Skokholm are ongoing. Chick ringing also occurs at these colonies, as it does at Lundy (and probably other colonies). Long-term adult survival data is available for herring gull, lesser black-backed gull, razorbill, guillemot and puffin at Skomer, with similar available data from the Isle of May.

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.4 Reconstructing adult survival rates for populations where empirical estimates are lacking

Short summary of proposed research

This project addresses the lack of population-specific empirical estimates of kittiwake survival rates. It will make use of an existing modelling approach developed by the University of Glasgow to reconstruct survival estimates for kittiwake colonies of interest where this information is lacking. Better estimates of key demographic rates would improve parameterisation of population models (e.g. PVAs, meta-population models).

Applicability to other species

This RO has been addressed by the work in Horswill *et al*. (2021), which reconstructed kittiwake adult survival rates for 68 populations in the UK/Ireland. With their approach, they quantify the life-history trade-offs between adult survival and fecundity.

Extension of the model to other seabird species could be achieved in the manner described for kittiwake. Review of species for which population-specific estimates of survival rates are lacking would be required, followed by collation of breeding success data from the Seabird Monitoring Programme as per kittiwake proposal.

Extension of the model to other life-history traits may also be considered, although feasibility would highly depend on a robust understanding of how different life-history traits relate to each other by species.

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

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Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.5 Estimating the form and strength of compensatory density-dependence in kittiwake population dynamics at different spatial scales

Short summary of proposed research

This project makes use of the rich kittiwake colony monitoring datasets available in the UK, as well as existing robust population modelling approaches, to try to detect patterns of compensatory density-dependence in kittiwake colonies. The form and strength of density dependence used in PVA models strongly influences model predictions about how the population will respond to additional mortality. Obtaining and implementing novel empirical data on how density dependence operates on populations and the spatial and temporal scales over which density dependence might occur will improve confidence in PVA predictions.

RO3.5a A critical assessment of available kittiwake colony data.

RO3.5b Measuring compensatory density dependence at different scales using data collected across the Seabird Monitoring Programme, identifying whether density dependence is uniform between populations (using state-space population model for colonies with sufficient data).

RO3.5c Measuring compensatory density dependence by modelling carrying capacity: meta-population modelling including regional and local carrying capacities.

Applicability to other species

Application of this RO would be feasible for other species. However, a review of the density-dependant effects exhibited in other species would be a necessary first step, as the form (compensatory or depensatory) or strength of density-dependence is likely to vary with species and potentially colony too.

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

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Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.6 Detecting depensation effects by modelling kittiwake population dynamics scales

Short summary of proposed research

With this project, it is proposed to build a model to assess the relative importance of depensatory density dependence in breeding kittiwake populations, evaluate its strength and infer where and when this process may be more likely to occur. Identifying at what population size/density kittiwake populations are at risk of declining to extinction due to depensation effects is important as additional mortality on populations could inadvertently push populations into such a decline.

RO3.6a Review of kittiwake monitoring data - identify colonies that are declining or have undergone sharp declines in the past that could be attributed to predation.

RO3.6b Modelling depensation effects - develop a model that includes a depensation term.

Applicability to other species

While RO3.6a should be feasible to apply to any species, the ability to apply RO3.6b will be dependent on data availability on other species. However, colonies vulnerable to predation may be identified through other means, such as through the emerging Seabird Conservation Strategies.

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651*. JNCC, Peterborough, ISSN 0963-8091.

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Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.7 Assessing the importance of non-breeding birds in UK kittiwake populations

Short summary of proposed research

This desk-based study would estimate the extent of non-breeding in UK kittiwake populations, using available data on population size, breeding success and adult survival. This would improve the context of PVA models and help anticipate the ability of kittiwake populations to buffer against additional mortality caused by offshore wind.

Applicability to other species

It is generally considered that sabbaticals from breeding are relatively common in all long-lived species such as seabirds. In principle, sabbatical rates for other species could be estimated. However, it would likely be a similar process as that proposed for kittiwake, and there may not be sufficient current data for some species:

- What empirical data are available, for example, from long-term monitoring of individual movements (e.g. with GLS tags or re-sighting data of ringed birds);
- Can the available information provide insights on the spatial scale of influence of non-breeders (e.g. where do non-breeders recruit);
- What additional analyses could be done to estimate the extent of non-breeding in seabird species' populations from available data on population size, breeding success and adult survival, and
- What additional data would need to be collected to increase robustness of the results.

This should be feasible for all seabird species.

To note that this question was also raised at the NatureScot Marine Bird Impact Assessment Guidance Workshop (20 February 2020).

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

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Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.8 Examining the ecosystem processes driving the relationship between kittiwake breeding success and sea surface temperature

Short summary of proposed research

This project will improve understanding of how climate change is impacting kittiwake productivity and how other factors may be compounding the negative effects of warming seas. This RO will examine how various environmental and biological factors may have led to variation in breeding success between colonies and within colonies over time. Better understanding of what determines productivity at different colonies will improve predictions of how kittiwake populations are likely to change in the future due to climate change, along with other drivers of change such as offshore wind development. It will also ensure that potential conservation measures account for environmental and biological drivers of population change, and that conservation measures are effective and achieve the desired outcomes.

Applicability to other species

Daunt & Mitchell (2013) reviewed the potential consequences of climate change on seabirds in UK waters. JNCC Report 475j examines the relationship between breeding productivity and food availability (particularly age class 0 sandeel) for a number of seabird species breeding on the Isle of May, and Wanless *et al.* (2005) looked at food quality and breeding success of seabirds in the North Sea. More recently, Sadykova *et al*. (2020) has attempted to model the overlap of gannet, kittiwake and guillemot foraging and prey (sandeel and herring) with current future climate predictions to 2050. A relationship between sea surface temperature and Manx shearwater chick mass has been observed on Skomer Island (Riou *et al.* 2011). Extending this RO to other species is in principle feasible, but is reliant on understanding several key factors, not least of which is the diet of those species and data on the distributions and requirements of those prey species.

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.9 Kittiwake diets during the breeding season, and the relationship between prey availability and productivity

Short summary of proposed research

This project is a combination of desk-based and field studies to determine kittiwake dietary patterns during the breeding season and improve our understanding of the relationship between non-sandeel prey availability and productivity. This RO will help build confidence in how kittiwake populations are responding to declines in sandeel availability and thus assess their resilience to offshore wind farm-induced mortality. This would also provide key evidence to inform conservation measures, such as how kittiwake populations might respond to changes in management of commercial fisheries.

RO3.9a Spatial and temporal assessment of kittiwake diets, foraging distributions and prey distributions during the breeding season: desk-based study.

RO3.9b Regional comparison of kittiwake diets during the breeding season: field studies.

RO3.9c Relating prey availability to productivity: desk-based study.

Applicability to other species

JNCC Report 475j examines the relationship between breeding productivity and food availability (particularly age class 0 sandeel) for a number of seabird species breeding on the Isle of May. Similarly, diet information is available to some degree for most UK species, but is variable in extant and contemporaneousness; e.g. Guillemot (Anderson *et al.* 2013; Ouwehand *et al.* 2005; Wilson *et al.* 2005); Razorbill (Chimienti *et al.* 2015); Shag (Howells *et al.* (2018); Puffin (from a few key sites; also note RSPB citizen science project Puffarazi); Manx shearwater (Camphuysen 2005; Cramp and Brookes 1982; Thompson 1987).

Given age of some information, and that some of the studies above have highlighted changes in diet over their study periods, an evidence gap review would be needed before further work is developed. However, where sufficient good quality data on diet exists, then comparison with productivity data in e.g. Seabird Monitoring Programme should be feasible.

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.10 Assessing the current and future condition of alternative fish prey populations: a desk-based study

Short summary of proposed research

With this project, it is proposed to review the literature on forage fish species, specifically population status and trends, drivers of population dynamics, current fishing pressure and projected impacts of climate change on forage fish populations. This information will assist with identifying kittiwake colonies that are vulnerable to additional mortality and those that are likely to be more resilient to additional mortality, e.g. from OWF development, due to predicted availability of prey/forage fish species. Additionally, this will help assess which conservation management measures may be ineffective due to changes in forage fish populations.

Applicability to other species

The scope of this RO could be easily extended to other seabird species preying on similar fish prey as kittiwake (e.g. auks, divers).

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

For further information, contact OWSMRF@jncc.gov.uk

Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.11 Quantifying the effects of fisheries management on kittiwake demography

Short summary of proposed research

This project involves designing a monitoring plan to maximise power to detect changes in kittiwake demographic rates that could be attributed to changes in management of commercial fisheries (i.e. sandeels). This would be followed by data collection and analyses prior to changes in fishing effort, which would provide a baseline against which to assess demographic response to management. This project will enable evaluation of the effectiveness of fisheries-related conservation measures.

Applicability to other species

The lesser sandeel is a prey for many seabird species in the North Sea. Relative contributions of sandeels to the diet of seabirds vary by species, regions and years. Although changes in sandeel availability have been related to reduced productivity in some species and years (e.g. common guillemots; Rindorf *et al*. 2000), magnitude of changes is thought to be relatively low compared to kittiwake.

See also JNCC Report 475j that examines the relationship between breeding productivity and food availability (particularly age class 0 sandeel) for a number of seabird species breeding on the Isle of May.

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

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Knowledge Gap 3 -
Improving confidence in modelling population consequences of wind farm effects (Ruffino *et al*. 2020*)

RO3.12 Predicting the demographic consequences of various potential measures to manage pressures on kittiwake populations

Short summary of proposed research

This project would develop a strategic modelling framework that would enable identification of those pressures that exert the most detrimental effects on kittiwake demographic rates and then evaluate potential management options in terms of population rates of change. This information would bring wider context to current PVA assessments of population response to offshore wind mortality and inform likely efficacy of potential conservation measures. Specifically, this project would demonstrate the relative impact of offshore wind development on kittiwake populations, alongside other drivers of population change.

RO3.12a Identify the proximate causes of population decline.

RO3.12b Testing the effectiveness of a series of candidate management measures.

Applicability to other species

The proposed modelling framework has been developed for populations of marine mammals and seabirds (e.g. Matthiopoulos *et al*. 2014; Miller *et al*. 2019). While the theoretical part of this project could be applicable to other seabird species, empirical evidence on pressures (e.g. variation in fishing effort or annual predation rates over time) would be needed to quantify the relative contribution of specific pressures on demographic rates.

Reference and contact

*Ruffino L., Thompson, D. & O'Brien, S. 2020. Black-legged kittiwake population dynamics and wider drivers of population change in the context of offshore wind development, *JNCC Report No. 651.* JNCC, Peterborough, ISSN 0963-8091.

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