



Department for Energy Security & Net Zero

Recent Offshore Energy SEA funded projects

Since 1999, the UK's Department for Energy Security & Net Zero (DESNZ) and its forerunner departments Offshore Energy SEA programme has funded a significant number of marine surveys and research projects to improve the information base for undertaking strategic assessment and support activity specific consenting. The reports of, and data from, these studies are publicly available and deposited in the SEA data archive hosted by the [British Geological Survey](#), and the output from the most recent studies are available on the [SEA pages of the gov.uk website](#).

The more recent studies are tabulated below, arranged under four headings: Marine mammals (including noise), Birds, Seabed and Water Column and Cultural, Socio-Economic and Other. A summary of the research, its status and a link to the project report (where published) are also provided. The authors and researchers involved in the SEA studies have been encouraged to submit papers for peer reviewed publication, and recent publications related to each project are also listed.

Marine mammals (including noise)

Characterisation of Acoustic Fields Generated by UXO Removal: Phase 1 (OESEA-19-104), Phase 2 (OESEA-19-107), Phase 3 (OESEA-20-110), Phase 4 (OESEA-21-127) & Phase 5 (OESEA-21-128, 22-142)
National Physical Laboratory & University of Loughborough

Project Ongoing

Project overview

This project will establish an improved understanding of the sound generated during disposal of unexploded ordnance (UXO) at sea to underpin more realistic exposure assessments, identify appropriate mitigation and guide European Protected Species (EPS) licence applications. Completed elements of this project are: a review of the scientific research in the field and current operational procedures for UXO clearance operations, provision of a guidance protocol for those undertaking UXO sound measurements at sea, an experimental study in a controlled environment (flooded quarry) to characterise the acoustic 'near-field' of explosives and to assess the effectiveness of mitigation methods (e.g. deflagration), collection and analysis of measurements made during a variety of UXO removals by developers, and sea trials of sound generation and long-range propagation during UXO clearance off Denmark using high- and low-order techniques. Analysis of samples collected during UXO clearance to understand chemical contaminant release, and further quarry studies of the acoustic outputs of other UXO clearance techniques, has been undertaken.

Outputs

Research reports:

Cheong S-H, Wang L, Lepper P & Robinson S (2020). Characterisation of Acoustic Fields Generated by UXO Removal - Phase 2. [NPL Report AC 19, 60pp](#).

NPL & Loughborough University (2020). Protocol for In-Situ Underwater Measurement of Explosive Ordnance Disposal for UXO, [version 2, 28pp](#).

NPL (2023). Characterisation of acoustic fields generated by UXO removal. Phase 5B quarry trials of bubble curtain mitigation. [NPL Report AC 22, 25pp](#)

NPL (2023). Characterisation of acoustic fields generated by UXO removal Phase 5B quarry trials of ECS low-order technology. [NPL Report AC 23, 29pp](#).

Peer reviewed papers:

Robinson SP, Wang L, Cheong S-H, Lepper PA, Marubini F & Hartley JP (2020). Underwater acoustic characterisation of unexploded ordnance disposal using deflagration. [Marine Pollution Bulletin 160: 111646](#)

Robinson SP, Wang L, Cheong S-H, Lepper PA, Hartley JP, Thompson PA, Edwards E & Bellmann M (2022). Acoustic characterisation of unexploded ordnance disposal in the North Sea using high order detonations. [Marine Pollution Bulletin 184: 114178](#).

Lepper PA, Cheong S-H, Robinson SP, Wang L, Tougaard J, Griffiths ET & Hartley JP (2024). In-situ comparison of high-order detonations and low-order deflagration methodologies for underwater unexploded ordnance (UXO) disposal. [Marine Pollution Bulletin 199: 115965](#).

**SCANS-IV Planning Support (OESEA-21-136)
SMRU/University of St Andrews**

Project Completed

Project overview

This project was to facilitate the successful planning and coordination of the SCANS-IV survey which was undertaken in summer 2022. The SCANS-IV surveyed all European Atlantic waters from the Strait of Gibraltar in the south to 62°N in the north and extending west to the 200 nm limits of all EU Member States. The final surveyed area excluded offshore waters of Portugal and waters to the south and west of Ireland which were surveyed by the Irish ObSERVE project. The project made input to the design of a large-scale line transect aerial/ship survey for cetaceans in European Atlantic shelf waters, the data analyses and formulation of a workable survey programme structure and governance framework for the future, including a review of the structure/governance of other large-scale cetacean survey programmes.

Outputs

Research reports:

Gilles A, Authier M, Ramirez-Martinez NC, Araújo H, Blanchard A, Carlström J, Eira C, Dorémus G, Fernández-Maldonado C, Geelhoed SCV, Kyhn L, Laran S, Nachtsheim D, Panigada S, Pigeault R, Sequeira M, Sveegaard S, Taylor NL, Owen K, Saavedra C, Vázquez-Bonales JA, Unger B, Hammond PS (2023). Estimates of cetacean abundance in European Atlantic waters in summer 2022 from the SCANS-IV aerial and shipboard surveys. [Final report published 29 September 2023](#). 64 pp.

Porpoise behavioural response to decommissioning noise (OESEA-21-133 & OESEA-21-134)

Project Completed

University of Aberdeen and National Physical Laboratory

Project overview

This project is to improve understanding of harbour porpoise responses to offshore installation presence and to decommissioning activities. Between April and September 2021 2 Soundtraps and 37 CPODs were deployed in the Moray Firth in the vicinity of the Jacky platform and along a transect extending to the Beatrice Bravo platform and 2 wind turbines (all ceased production) which allowed porpoise presence and foraging behaviour to be monitored before, during and after decommissioning of one of the structures. The Soundtraps provided excellent characterisation of the sounds produced by the different decommissioning activities (e.g. suction can removal and jacket lifting by a large semi-submersible crane vessel) which can be compared to coincident porpoise behaviour. Several papers are in draft to be submitted to relevant journals for peer review.

Outputs

Peer reviewed papers:

Fernandez-Betelu O, Graham IM & Thompson PM (2022). Reef effect of offshore structures on the occurrence and foraging activity of harbour porpoises. [Frontiers in Marine Science 9: 980388](#).

Fernandez-Betelu O, Graham IM, Malcher F, Webster E, Cheong S-H, Wang L, Iorio-Merlo V, Robinson S & Thompson PM (2024). Characterising underwater noise and changes in harbour porpoise behaviour during the decommissioning of an oil and gas platform. [Marine Pollution Bulletin 200: 116083](#).

Estimating survival and dispersal of grey seal pups (OESEA-20-121, OESEA-21-131 & 22-144) University of St Andrews	Project Ongoing
Project overview	
<p>Around the UK there are stark differences in the regional population trajectories of grey seals. Evidence from the Wales and SW England Seal Management Units (SMUs) indicates that the population is increasing. This is despite an estimated unsustainable level of bycatch mortality that far exceeds the Potential Biological Removal limits. The SW British grey seal population must therefore be receiving significant immigration. The source population must be in the UK and is most likely the Western Isles SMU. This project aims to elucidate this issue through seal tracking and thus provide information essential to strategic and project level assessments. ARGOS satellite tags were deployed on 50 grey seal pups on the Monach Isles in November 2021. Adverse weather prevented the deployment of a further 25 tags in November 2022, which is now planned for November 2024.</p>	
Outputs	
<i>Project in progress</i>	
Small cetacean population ecology to inform conservation and management (OESEA-20-121) University of St Andrews	Project Ongoing
Project overview	
<p>This project is to improve understanding of the population ecology of harbour porpoises and, potentially, common dolphins. Much valuable information about the biology and abundance of small cetaceans around the UK has been collected over the past thirty years. However, with the exception of photo-id based studies of bottlenose dolphins, little effort has been made to understand the underlying population level processes that may explain any observed temporal trends in abundance. Key factors in developing an understanding of population ecology are the feeding habits, growth rates, and condition of individuals within the population, all of which may influence population growth rates. This understanding will inform efforts to assess how human activities may be impacting small cetacean populations, as well as conservation measures and site management.</p>	
<p>Stomach contents and teeth are routinely collected by the UK cetacean strandings schemes, augmented by samples from the protected species bycatch monitoring programme. Biological samples from these schemes have been used in <i>ad hoc</i> studies in the past to describe feeding habits of some species and to provide age estimates of some individuals. These two data sources (coupled with standard measures of length, girth and maturity) are key to understanding the population ecology of the species of interest. Among the stranded and bycaught cetaceans recorded or necropsied in the UK, harbour porpoises are by far the most common, but common dolphins are also found in useable numbers. The project will address a series of questions including inter-annual trends in diet composition, prey availability and prey preference; variation in diet by porpoise age, size, sex or reproductive status; reliability of age determinations; and population level implications of predicted age distribution.</p>	
Outputs	
<i>Project in progress</i>	
Causes of harbour seal decline in the southern North Sea (OESEA-21-138, OESEA-23-154) University of St Andrews	Project Ongoing
Project overview	
<p>Recent counts of harbour seal in the southeast England Seal Management Unit have revealed rapid declines in abundance of approximately 25% since 2018. This project aims to investigate the causes of this decline through seal tracking and thus provide information essential to strategic and project level assessments. The project is focussed on improving understanding of seal behavioural and spatial ecology and is part of a wider initiative with other work packages investigating patterns in seal diet and health, and trends in harbour and grey seal counts. Tags were deployed in spring 2023.</p>	
Outputs	
<i>Project in progress</i>	

Climate Change and seal populations of the United Kingdom (OESEA-20-118) University of St Andrews	Project Ongoing
Project overview	
<p>This PhD studentship follows from several BEIS SEA funded tagging studies of harbour & grey seals around the UK and will investigate the impact of environmental variation at different time scales on grey and harbour seal distribution and movement.</p>	
<p>Seal population dynamics are a complex interaction of multiple factors operating on short and longer timescales. The ability to disentangle cause from effect is fundamental to sound assessments and environmental management decisions. For example, in the southern North Sea, the 2019 moult count of harbour seals in the Wash indicated a number 27.5% lower than the mean of the previous 5 years). The 2020 count was 21.5% lower than that mean suggesting that the 2019 count is not an anomaly. There are numerous factors potentially involved such as prey availability, accumulation of biotoxins, interspecific competition with grey seals, potentially mediated through the increase in offshore windfarm developments. The results will have implications for marine spatial planning, marine energy development strategic and project assessments, the management of existing conservation sites designated for seals, and Habitats Regulations Assessments.</p>	
Outputs	
<i>Project in progress</i>	
NIRS tags to study physiological and energetic consequences of noise Phase 1 (OESEA-18-87), Phase 2 (20-111), Phase 3 (22-148) University of St Andrews	Project Ongoing
Project overview	
<p>There are no direct measurements of the energetic consequences of behavioural responses of marine mammals to offshore activities, including those which are noise generating such as pile driving, seismic surveys, shipping, and sonar. Even in the absence of permanent or temporary effects on hearing, there may be significant metabolic costs by moving away from favoured foraging grounds or transit routes. However, these are difficult to quantify as there are no means by which to accurately assess short-term changes in metabolic rates.</p>	
<p>Recent advances in near-infrared spectroscopy (NIRS) allow non-invasive, real-time measurements of blood oxygenation in animals, and the ability to detect and monitor haemodynamic activity in parts of the cerebral cortex in free ranging seals has already been demonstrated. Localised cerebral blood flow is closely associated with brain region activation and NIRS has been used to demonstrate changes in regional blood flow in humans during playbacks of sounds. The system has been tested on freely swimming seals in the captive facility at SMRU and brain haemodynamics in juvenile grey seals was recorded during a series of controlled sound exposure trials using a range of anthropogenic and control signals. Phase 2 involved the integration of the NIRS system with GPS/GSM tags so that they can be deployed for several months on wild animals. Future work will include validation of the system and collection of test datasets from human and pinniped divers, followed by full-scale field deployment in the UK.</p>	
Outputs	
Research reports: <i>Project in progress.</i>	
Peer reviewed papers: McKnight JC, Ruesch A, Bennett K, Bronkhorst M, Balfour S, Moss SEW, Milne R, Tyack PL, Kainerstorfer J & Hastie GD (2021). Shining new light on sensory brain activation and physiological measurement in seals using wearable optical technology. Philosophical Transactions of the Royal Society B 376: 20200224 . McKnight JC, Mulder E, Ruesch A, Kainerstorfer J, Wu J, Hakimi N, Balfour S, Bronkhorst M, Horschig JM, Pernet F, Sato K, Hastie GD, Tyack P & Schagatay E (2021). When the Human Brain Goes Diving: Using NIRS to Measure Cerebral and Systemic Cardiovascular Responses to Deep, Breath-Hold Diving in Elite Freedivers. Philosophical Transactions of the Royal Society B 376: 20200349 . Ruesch A, McKnight JC, Fahlman A, Shinn-Cunningham BG & Kainerstorfer JM (2022). Near-Infrared Spectroscopy as a Tool for Marine Mammal Research and Care. Frontiers in Physiology 12: 816701 .	

Aerial survey data for monitoring harbour porpoise population health (OESEA-18-89)
SMRU Consulting

Project Completed

Project overview

This study explored the potential for aerial survey images to provide information on the age structure and body condition of harbour porpoise, and therefore make inferences about population health and potentially provide early warning signs of changes in abundance. A sample of 400 images was obtained from two survey companies, from which measurement of the length and width of animals were made.

Measuring width was challenging due to image quality constraints and animal position, and showed high inter-user error; therefore, it was not possible to obtain any sensible estimate of body condition based on measured animal width. Furthermore, the effects of reproductive status in females and seasonal variations in body mass and girth in both sexes limit the appropriateness of width as an indicator of animal health. Measuring length was also subject to animal position and image quality issues, but was a more reliably measured metric with lower inter-user error. A review of literature revealed variation in the age and size of animals at sexual maturity, which, in addition to sexual dimorphism, provides considerable challenges in assigning stage structure to harbour porpoises based on length measurements alone. Nonetheless, length thresholds were proposed to estimate the minimum proportion of immature (<127cm) and mature (≥152cm) animals within a sample/population.

Additional work was recommended to obtain a better understanding of the current/recent stage structure of the harbour porpoise population around the UK including analysing more survey imagery, exploring automated approaches to measuring animals; collating and analysing more data on age or length at sexual maturity; and, review literature to determine other suitable metrics/approaches of how demographic parameters have been used to supplement population health monitoring.

Outputs**Research reports:**

Sinclair, RR & Booth, CG (2019). Aerial survey data for monitoring harbour porpoise population health. Report No. [SMRUC-BEI-2019-003, 66pp.](#)

Abundance and distribution of beaked whales and other deep-diving cetaceans around Britain (OESEA-17-83)
University of St Andrews

Project Completed

Project overview

Beaked whales and other species of deep-diving cetaceans are vulnerable to anthropogenic sources of noise, including from development of offshore energy. Information on the distribution and abundance of beaked whales is sparse, especially at a large scale, but there are additional data from various sources that add considerably to current knowledge. These sources include the 2016 SCANS-III survey in European Atlantic waters, the Faroes block of NASS 2015, the Irish ObSERVE project in 2015/16, and previously unanalysed data from JNCC. These data have been used to provide the most comprehensive description of the distribution and abundance of beaked whales and other deep-diving cetaceans around Britain.

Design-based (block-based) estimates of abundance had been calculated from SCANS-III data but only for all species combined for beaked whales. This project has derived abundance estimates for the main beaked whale species, as well as sperm whales and pilot whales, fitted habitat use models to SCANS-III data on deep-diving cetaceans using as covariates features that explain the most variability in abundance to investigate potential environmental drivers of distribution, and predicted density surfaces developed based on best-fitting models.

Outputs**Research reports:**

Lacey C & Hammond PS (2023). Distribution and abundance of beaked whales and other deep-diving in European Atlantic Waters. [Report to BEIS](#), 59pp.

iPCoD Expert Elicitation Updates (OESEA-17-82) SMRU Consulting	Project Completed
Project overview	
<p>The Interim Population Consequences of Disturbance (iPCoD) framework was developed by SMRU Consulting and the University of St Andrews in 2013 to forecast the potential effects on marine mammal populations in UK waters of disturbance and hearing loss (permanent threshold shift, PTS). Due to considerable knowledge gaps on the potential effects of disturbance or PTS on vital rates (e.g. survival, fertility), the framework was developed with the quantification of these effects determined via expert elicitation, conducted in 2013 using an online questionnaire, which at the time was considered an interim solution. The objective of this study was to conduct expert elicitation workshops to update the transfer functions on the effects of hearing loss and behavioural disturbance on survival and fertility in several UK marine mammal species.</p>	
<p>Two workshops were held in 2018, one focussing on PTS and one on behavioural disturbance, each lasting 2-3 days and comprising leading experts in the subject matter. Experts discussed the evidence, defined the scope of the elicitation, and produced probability distributions to quantify the effects of PTS and behavioural disturbance (resulting from exposure to low-frequency broadband pulsed noise) on survival and fertility in harbour porpoise, harbour seal, grey seal and bottlenose dolphins (PTS only).</p>	
<p>The results of the exercise reveal considerable differences to those conducted in 2013; overall, experts indicated that effects were likely to be less severe than previously predicted, and this is now reflected in new iPCoD scenarios. Differences over the 2013 results were driven by new empirical data collected and published since then; the presentation of a dynamic energy budget model for harbour porpoise to help guide discussions and test expert theories on the effects of disturbance on vital rates; and, the face-to-face element of the workshop to allow discussion among experts, in particular prior-agreement of the scope of the elicitation and definition of key terms. Recommendations for further work include research towards replacing the elicited relationships with empirically derived ones and, where appropriate, validating the existing relationships. Additionally, there will likely be value in revisiting the 2018 elicitations in the light of new learning.</p>	
Outputs	
Research reports:	
<p>Booth CG & Heinis F (2018). Updating the Interim PCoD Model: Workshop Report - New transfer functions for the effects of permanent threshold shifts on vital rates in marine mammal species. Report Code SMRUC-UOA-2018-006, submitted to the University of Aberdeen and Department for Business, Energy and Industrial Strategy (BEIS). May 2018, 34pp.</p>	
<p>Booth CG, Heinis F & Harwood J (2019). Updating the Interim PCoD Model: Workshop Report - New transfer functions for the effects of disturbance on vital rates in marine mammal species. Report Code SMRUC-BEI-2018-011, submitted to the Department for Business, Energy and Industrial Strategy (BEIS), February 2019, 28pp.</p>	
Seal habitat preference and distribution on west and north UK coasts (OESEA-16-76, OESEA-17-77, OESEA-17-85 and OESEA-18-92) SMRU	Project Completed
Project overview	
<p>This study includes a targeted programme of grey seal tagging and spatial-temporal analyses of both grey seal (current deployment of 48 GPS/GSM tags) and harbour seal (previous deployment) high-resolution telemetry data. Ten tags were deployed on grey seals on Bardsey in 2018, with a further ten planned for deployment on Ramsey in 2019. A further 50 tags were deployed across four sites in the Western Isles (Monachs), West Scotland (Islay/Colonsay), Orkney (Pentland Firth) and North Wales (Dee Estuary) in 2017, and another 17 were deployed in Orkney (Pentland Firth) and East Scotland (Moray Firth) in 2018. The most recent tagging included a combination of GPS/GSM tags and GPS/GSM-ARGOS tags, with the latter providing the ability to provide at-sea location in near real time. These data are being supplemented by similar data from University College Cork, which indicates interchange of seals between Ireland and Wales.</p>	
<p>The deployment of additional GPS/GSM tags took place on Bardsey in 2018 and on Skomer and Ramsey in spring 2019, with the aim of filling an important gap in spatial coverage of seal habitat preference and distribution on the west Wales coasts.</p>	

Outputs	
Research reports: Carter, M. I. D. et al. (2020) Habitat-based predictions of at-sea distribution for grey and harbour seals in the British Isles. Sea Mammal Research Unit, University of St Andrews, Report to BEIS, OESEA-16-76/OESEA-17-78 .	
Peer reviewed papers: Carter MID, Boehme L, Cronin MA, Duck CD, Grecian WJ, Hastie GD, Jessopp M, Matthiopoulos J, McConnell BJ, Morris CD, Moss SEW, Thompson D, Thompson PM & Russell DJF (2022). Sympatric seals, satellite tracking and protected areas: habitat-based distribution estimates for conservation and management. Frontiers in Marine Science 9: 875869 .	

Tidal stream device effects on marine animals (OESEA-16-75) University of Aberdeen	Project Completed
Project overview	
The project builds on previous and existing NERC and other projects on tidal turbines in the Pentland Firth and involved the development of software and algorithms to process and associate incoming data streams from instrumented turbines. This combined analysis of ecological, environmental and physical data (e.g. hydrodynamics), will aid understanding of animal behaviour in a tidal site and around an operating tidal turbine, and the mechanisms affecting predator-prey interactions to inform scaling up to larger arrays. The detailed characterisation of inflow turbulence and its impact on strain gauge measurements will allow development of adaptive processing techniques to remove physical interference in strain gauge measurements e to isolate collision events.	
Outputs	
Peer reviewed papers: Williamson B, Fraser S, Williamson L, Nikora V & Scott B (2019). Predictable changes in fish school characteristics due to a tidal turbine support structure. Renewable Energy 141: 1092-1102 . Williamson BJ, Blondel P, Williamson LD & Scott BE (2021). Application of a multibeam echosounder to document changes in animal movement and behaviour around a tidal turbine structure. ICES Journal of Marine Science 78: 1253-1266 .	

Behavioural responses by seals to offshore energy activities (OESEA-16-74) University of St Andrews	Project Completed
Project overview	
This project is a jointly funded (with the University of St Andrews) PhD studentship to investigate the behavioural responses of seals to a range of real and simulated anthropogenic sound sources, including tidal turbines, pile-driving and Acoustic Deterrent Devices (ADDs). The data have been already collected (high-resolution tagging data); the project is focussed on the analysis of individual movement patterns by seals in relation to estimated sound exposure.	
Outputs	
Peer reviewed papers: Whyte KF, Russell DJF, Sparling CE, Binnerts B & Hastie GD (2020). Estimating the effects of pile driving sounds on seals: Pitfalls and possibilities. Journal of the Acoustical Society of America 147: 3948-3958 .	
PhD thesis: White KF (awarded 2022). Behavioural responses by seals to offshore energy activities. University of St Andrews. https://doi.org/10.17630/sta/222	

Analysis of seal behaviour at sea (OESEA-15-66) University of St Andrews	Project Completed
Project overview	
High resolution GPS/GSM tags were deployed on 25 harbour seals and 20 grey seals in the southern North Sea to study animal activity budgets (resting, foraging and travelling intervals) at 2 hourly intervals. Data for 21 and 17 harbour and grey seals respectively was considered to be of sufficient quality to be used in the study. Activity budgets were defined within a Bayesian state-space model. Location data was treated both geographically (i.e. the recorded movements) and as the vector of seal speed and current speed to avoid potential misinterpretation of foraging and travelling behaviour due to tidal flow.	
Overall activity budgets were similar for harbour and grey seals with time divided approximately between resting (30%), foraging (45%) and travelling (25%). Significantly more time was spent foraging (at the expense of travelling) in hydro-space compared to geo-space, though note that for hydro-space there is an unknown error associated with the current data used. These activity budgets could serve as a baseline to the proportion of time in each state which can be compared with future telemetry data to determine any changes in foraging effort.	
Outputs	
Research reports: Russell DJF (2016). Activity budgets: analysis of seal behaviour at sea. Report for the Department for Business, Energy and Industrial Strategy, 21pp.	
Analysis of impulsive sounds (OESEA-15-61) SMRU Ltd, with Cefas and University of Aberdeen	Project Completed
Project overview	
It is common practice to compare predicted underwater sound exposure with predefined threshold criteria to assess the risk of injury from noise generating anthropogenic activities. Commonly adopted threshold criteria differentiate between impulsive and non-impulsive sounds, with impulsive sounds (e.g. seismic, piling) having a greater potential for auditory damage and behavioural response. However, over large distance, impulsive sounds may lose their impulsive characteristics with potential implications for impact assessment. A limiting factor in current understanding is the paucity of empirical data; to address this gap, this study uses previously recorded sounds to investigate how acoustic signals vary as a result of propagation effects.	
Outputs	
Research reports: Hastie G, Götz T, Russell D, Janik VM, Thompson P & Merchant N (2017). Range-dependent characteristics of impulsive sounds: implications for marine mammal behavioural responses and auditory damage. Report to BEIS.	
Peer reviewed papers: Hastie G, Merchant ND, Götz T, Russell DJF, Thompson P & Janik VM (2019). Effects of impulsive noise on marine mammals: investigating range-dependent risk. Ecological Applications 29: E01906.	
Comparing the performance of Interim PCoD and the Moray Firth Seal Assessment Framework (OESEA-14-48) University of Aberdeen and others	Project Completed
Project overview	
This study has used available data from intensively studied harbour seal populations (Moray Firth & the Wash) to compare the performance of two assessment frameworks under different development scenarios. A further element, a new expert elicitation exercise was undertaken in 2017 to allow enhancement of the models.	
Outputs	
Research reports: Thompson P, Harwood J, Booth C, Hastie G & McLean N (2017). Comparing the performance of Interim PCoD and the Moray Firth Seal Assessment Framework. Report to BEIS.	

Southern North Sea seal tagging (OESEA-14-47) and update to grey seal usage maps (OESEA-15-65) SMRU/University of St Andrews	Project Completed
Project overview	
<p>The project aim is to improve understanding of areas of grey seal usage in the southern North Sea where grey seal populations are rapidly increasing. Previous tagging data is sparse and old, and the foraging areas overlap with proposed offshore wind farm and gas field developments. Twenty-one GPS/GSM tags were deployed on grey seals at Blakeney Point and at Donna Nook to provide improved understanding of transit routes, foraging areas, SAC haulout site fidelity, and interspecific interaction with harbour seals. Fieldwork was undertaken in May 2015.</p> <p>This work has also fed into a separate project to update grey seal usage maps, with data from the above tags and some additional tags deployed in eastern Scottish waters in 2013 being combined to provide data based on 175 tags spanning the years 1991-2015. When combined with 2014 population data, species distribution maps and confidence intervals were mapped on a 5x5km grid.</p>	
Outputs	
<p>Research reports: Russell DJF (2016). Movements of grey seal that haul out on the UK coast of the southern North Sea. Report for the Department of Energy & Climate Change, 18pp.</p> <p>Jones EL & Russell DJF (2016). Updated grey seal (<i>Halichoerus grypus</i>) usage maps in the North Sea. Report for the Department of Energy & Climate Change, 15pp. Latest GIS data.</p>	
<p>Peer reviewed papers: Wyles HME, Boehme L, Russell DJF & Carter MID (2022). A Novel Approach to Using Seabed Geomorphology as a Predictor of Habitat Use in Highly Mobile Marine Predators: Implications for Ecology and Conservation. Frontiers in Marine Science 9:818635.</p>	
Tidal stream noise propagation (OESEA-13-42) SAMS (with University of Loughborough)	Project Completed
Project overview	
<p>From first principles, since sound velocity in water is high (1500 m/s) relative to tidal current velocity (max 4 m/s), flow should have negligible effect – however, field data indicate that this may not be the case with several possible influences identified e.g. effects of turbulence on absorption, vertical density stratification, topographic constraints. To test this, receiver stations and an acoustic source were set up in slack water with an intervening area of strong tidal flow in Falls of Lora, Connel, Argyll. Measurements were made at different tidal states (spring ebb, and slack neap) with peak flow measurements recorded at ~3m/s.</p> <p>Potential influences include basin shape, water column and sediment properties and water surface smoothness. Sound propagation was found to vary, with lower acoustic levels recorded during high tidal flow periods compared to low flow periods for frequencies in the 200Hz-6.3kHz range, with this observation gradually reversed for frequencies below 200Hz. Higher attenuation rates during higher flow periods for frequencies of interest were recorded, perhaps due to increased suspended sediment and entrained bubbles, as were higher background noise levels leading to lower source to background noise ratios. This may possibly be advantageous in terms of effects on hearing, but less so for avoidance of tidal structures.</p>	
Outputs	
<p>Research reports: Lepper PA, Elliot J, Benjamins S & Wilson B (2016). Variation in acoustic propagation across a tidal flow. SAMS and the University of Loughborough, 10pp.</p>	

Measuring fine scale marine mammal responses around an operational tidal turbine (OESEA-13-38)
SMRU/SMRU Ltd.

Project Completed

Project overview

An understanding of marine mammal behaviour in the vicinity of tidal turbines is important in the prediction of potential impacts on individual species from the wider deployment of devices and arrays. Work to date by SMRU at the SeaGen tidal turbine, Strangford Lough, has sought to develop an active multibeam sonar system to detect the movement of marine mammals in proximity to the device. A range of systems were assessed during a DECC (now BEIS) funded study by SMRU (OESEA-11-23). As a result of this project, multibeam imaging sonar was trialled on SeaGen (see figure below) and capabilities for identifying marine mammals and tracking individuals around the turbine are much improved, but would benefit from validation by visual means or high resolution tagging.

Operational licence conditions of the Strangford Lough turbine were such that the turbine was shut down when marine mammals are within 30m of the installation. The resulting data from the development of the active sonar system has been useful, but has not resolved the gap in understanding interactions of marine mammals with tidal turbines in continuous operation. In order to help fill this data gap and to further develop the active sonar system, permission was granted by the Northern Ireland Department of Environment Marine Division to temporarily suspend the shutdown protocol. However, the decision to decommission the tidal turbines meant that this aspect of the project could not be taken forward.

Outputs**Peer reviewed papers:**

Sparling C, Lonergan M & McConnell B (2017). Harbour seals (*Phoca vitulina*) around an operational tidal turbine in Strangford Narrows: no barrier effect but small changes in transit behaviour. [Aquatic Conservation: Marine Freshwater Ecosystems 28: 194-204.](#)

Joy R, Wood JD, Sparling CE, Tollit DJ, Copping AE & McConnell BJ (2018). Empirical measures of harbor seal behavior and avoidance of an operational tidal turbine. [Marine Pollution Bulletin 136: 92-106.](#)

Sonar detection of marine mammals (OESEA-11-23)
SMRU Ltd.

Project Completed

Project overview

Currently, there is an information gap on the environmental impacts of tidal stream marine renewable energy devices on marine mammals (seals, whales and dolphins) as few of these devices have been installed in the sea. A principal environmental concern is the potential for physical injury to marine mammals through direct contact with rotating turbine blades and there is a need to improve understanding of this risk. The ability to detect and track marine mammals (or other large animals such as basking sharks) around devices would assist with such understanding. The information will aid environmental impact assessments and permitting decisions, including European Protected Species licensing and assessments of plans or projects under the Habitats Regulations.

The four-phase project involved collaborations between marine mammal specialists, marine renewable developers, and sonar engineers to develop a user-friendly sonar system for the marine renewable industry. The four phases involved: Identification of the requirements of a generic sonar monitoring system for the renewable energy industry, Formal trials with captive seals to test the system prior to any further development and subsequent field deployment, Development and upgrading of selected system based on the findings of the previous phase, Upgraded sonar deployed on the SeaGen tidal turbine in Strangford Lough for a period of several months to evaluate the efficiency and reliability of the system. A secondary objective was to evaluate the frequency of encounters between marine mammals and the tidal turbine, and to measure potential behavioural responses to turbine operation.

Outputs**Research reports:**

Hastie GD (2012). Tracking marine mammals around marine renewable energy devices using active sonar. Report to the Department of Energy and Climate Change. [SMRU Ltd report URN:12D/328, 99pp.](#)

Seal distribution and ecology (OESEA-10-10) SMRU/University of St Andrews	Project Completed
Project overview	
<p>SMRU holds a large database of telemetry data on grey and harbour seals (600 tags have been deployed on seals around the UK since 1988), which presented the opportunity to collate, analyse and interpret seal data for UK waters as a whole. Tagging has been carried out over various years, seasons, and regions and with animals of different ages and sexes. This tagging information represents one of the most comprehensive datasets for two seal species worldwide. The range of spatial, temporal, age and other data enabled a wide variety of analyses to be undertaken. The results provide baseline information and enhanced ecological understanding which in turn can inform conservation and development consenting decisions.</p>	
Outputs	
<p>Research reports: SMRU (2014). Seal at-sea distribution, movements and behaviour. Report to the Department of Energy and Climate Change. SMRU report URN 14D/085, 25pp + appendices.</p>	
<p>Peer reviewed papers: McClintock BT, Russell DJF, Matthiopoulos J & King R (2013). Combining individual animal movement and ancillary biotelemetry data to investigate population-level activity budgets. Ecology 94: 838-849.</p> <p>Russell DJ, McConnell BJ, Thompson D, Duck CD, Morris C, Harwood, J & Matthiopoulos J (2013). Uncovering the links between foraging and breeding regions in a highly mobile mammal. Journal of Applied Ecology 50: 499-509.</p> <p>Russell DJF, McClintock BT, Matthiopoulos J, Thompson PM, Thompson D, Hammond PS, Jones EL, MacKenzie ML, Moss S & McConnell BJ (2015). Intrinsic and extrinsic drivers of activity budgets in sympatric grey and harbour seals. Oikos 124: 1462-1472.</p> <p>Jones EL, McConnell BJ, Smout S, Hammond PS, Duck CD, Morris CD, Thompson D, Russell DJF, Vincent C, Cronin M, Sharples RJ & Matthiopoulos J (2015). Patterns of space use in sympatric marine colonial predators reveal scales of spatial partitioning. Marine Ecology Progress Series 534: 235-249.</p>	
The effects of wind farm construction and operation on harbour seals in the south western North Sea (OESEA-11-24) SMRU/University of St Andrews	Project Completed
Project overview	
<p>Seals have sensitive low- to mid-frequency hearing (50Hz to 86kHz) which overlaps much of the sound generated during wind farm construction (e.g. pile-driving) and operation and therefore makes them potentially susceptible to behavioural disturbance as well as auditory damage. Impulsive underwater sounds during pile-driving have the potential to elicit strong behavioural reactions which may affect foraging behaviour and location but it is currently not known how long such effects will persist. There are also concerns that marine mammals may avoid operational wind farms because of the low intensity but continuous noise associated with arrays of functioning turbines. Alternatively, they may be attracted to wind farms if any 'reef effect' enhances local fish abundance.</p>	
<p>The Wash in south east England is an area of past and current wind farm construction and also an internationally important area (Special Area of Conservation) for harbour seals, with their historic foraging areas overlapping with wind farms and therefore ideal to study the response of seals to wind-farm developments from tagging data.</p>	
<p>The 2012 project built on baseline data collected between 2003 and 2006 largely with DECC (now BEIS) SEA funding and worked alongside a complimentary project in the Thames Estuary (supported by Zoological Society of London). Since the original tagging studies wind farm construction has taken place in the southern North Sea, largely within territorial waters, which are used by the study animals. Additional wind farms located further offshore have also been consented or are under construction.</p>	

Outputs

Peer reviewed papers:

Russell DJF, Brasseur SMJM, Thompson D, Hastie GD, Janik VM, Aarts G, McClintock BT, Matthiopoulos J, Moss S & McConnell B (2014). Marine mammals trace anthropogenic structures at sea. [Current Biology 24: R638-R639](#).

Hastie GD, Russell DJF, McConnell B, Moss S, Thompson D & Janik VM (2015). Sound exposure in harbour seals during the installation of an offshore wind farm: predictions of auditory damage. [Journal of Animal Ecology 52: 631–640](#).

Hastie GD, Russell DJF, McConnell BJ, Thompson D & Janik VM (2016). Multiple-pulse sounds and seals: results of a harbour seal (*Phoca vitulina*) telemetry study during windfarm construction. [Advances in Experimental Medicine and Biology 875: 425-430](#).

Russell DJF, Hastie GD, Thompson D, Janik V, Hammond P, Scott-Hayward L, Matthiopoulos J, Jones E & McConnell B (2016). Avoidance of windfarms by harbour seals is limited to pile driving activities. [Journal of Applied Ecology 53: 1642-1652](#).

Lucke K, Hastie GD, Ternes K, McConnell B, Moss S, Russel DJ, Weber H & Janik VM (2016). Aerial low-frequency hearing in captive and free-ranging harbour seals (*Phoca vitulina*) measured using auditory brainstem responses. [Journal of Comparative Physiology A 202: 859-868](#).

A study to assess cetacean behavioural responses to pile-driving (OESEA-11-29)
University of Aberdeen

Project Completed

Project overview

There is limited information on the scale at which marine mammals may be disturbed by pile-driving or other anthropogenic noise, with previous assessments highlighting the need for more data on the duration of displacement following pile-driving activity. This information is important for determining whether intermittent pile-driving can lead to either intermittent or complete exclusion of animals from the area during a construction period. Such information will help further inform environmental impact assessment at a strategic and project level.

This project built on DECC (now BEIS) and industry funded studies in the Moray Firth which have provided significant baseline data on the occurrence of marine mammals in the area and their responses to sound sources from 2 seismic surveys. The original scope of this study was to assess marine mammal responses to piling during the installation of a meteorological mast within a Moray Firth wind farm development zone. Since the met mast installation did not proceed, the study used the development of the Nigg Energy Park to assess responses of both bottlenose dolphins and harbour porpoises to piling activity (both impact and vibropiling) during jetty construction over the winter of 2013/14.

Outputs

Peer reviewed papers:

Graham IM, Pirota E, Merchant ND, Farcas A, Barton T, Cheney B, Hastie GD & Thompson PM (2017). Responses of bottlenose dolphins and harbour porpoises to impact and vibration piling noise during harbour construction. [Ecosphere 8: e01693](#).

Farcas A, Thompson PM & Merchant ND (2016). Underwater noise modelling for environmental impact assessment. [Environmental Impact Assessment Review 57: 114-122](#).

SCANS-III Planning Support (OESEA-11-30)		Project Completed
SMRU/University of St Andrews		
Project overview		
<p>SCANS-III builds on previous large scale cetacean surveys beginning in 1994 (Small Cetaceans in European Atlantic waters and the North Sea, SCANS) and followed by SCANS II (2005) and CODA (2007). The Department provided staff in order to facilitate the planning and European partner alignment for 3rd SCANS survey. Surveys were successfully conducted in 2016 in order to meet the objective of estimating the abundance of all cetacean species in shelf and oceanic waters of the European Atlantic continental shelf, and results are available from the SCANS-III website.</p>		
Outputs		
<p>SCANS-III website: http://synergy.st-andrews.ac.uk/scans3/</p>		

The eastern Scotland bottlenose dolphin population: Improving understanding of ecology outside the Moray Firth SAC to inform marine energy consenting decisions (OESEA-11-31, OESEA-14-44)		Project Completed
University of St Andrews		
Project overview		
<p>A small, seemingly resident population of bottlenose dolphins <i>Tursiops truncatus</i> exists off the east coast of Scotland. They typically range from coastal waters of the Moray Firth to the Firth of Forth, with occasional observations from further offshore in the North Sea; the dolphins are most frequently sighted within the inner Moray Firth and this has been an area of focus for bottlenose dolphin research, with former studies funded by DECC (now BEIS), and undertaken by SMRU, University of Aberdeen, SNH and others. Sighting histories of individual animals were constricted using photo-identification of long-lasting natural marks. Animals are known to range along the east coast but there is much spatial and temporal variability between individuals. Dolphins were encountered more often in and around the Tay estuary in waters less than 20m and within 2km of the coast. Encounter rates were consistently high in the Tay, with 2009-13 estimates representing approximately 35-46% of the Scottish east coast population. Dolphins were also frequently encountered along the coast between Montrose and Aberdeen, with an estimated 25% of the population occurring between Stonehaven and Aberdeen, and >60% using the area between the Firth of Forth and Aberdeen in 2012 and 2013.</p> <p>The project sought to improve the understanding of the distribution and abundance of bottlenose dolphin outside of the Moray Firth and of the ecology of the population throughout its range, such that the results of the study will contribute to informing offshore energy consenting decisions.</p>		
Outputs		
Research reports:		
<p>Quick N, Arso M, Cheney B, Islas V, Janik V, Thompson PM & Hammond PS (2014). The east coast of Scotland bottlenose dolphin population: improving understanding of ecology outside the Moray Firth SAC. Document produced as part of UK Department of Energy and Climate Change's offshore energy Strategic Environmental Assessment Programme, URN 14D/086, 87pp.</p>		
Peer reviewed papers:		
<p>Arso Civil M, Quick N Cheney B Pirotta E, Thompson P & Hammond P (2019). Changing distribution of the east coast of Scotland bottlenose dolphin population and the challenges of area-based management. Aquatic Conservation: Marine and Freshwater Ecosystems 29: 178-196.</p> <p>Arso Civil M, Cheney B, Quick NJ, Islas-Villanueva V, Graves JA, Janik VM, Thompson PM & Hammond PS (2019). Variation in age- and sex-specific survival rates help explain population trend in a discrete marine mammal population. Ecology and Evolution 9: 533-544.</p> <p>Quick NJ, Cheney B, Thompson PM & Hammond PS (2017). Can the camera lie? A non-permanent nick in a bottlenose dolphin (<i>Tursiops truncatus</i>). Aquatic Mammals 43: 156-161.</p>		

Birds

Trial of kittiwake tagging using harness attachment (OESEA-20-114 and OESEA-21-139)
British Trust for Ornithology

Project Ongoing

Project overview

Kittiwakes are features of numerous UK Special Protection Areas and are a species of concern in relation to several offshore windfarm consent applications. The potential major scale of windfarm development around the UK indicates a strategic information need on kittiwake behaviour around turbines both during the breeding season and at other times of the year. The weight of tags available to allow data collection on kittiwake location and behaviour year round is such that they require a different method of attachment to the birds. The project is to develop harness attachments for kittiwakes and deploy tags on birds breeding at a NE Scotland colony. The first phase in 2021 was unsuccessful and a second phase planned for summer 2022 was postponed due to avian flu restrictions. Work took place in summer 2023 using a new harness design. Results indicate further work with tag manufacturers is needed to ensure successful long term attachment of tags.

Outputs

Research reports:

Project in progress

Peer reviewed papers:

Clewley GD, Ponchon A, Davies JG, Humphreys EM, O'Hanlon NJ, Weston E, Boulinier T & Cook ASCP (2022). Acute impacts from Teflon harnesses used to fit bio-logging devices to Black-legged Kittiwake *Rissa tridactyla*. *Ringing & Migration* **36**: 69-77.

Shelduck – Migrations, flight heights and interactions with offshore windfarms (OESEA-20-112, OESEA-23-152)
British Trust for Ornithology & University of Liverpool

Project Ongoing

Project overview

A PhD studentship "Understanding the Annual Cycle of a Wildfowl Migrant, the Common Shelduck, and the Risks Posed by Offshore Wind Farm Developments" follows the SEA funded review of Shelduck migratory movements in the UK and across the North Sea and a pilot tagging project. The studentship aims to establish a more holistic view of the annual cycle of movements of the British and Irish Shelduck population and to evaluate what proportion of this population is likely to interact with OWFs annually. Fine-scale movement data from new tagging at various locations around the UK, and feather collection for isotopic analysis at various SPAs carried out in 2021, 2022 and 2023, will allow assessment of the potential impacts of OWFs on the British and Irish population. The potential major scale of windfarm development in the southern North Sea indicates a strategic information need for assessments at individual windfarm, cumulative and strategic levels. Anticipated to be an exemplar case study of the potential impacts of OWFs on migratory waterbirds. A website has been set up to facilitate data gathering and awareness:

<https://shelducks.co.uk/gps-tracking/>

Outputs

Project in progress.

Advancing understanding of the impact of offshore windfarms on seabird metapopulations – northern gannets (OESEA-20-115 & OESEA-21-135)
University of Glasgow

Project Ongoing

Project overview

This project is to extend the novel metapopulation model for northern gannets developed at the University of Glasgow to estimate the exact drivers of connectivity between colonies and seasonal demography. This will allow the quantification of the repercussions of past and future marine developments (primarily offshore windfarms) across the reaches of the colony network. An extension to this project is to undertake tagging to obtain fine-scale space use by gannets post-breeding and over winter. Tags were due to be deployed at colonies in Scotland and Norway in 2022, but avian flu restrictions limited fieldwork in 2022 other than at Bass Rock. This has contributed to a NERC Urgency Funding project "Population-level impact and geographic spread of highly pathogenic avian influenza virus H5N1 outbreak in gannets".

Outputs

Research reports:

Project in progress.

Peer reviewed papers:

Jeglinski Jana WE, Wanless S, Murray S, Barrett RT, Gardarsson A, Harris MP, Dierschke J, Strøm H, Lorentsen S-H & Matthiopoulos J (2023). Metapopulation Regulation Acts at Multiple Spatial Scales: Insights from a Century of Seabird Colony Census Data. [Ecological Monographs 93\(2\)](#): e1569.

Fine-scale migration and early wintering ecology of immature and adult northern gannets (OESEA-22-149, OESEA-23-153)
University of Glasgow

Project Ongoing

Project overview

This project is to close the remaining major gap in understanding of the behaviour of different age classes of gannets, that of immature birds (1 to 4 years old) before they become mature and start breeding. Such evidence as there is suggests that movement patterns in immature birds are very different to those of adults, making much more exploratory migrations across the North Sea, around the UK and to the north and south. To cover areas of importance of future windfarm developments tagging took place at two colonies in summer 2023; Bass Rock (Firth of Forth) and Grassholm (off Pembrokeshire).

The project contributed to NERC Urgency Funding project “Population-level impact and geographic spread of highly pathogenic avian influenza virus H5N1 outbreak in gannets”,

Outputs

Research reports:

Project in progress.

Peer reviewed papers:

Jeglinski JWE, Lane JV, Votier SC, Furness RW, Hamer KC, McCafferty DJ, Nager RG, Sheddan M, Wanless S & Matthiopoulos J (2024). HPAIV outbreak triggers short-term colony connectivity in a seabird metapopulation. [Scientific Reports 14: 3126](#).

Lane JV, Jeglinski JWE et al. (2023). High pathogenicity avian influenza (H5N1) in Northern Gannets (*Morus bassanus*): Global spread, clinical signs and demographic consequences. [Ibis](#) 166: 633-650 .

Grémillet D, Ponchon A, Provost P, Gamble A, Abed-Zahar M, Bernard A, Courbin N, Delavaud G, Deniau A, Fort J, Hamer KC, Jeavons R, Lane JV, Langley L, Matthiopoulos J, Poupart T, Prudor A, Stephens N, Trevail A, Wanless S, Votier SC, Jeglinski JWE (2023). Strong breeding colony fidelity in northern gannets following high pathogenicity avian influenza virus (HPAIV) outbreak. [Biological Conservation 286: 110269](#).

Developing the theory of disturbances in metapopulations: applications to seabirds and renewables (OESEA-23-155)
University of Glasgow

Project Ongoing

Project overview

A metapopulation is a network of discrete subpopulations that are spatially or socially segregated and connected by the movement of dispersing individuals. Connectivity between subpopulations means that disturbances at any location or spatial scale in the network can cause a ‘ripple effect’ that can influence the size or dynamics of other subpopulations in the network. Ripple effects can be adverse, e.g., by enhancing disease transmission in a metapopulation or beneficial e.g. through ‘rescue effects’, where subsidies from other subpopulations buffer against the adverse effect of disturbances.

This PhD studentship will focus on interactions between offshore windfarms and northern gannets (*Morus bassanus*), a large species of which the UK holds over 55% of the global population and is a feature of several UK Special Protection Areas. There is clear evidence of displacement of gannets from windfarm footprints and given the projected expansion of offshore wind there is a need for improved theoretical understanding and modelling capability to inform consideration of population consequence for strategic assessment and consenting. The research will build on a long series of gannet focused SEA projects with the RSPB and the Universities of Leeds and Glasgow which (with other studies) provide the detailed understanding necessary to support this research.

Outputs

Research reports:

Project in progress

Tracking Juvenile northern gannets using microwave telemetry solar Argos/GPS PTTs as a contribution to assessing the risks from offshore windfarms (OESEA-18-86, OESEA-18-95 and OESEA-19-98) **Project Completed**
 University of Leeds

Project overview

This project follows on from previous gannet tagging work (OESEA-13-41 and 14-46) with the deployment in October 2018 of 21 solar Argos/GPS PTTs tags on juvenile gannets at Bass Rock. The tags may transmit data for up to 12 months before they are lost due to juvenile moult, however this may also be limited by juvenile mortality which is high. A second phase of tagging took place in 2019 which involved the deployment of a further 21 tags at the Bass Rock colony.

Outputs

Peer reviewed papers:

Lane JV, Pollock CJ, Jeavons R, Sheddan M, Furness RW & Hamer KC (2021). Post-fledging movements, mortality and migration of juvenile northern gannets. [Marine Ecology Progress Series 671: 207–218](#).

Pollock CJ, Lane JV, Buckingham L, Garthe S, Jeavons R, Furness RW, Hamer KC (2021). Risks to different populations and age classes of gannets from impacts of offshore wind farms in the southern North Sea. [Marine Environmental Research 171: 105457](#)

Measuring the interaction between marine features of Special Protection Areas (SPAs) with offshore wind farm development zones through telemetry: lesser black-backed gulls and herring gulls on the Forth Islands SPA (OESEA-18-91, OESEA-19-99, OESEA-21-126, OESEA-21-137, OESEA-23-151) **Project Ongoing**
 British Trust for Ornithology

Project overview

This project extends previous tagging work undertaken by BTO covering lesser black-backed gulls (e.g. OESEA-11-28, OESEA-13-40, OESEA-15-50) from Orford Ness in the Alde-Ore SPA, Skokholm and Skomer SPA, Morecambe Bay and Duddon Estuary SPA, to those at two sites within the Firth of Forth (Isle of May SSSI and Forth Islands SSSI/SPA). The aim of the project is to provide an assessment of how gulls from the Forth Islands SPA interact with proposed wind farm areas in the Firth of Forth and to provide evidence that may be of wider value in understanding wind farm impacts. Data has been collected over three breeding seasons (2019, 2020 and 2021) and two non-breeding seasons (2019/20 and 2020/21) and because of Covid restrictions on fieldwork, the project duration has been extended by a year, with data collected during 2022. Data has been collected using the same GPS/GSM tags as used in previous OESEA-funded lesser black-backed gull studies to allow for better comparability of results, with the addition of an altimeter to more accurately record flight heights.

Outputs

Research reports:

Annual progress reports prepared.

Peer reviewed papers:

Johnston DT, Thaxter CB, Boersch-Supan PH, Davies JG, Clewley GD, Green RMW, Shamoun-Baranes J, Cook ASCP, Burton NHK & Humphreys EM (2023). Flight heights obtained from GPS versus altimeters influence estimates of collision risk with offshore wind turbines in Lesser Black-backed Gulls *Larus fuscus*. [Movement Ecology 11: 66](#).

Johnston DT, Thaxter CB, Boersch-Supan PH, Humphreys L, Bouten W, Clewley GD, Scragg ES, Masden EA, Barber LJ, Conway G, Clark NA, Burton NHK & Cook ASCP (2022). Investigating avoidance and attraction responses in Lesser Black-backed Gulls *Larus fuscus* to offshore wind farms. [Marine Ecology Progress Series 686: 187-200](#).

Review of the migratory movements of Shelduck to inform understanding of potential interactions with offshore wind farms in the southern North Sea (OESEA-18-88, OESEA-18-94 & OESEA-19-103) **Project Completed**
 British Trust for Ornithology

Project overview

The aims of the research was to provide an overview of the current knowledge on the migratory movements of the UK population of shelduck by undertaking a literature review and analysis of ring-recovery data from the British and Irish Ringing Scheme, and to place these movements in the context of offshore wind farms.

It was found that available literature provide a reasonable level of information on shelduck distribution and timings of their migration. The majority of UK shelduck migrate across the North Sea twice annually, travelling to and from a major moulting site in the Helgoland Bight, generally leaving the UK between late-June and early-August, and returning between October and February.

Little is known about which individuals from the UK breeding range migrate to the Helgoland Bight, with some birds from the same breeding area remain and moult in the UK whilst others cross the North Sea to moult. It is not currently possible to link individuals between their breeding, moulting and non-breeding areas, and hence to which individual SPAs non-breeding shelduck may interact with offshore wind farms. Additionally, no information on specific migratory pathways is available and there is therefore a need for information to understand any potential interaction with offshore wind farms.

The most significant knowledge gaps are the lack of data on specific migratory routes across the North Sea, associated flight heights and shelduck behavioural responses to offshore structures. As a result, a pilot study commenced in 2019 with the planned deployment of 10 tags on shelduck on the east coast of England, and immediately prior to their migration to moulting locations. Four shelduck were tagged, following which they migrated across the North Sea initially to the Dutch Wadden Sea, with onward movements to the German Bight shown by three individuals. A number of recommendations were made for future research, now facilitated through a PhD studentship (OESEA-20-112, OESEA-23-152, see above).

Outputs

Research reports:

Green R, Burton NHK & Cook ASCP (2019). Review of the migratory movements of Shelduck to inform understanding of potential interactions with offshore wind farms in the southern North Sea. [BTO Research Report 718, 39pp.](#)

Green R, Burton NHK & Cook ASCP (2020). Pilot Tracking Study of the Migratory Movements of Shelduck to Inform Understanding of Potential Interactions with Offshore Wind Farms in the North Sea. [BTO Research Report 725, 48pp.](#)

Peer reviewed papers:

Green RMW, Burton NHK & Cook ASCP (2021). Migratory movements of British and Irish Common Shelduck *Tadorna tadorna*: a review of ringing data and a pilot tracking study to inform potential interactions with offshore wind farms in the North Sea. [Ringing & Migration 34: 71-83.](#)

Migrations of UK wintering waders over the North Sea in relation to environmental conditions and offshore windfarms (OESEA-22-143) **Project Ongoing**
 British Trust for Ornithology

Project overview

A recent review of migration in relation to offshore wind farm (OWF) developments has highlighted substantial knowledge gaps about the collision risk of migrant waders with OWFs, specifically in relation to their migration routes, timing, flight heights and flight speeds. Around 300,000 oystercatchers (*Haematopus ostralegus*) and 125,000 curlew (*Numenius arquata*) overwinter in the UK, with large numbers of both species crossing the North Sea annually in autumn and spring on their migrations between breeding sites and estuaries around the coasts of Britain and Ireland. The overall aim of the project is to analyse the existing migration data collected from tracked curlews and oystercatchers to provide the strategic information needed for assessments at individual windfarm, cumulative and strategic levels.

Outputs

Project in progress.

**Red-throated diver tagging and energetics (OESEA-17-84, OESEA-18-90, OESEA-19-100 & OESEA-20-117)
JNCC**

Project Completed

Project overview

Offshore wind farms are known to cause displacement of wintering red-throated divers (*Gavia stellata*), however, the consequences of this displacement at the individual and population level are unknown. Co-funded by BEIS, this project will investigate the energetics of red-throated divers by this using time depth recorders and geolocators attached to divers on their breeding grounds. Novel information on foraging behaviour of divers is to be obtained.

During the summer of 2018, a total of 74 red-throated divers were tagged (31 red-throated divers were tagged in southern Finland, 31 in Scotland and 12 in Iceland), with further tags deployed in 2019. All birds were fitted with a time-depth recorder and a geocator tag, as well as a metal ring with a unique number. There was no evidence that the tags deployed in 2018 had adverse effects on the breeding success of the birds.

Data recovered from tags has been analysed as part of a PhD studentship at the University of Liverpool. The results provide insights on the capacity of the birds to cope with additional energetic costs, for example from displacement of wintering red-throated divers.

Outputs**Research reports:**

O'Brien S, Ruffino L, Lehtikoinen P, Johnson L, Lewis M, Petersen A, Petersen IK, Okill D, Väisänen R, Williams J & Williams S (2018). Red-Throated Diver Energetics Project - 2018 Field Season Report. JNCC Report No. 627. [JNCC, Peterborough, 30pp.](#)

O'Brien S, Ruffino L, Johnson L, Lehtikoinen P, Okill D, Petersen A, Petersen IK, Väisänen R, Williams J & Williams S (2019). Red-Throated Diver Energetics Project - 2019 Field Season Report. JNCC Report No. 637. [JNCC, Peterborough, 20pp.](#)

Thompson D, O'Brien S, Ruffino L, Johnson L, Lehtikoinen P, Okill D, Petersen A, Krag I, Väisänen R, Williams J & Williams S (2020). Red-Throated Diver Energetics Project - 2020 Field Season Report. JNCC Report No. 673. [JNCC, Peterborough, 15pp.](#)

Thompson D, Johnson L, Williams J & Williams S (2022). Red-Throated Diver Energetics Project - 2021 Field Season Report. JNCC Report No. 697. [JNCC, Peterborough, 8pp.](#)

Thompson DL, Duckworth J, Ruffino L, Johnson L, Lehtikoinen P, Okill D, Petersen A, Petersen IK, Väisänen R, Williams J, Williams S, Green J, Daunt F & O'Brien S (2023). Red-Throated Diver Energetics Project: Final Report. JNCC Report 736. [JNCC, Peterborough, 13pp.](#)

Peer reviewed papers:

Duckworth J, O'Brien S, Väisänen R, Lehtikoinen P, Petersen IK, Daunt F & Green JA (2020). First biologging record of a foraging red-throated loon *Gavia stellata* shows shallow and efficient diving in freshwater environments. [Marine Ornithology 48: 17–22.](#)

Duckworth J, O'Brien S, Petersen IK, Petersen A, Benediktsson G, Johnson L, Lehtikoinen P, Okill D, Väisänen R, Williams J, Williams S, Daunt F & Green JA (2021). Spatial and temporal variation in foraging of breeding red-throated divers. [Journal of Avian Biology 52: 1–12.](#)

Duckworth J, O'Brien S, Petersen IK, Petersen A, Benediktsson G, Johnson L, Lehtikoinen P, Okill D, Väisänen R, Williams J, Williams S, Daunt F & Green JA (2022). Winter locations of red-throated divers from geolocation and feather isotope signatures. [Ecology and Evolution 12: e9209.](#)

PhD thesis:

Duckworth JA (awarded 2023). Using behavioural and energetic insights to assess the impacts of displacement from offshore wind farms on red-throated divers (*Gavia stellata*). University of Liverpool. <http://doi.org/10.17638/03170909>. Jointly funded with NERC, The Crown Estate, and various wind farm developers.

Review of the potential of seabird colony monitoring to inform monitoring programmes for consented offshore wind farm projects (OESEA-17-77) BTO	Project Completed
Project overview	
<p>Demographic models used as part of EIA and Habitat Regulations Assessment (HRA) for offshore wind farms require baseline information on the abundance and demographic parameters of the bird populations concerned. However, it is unclear the extent to which the demographic data used in these models relate to the specific sites considered in assessments and whether existing monitoring of seabird populations at a colony level has sufficient statistical power to detect changes of relevance.</p> <p>Through a review of HRAs for 21 consented but not operational offshore wind farms, the project identified 16 species within 38 SPAs for which likely significant effects in relation to offshore wind farms could not be ruled out during HRA screening. Using data collected by the Seabird Monitoring Programme (SMP) and the Retrapping Adults for Survival (RAS) scheme, sites were identified in SPAs where baseline data are available to inform monitoring programmes for the offshore wind farms. A power analysis was undertaken in order to determine the extent to which changes in abundance, breeding success and survival could be detected in populations given current levels of monitoring.</p> <p>There are significant gaps in the monitoring of populations within SPAs for which HRA was carried out. Limitations in the spatial and temporal coverage of existing monitoring mean that existing data typically lack sufficient statistical power to detect the changes that may be associated with the effects of offshore wind farms. Productivity tended to be more widely monitored than abundance and data tended to have greater power to detect changes related to the effects of offshore wind farms, however, in the case of species with highly variable annual breeding success (e.g. large gulls and terns), it was easier to detect population level changes through monitoring abundance. Adult survival is the most poorly monitored of the parameters considered, but this would be of value in detecting more subtly population-level impacts and in the assessment of cumulative effects.</p> <p>The work highlights the potential to improve both monitoring and analysis of data collected as part of monitoring, and a number of recommendations are made to suggest how current approaches could be enhanced to support monitoring the effects of offshore wind.</p>	
Outputs	
<p>Research reports: Cook ASCP, Humphreys EM, Robinson RA & Burton NHK (2019). Review of the potential of seabird colony monitoring to inform monitoring programmes for consented offshore wind farm projects. BTO Research Report 712, 161pp.</p>	
High resolution tagging of gannets (OESEA-14-46) University of Leeds	Project Completed
Project overview	
<p>This project is a follow-on piece of work to previous University of Leeds (OESEA-13-41) and RSPB (OESEA-11-27) tagging studies to allow improved collision risk modelling. The foraging behaviour of birds remains a key data gap in the assessment of potential effects of offshore wind farms.</p> <p>The study tagged 35 adult gannets (129 foraging trips for 31 birds were received, also note pressure loggers were also added to some adults) and 22 immature gannets (118 foraging trips for 15 birds were received) from the Bass Rock colony between June and August 2015. The data received provided information on bird behaviour (foraging, distribution) and time spent within proposed wind farm sites. Differences between adult and immature birds and between sexes were observed but were considered minor such that similar potential collision risks could be considered for each, that is that the greatest risk to collision is likely to be during periods of active foraging. Further research is required on immature birds, including flight heights, wind turbine avoidance rates and numbers of immature birds attending colonies.</p>	
Outputs	
<p>Research reports: Hamer KC, Gecian WJ & Lane J (2017). Fine-scale foraging behaviour of adult and immature northern gannets: distributions, movements and potential interactions with offshore wind-farms. University of Leeds, 23pp.</p>	
<p>Peer reviewed papers: Grecian WJ, Lane JV, Michelot T, Wade HM & Hamer KC (2018). Understanding the ontogeny of foraging behaviour: insights from combining marine predator bio-logging with satellite-derived oceanography in hidden Markov models. Journal of the Royal Society Interface 15: 20180084.</p>	

<p>Cross-validation of at-sea survey and GPS tracking methods to determine marine distribution of seabirds (OESEA-15-54) RSPB</p>	<p>Project Completed</p>
<p>Project overview</p>	
<p>Comparison of estimates derived from at-sea survey and GPS tracking data, to determine:</p> <ol style="list-style-type: none"> 1. whether there is broad agreement in the patterns of distribution and densities estimated from the two methods 2. causes of any discrepancies in distribution estimates 3. whether the inability to conduct survey in sea states greater than F4 lead to bias in measured distributions, due to birds favouring sheltered locations, or spending more time at the colony or on the water surface than in flight, during poor weather 4. whether inability to conduct at-sea survey during the night leads to seriously biased estimates of marine distribution during the entire 24 hour cycle. <p>The analyses are of RSPB tracking data collected in 2015 from razorbill and guillemots breeding on the Shiant Isles, and simultaneous surveys in the waters of the Minch surrounding the breeding colony. Similarity between boat-based and GPS tracking was high for razorbills whereas only moderate similarity was found for guillemots.</p>	
<p>Outputs</p>	
<p>Research reports: Carroll MJ, Wakefield ED, Scragg ES & Bolton M (2017). Cross-validation of at-sea survey and GPS tracking methods to determine marine distribution of seabirds. RSPB Centre for Conservation Science, 41pp.</p>	
<p>Peer reviewed papers: Carroll MJ, Wakefield ED, Scragg ES, Owen E, Pinder S, Bolton M, Waggitt JJ & Evans PGH (2019). Matches and mismatches between seabird distributions estimated from at-sea surveys and concurrent individual-level tracking. Frontiers in Ecology and Evolution 7:333.</p>	
<p>Gannet flight behaviour (OESEA-13-41) University of Leeds</p>	<p>Project Completed</p>
<p>Project overview</p>	
<p>In order to assess potential collision risks, and other impacts, e.g. displacement, from the construction offshore wind farms, and therefore also the potential for effects on individuals, populations and the status of any related conservation sites, data on flight heights and tracks of relevant birds are required. Large colonies of northern gannets are present in relatively close proximity to several proposed offshore wind sites, or within foraging range of these sites.</p> <p>This project extends a NERC-funded study carried out over the summers of 2010-2012 where GPS tracks of gannets foraging from Bass Rock were collected. While GPS loggers accurately recorded location in the horizontal plane, errors associated with height estimates were large and unpredictable. Therefore, during the 2010-2012 study, a bird-borne pressure logger was trialed (11 in 2011 and 5 in 2012) on a subset of tagged birds with a view to using the barometric technique to estimate flight height more accurately; such loggers have had previous success recording the flight heights of other birds (e.g. red-footed boobies and frigate birds) whereby altitude was derived from the pressure difference between a sea-level weather station and the logger. The work was intended as a proof of concept study to determine that accurate three dimensional foraging data could be collected. It was found that during commuting to foraging areas, birds flew at a median height of 12m, which increased to 27m during active foraging, therefore collision risk may differ depending on which of these behaviours is being exhibited.</p>	
<p>Outputs</p>	
<p>Peer reviewed papers: Cleasby IR, Wakefield ED, Bearhop S, Bodey TW, Votier SC & Hamer KC (2015). Three-dimensional tracking of a wide-ranging marine predator: flight heights and vulnerability to offshore wind farms. Journal of Applied Ecology 52: 1474-1482.</p>	

Foraging ranges of northern gannets *Morus bassanus* in relation to proposed offshore wind farms in the UK 2010-2012 (OESEA-11-27)
RSPB

Project Completed

Project overview

Britain and Ireland are of outstanding international importance for their breeding seabirds for which they host a high proportion of the biogeographical populations of several species, one of which is the northern gannet (*Morus bassanus*). The UK hosts approximately 59% of the world population of gannets at colonies distributed mainly around the western and northern coasts of Britain. The only gannet colony in England is at Flamborough Head and Bempton Cliffs, a Special Protection Area (SPA) that includes gannet as part of the breeding seabird assemblage that forms a qualifying feature of the site. Gannets may be vulnerable to collision with offshore wind turbines; they have poor manoeuvrability and their long, narrow wings and high wing-loading (wing loading is the ratio of weight to wing area) are adaptations to using the wind to assist fast flight. The risk with wind farms is unclear, with it depending on levels of flight activity within the wind farm footprints and within the rotor swept area and extent of avoidance behaviour. It is known that gannets fly at and plunge-dive from elevations within rotor swept height.

The three seasons of study, in 2010 ($n=14$ birds), 2011 ($n=13$) and 2012 ($n=15$), have identified the previously unknown sea areas used by adult gannets from Bempton Cliffs. Locations during the three chick-rearing periods show a marked similarity in the area of active use, but a notable difference in the extent of the core area used in 2012. Distance to colony had the over-riding influence on foraging range. Relatively small annual samples mean that we remain unsure how representative the data are of year to year foraging activity by breeding gannets from Bempton Cliffs, especially in years of lower breeding productivity. However, the collective foraging range of the forty two tagged birds encompassed the full seaward radius around Bempton Cliffs such that the results represent the sea areas used by adult gannets, at least in seasons of good breeding productivity. Approximately 70% of foraging trips were within 50 km of Bempton Cliffs (mean range all three years, $43.0 \pm SD 49.1$ km, range 5-404km, $n=2,721$ trips), only 25 exceeding 200km, of which just two exceeded 300km.

Outputs**Research reports:**

RSPB (2011). Foraging ranges of northern gannets *Morus bassanus* in relation to proposed offshore wind farms in the UK. [RSPB Report to DECC, URN 11D/845, 19pp.](#)

RSPB (2012). Foraging ranges of northern gannets *Morus bassanus* in relation to proposed offshore wind farms in the UK: 2011. [RSPB Report to DECC, URN 12D/315, 29pp.](#)

RSPB (2013). Foraging ranges of northern gannets *Morus bassanus* in relation to proposed offshore wind farms in the UK: 2010-2012. [RSPB Report to DECC, URN 13D/306, 74pp.](#)

Peer reviewed papers:

Wakefield ED, Bodey TW, Bearhop S, Blackburn J, Colhoun K, Davies R, Dwyer RG, Green J, Grémillet D, Jackson AL, Jessopp MJ, Kane A, Langston RHW, Lesco  l A, Murray S, Le Nuz M, Patrick SC, P  ron C, Soanes L, Wanless S, Votier SC & Hamer KC (2013). Space partitioning without territoriality in gannets. [Science 341: 68-70.](#)

Langston R & Teuten E (2018). Ranging behaviour of northern gannets. [British Birds 111: 131-143.](#)

High resolution tagging of west coast lesser black backed gulls (OESEA-15-50)
BTO

Project Completed

Project overview

This study is the second phase of the work initiated with project OESEA-13-40. The research involves fieldwork, data recovery, analyses and reporting for lesser black-backed gulls fitted with Amsterdam GPS tags at Skokholm and South Walney for a second breeding season (2015) and two non-breeding seasons (2014/15 and 2015/16); and fieldwork data recovery, analyses and reporting for herring gulls fitted with Pathtrack GPS tags at South Walney for a second breeding season (2015) and two non-breeding seasons (2014/15 and 2015/16).

High resolution tagging of west coast lesser black backed gulls (OESEA-15-50) Project Completed

BTO

Outputs

Research reports:

Thaxter CB, Ross-Smith VH, Clark NA, Barber L, Clewley G, Conway G, Masden EA, Bouten W & Burton NHK (2015). Measuring the interaction between Lesser Black-backed Gulls and Herring Gulls from the Skokholm and Skomer SPA and Morecambe Bay SPA and offshore wind farm development sites: First Year Report. BTO Research Report No. 664, 68pp.

Thaxter CB, Ross-Smith VH, Clark NA, Clewley G, Barber L, Conway G, Harris SJ, Masden EA, Bouten W & Burton NHK (2016). Measuring the interaction between Lesser Black-backed Gulls and Herring Gulls from the Skokholm and Skomer SPA and Morecambe Bay SPA and offshore wind farm development sites: Second Year Report. BTO Research Report No. 681, 111pp.

Thaxter CB, Scragg ES, Clark NA, Clewley G, Humphreys EM, Ross-Smith VH, Barber L, Conway GJ, Harris SJ, Masden EA, Bouten W and Burton NHK (2018). Measuring the interaction between Lesser Black-backed Gulls and Herring Gulls from the Skokholm and Skomer SPA and Morecambe Bay SPA and offshore wind farm development sites: final report. BTO Research Report No. 702, 162pp

Peer reviewed papers:

Ross-Smith V, C, Clark NA, Shamoun-Baranes J, Bouten W & Burton NHK (2016). GPS telemetry reveals differences in the foraging ecology of breeding lesser black-backed gulls between three Special Protection Area colonies. [BOU Proceedings – Birds in time and space: avian tracking and remote sensing](#).

Ross-Smith V, Thaxter CB, Masden EA, Shamoun-Baranes J, Burton NHK, Wright LJ, Rehfisch MM & Johnston A (2016). Modelling flight heights of lesser black-backed gulls and great skuas from GPS: a Bayesian approach. [Journal of Applied Ecology 53: 1635-1891](#).

Thaxter CB, Ross-Smith VH, Clark NA, Bouten W & Burton NHK (2015). GPS telemetry reveals within-wind farm behavior of lesser black-backed gulls during the breeding season. In: Köppel J & Schuster E (eds.) Book of Abstracts (page 65). Conference on Wind energy and Wildlife impacts (CWW 2015), March 10-12, 2015. Berlin, Germany.

Thaxter CB (2017). Chapter 15: Tracking and telemetry of marine birds. In: Perrow, M. (ed.) Wildlife and Wind Farms: Offshore Volume 2: Conflicts and Solutions. Conservation Handbooks. Pelagic Publishing.

Thaxter CB, Ross-Smith VH, Bouten W, Masden EA, Clark NA, Conway GJ, Barber L, Clewley GD & Burton NHK (2018). Dodging the blades: new insights into three-dimensional space use of offshore wind farms by lesser black-backed gulls *Larus fuscus*. [Marine Ecology Progress Series 587: 247-253](#).

Thaxter CB, Ross-Smith VH, Bouten W, Clark NA, Conway GJ, Masden EA, Clewley GD, Barber LJ & Burton NHK (2019). Avian vulnerability to wind farm collision through the year: Insights from lesser black-backed gulls (*Larus fuscus*) tracked from multiple breeding colonies. [Journal of Applied Ecology 56: 2410-2422](#).

Tagging of Lesser black backed gulls (OESEA-13-40 and OESEA-13-40Var1) Project Completed

BTO

Project overview

Building on earlier BTO work (OESEA-11-28) 30 tags were fitted to Lesser black backed gulls on Skomer/Skokholm and Walney Islands to obtain data on migration routes and flying heights in different conditions.

Outputs

Peer reviewed papers:

Thaxter CB, Ross-Smith VH, Clark JA, Clark NA, Conway GJ, Marsh M, Leat EHK & Burton NHK (2014). A trial of three harness attachment methods and their suitability for long-term use on lesser black-backed gulls and great skuas. [Ringing & Migration 29: 65-76](#).

Ross-Smith V, Thaxter C, Clark N, Shamoun-Baranes J, Bouten W & Burton N (2016). GPS telemetry reveals differences in the foraging ecology of breeding lesser black-backed gulls between three Special Protection Area colonies. [BOU Proceedings – Birds in time and space: avian tracking and remote sensing](#).

Ross-Smith V, Thaxter CB, Masden EA, Shamoun-Baranes J, Burton NHK, Wright LJ, Rehfisch MM & Johnston A (2016). Modelling flight heights of lesser black-backed gulls and great skuas from GPS: a Bayesian approach. [Journal of Applied Ecology 53: 1635-1891](#).

Thaxter CB, Ross-Smith VH, Clark NA, Bouten W & Burton NHK (2015). GPS telemetry reveals within-wind farm behavior of lesser black-backed gulls during the breeding season. In: Köppel J & Schuster E (eds.) Book of Abstracts (page 65). Conference on Wind energy and Wildlife impacts (CWW 2015), March 10-12, 2015. Berlin, Germany.

Thaxter CB (2017). Chapter 15: Tracking and telemetry of marine birds. In: Perrow, M. (ed.) Wildlife and Wind Farms: Offshore Volume 2: Conflicts and Solutions. Conservation Handbooks. Pelagic Publishing.

Measuring the interaction between marine features of Special Protection Areas with offshore wind farm development sites through telemetry (OESEA-11-28) Project Completed BTO

Project overview

Potential areas for development of offshore wind farms include locations that may hold large numbers of seabirds, seaduck and other waterbirds. Both consented and proposed development sites within the North Sea may also overlap the foraging areas of seabirds that are features of protected sites. Offshore wind farms may potentially have an impact on these bird populations through four main effects: (1) displacement due to the disturbance associated with developments; (2) the barrier effect posed by developments to migrating birds and birds commuting between breeding sites and feeding areas; (3) collision mortality; (4) indirect effects due to changes in habitat or prey availability.

In summer 2011, GPS tags were fitted to 14 lesser black-backed gulls at Orford Ness, part of the Alde-Ore Estuary SPA. This was in addition to 11 birds tagged at this site in 2010. Following the tagging of four great skuas on the Foula SPA in Shetland in 2010, a further 10 birds were tagged in 2011. Ten great skuas were also tagged on the Hoy SPA in the Orkney archipelago. All individuals tagged were members of breeding pairs, and were caught on the nest. In summer 2012, 17 GPS-tagged lesser black-backed gulls returned to breed at Orford Ness (Alde-Ore Estuary SPA), including all 14 tagged in 2011 and three tagged in 2010. Only one tagged great skua returned to the Foula and Hoy breeding colonies in 2012, and this bird had lost its tag and harness, whereas a control group for skuas at both colonies showed a high return rate. No adverse effect had been seen during the 2011 breeding season, but clearly the attachment of the tags caused an adverse effect over the migration/winter period. While it is conceivable that the remaining tagged skuas just skipped a breeding attempt, this is considered unlikely. Consequently, the skua study was immediately terminated.

In total 13% of the 2,717 trips recorded in 2012 for lesser black-backed gulls contained a marine component. The maximum foraging range offshore in 2012 during breeding was 159km. Some individual gulls never ventured offshore, whilst others spent a substantial amount of time away from the colony at sea. The proportion of birds that used areas of operational, consented and proposed offshore wind farm areas was highest in 2010 (70% of 10 birds), similar in 2011 (78% of 18 birds) and lowest in 2012 (57% of 14 birds), however despite these high numbers of encounters, time spent in each wind farm area was relatively low (peaking at 4% in 2010) and area usage was 14% for the same year. For lesser black-backed gulls, the use of offshore areas and thus of the areas of operational, consented and proposed offshore wind farms during the breeding season (covering the pre-breeding, breeding and post-breeding periods) showed (1) individual, (2) seasonal, (3) sex-specific and (4) annual variations. Annual differences in the use of wind farm areas is such that tracking birds over longer periods may be necessary to avoid incorrect estimates of the level of risk to seabirds, additionally, the work also indicated it would be useful to investigate other populations of lesser black-backed gulls from other SPAs, and also migration strategies, or the exposure of other migratory species to offshore wind farms outside of the breeding season.

Outputs

Research reports:

Thaxter CB, Ross-Smith VH, Clark NA, Conway GJ, Rehfish MM, Bouten W & Burton NHK (2011). Measuring the Interaction Between Marine Features of Special Protection Areas with Offshore Wind Farm Development Sites Through Telemetry: first breeding season report. [BTO Research Report No. 590. Thetford, Norfolk. URN 11D/846, 70pp.](#)

Thaxter CB, Ross-Smith VH, Clark NA, Conway GJ, Wade H, Masden EA, Rehfish MM, Bouten W & Burton NHK (2012). Measuring the Interaction Between Marine Features of Special Protection Areas with Offshore Wind Farm Development Sites Through Telemetry: second breeding season report. [BTO Research Report No. 610, 50pp.](#)

Thaxter CB, Ross-Smith VH, Johnston A, Clark NA, Conway GJ, Wade H, Masden EA, Bouten W & Burton NHK (2013). Measuring the Interaction Between Marine Features of Special Protection Areas with Offshore Wind Farm Development Sites Through Telemetry: third year report. [BTO Research Report No. 639, 42pp.](#)

Thaxter CB, Ross-Smith VH, Clark NA, Conway GJ, Johnston A, Wade H, Masden EA, Bouten W & Burton NHK (2014). Measuring the Interaction Between Marine Features of Special Protection Areas with Offshore Wind Farm Development Sites Through Telemetry: Final Report. [BTO Research Report No. 649, 183pp.](#)

Measuring the interaction between marine features of Special Protection Areas with offshore wind farm development sites through telemetry (OESEA-11-28) Project Completed BTO

Peer reviewed papers:

Thaxter CB, Ross-Smith VH, Burton N, Wade H, Masden E & Bouten W (2013). Connectivity between seabird features of protected sites and offshore wind farms: lesser black-backed gulls and great skuas through breeding, migration and non-breeding seasons. [BOU proceedings – Marine Renewables and Birds](#).

Thaxter CB, Ross-Smith VH, Bouten W, Clark NA, Conway GJ, Rehfish MM & Burton NHK (2015). Seabird-wind farm interactions during the breeding season vary within and between years: A case study of lesser black-backed gull *Larus fuscus* in the UK. [Biological Conservation 186: 347-358](#).

Thaxter CB, Ross-Smith VH, Clark JA, Clark NA, Conway GJ, Masden EA, Wade HM, Leat EHK, Gear SC, Marsh M, Booth C, Furness RW, Votier SC & Burton NHK (2016). Contrasting effects of GPS device and harness attachment on adult survival of lesser black-backed gulls *Larus fuscus* and great skuas *Stercorarius skua*. [Ibis 158: 179-190](#).

Ross-Smith V, Thaxter C, Clark N, Shamoun-Baranes J, Bouten W & Burton N (2016). GPS telemetry reveals differences in the foraging ecology of breeding lesser black-backed gulls between three Special Protection Area colonies. [BOU Proceedings – Birds in time and space: avian tracking and remote sensing](#).

Wade HM, Masden EA, Jackson AC, Thaxter CB, Burton NHK, Bouten W & Furness RW (2014). Great skua (*Stercorarius skua*) movements at sea in relation to marine renewable energy developments. [Marine Environmental Research 101: 69-80](#).

Thaxter CB, Clark NA, Ross-Smith VH, Conway GJ, Bouten W & Burton NHK (2017). Sample size required to characterise area use of tracked seabirds. [The Journal of Wildlife Management 81: 1098-1109](#).

High resolution tagging of Bewick's swans (OESEA-12-35, OESEA-14-49 and OESEA18-93) Project Completed WWT

Project overview

The movement of several swan and goose populations along coastal Britain and through Scotland has been described through satellite-tracking studies undertaken by WWT under contract to COWRIE Ltd. and to DECC (now BEIS). These studies have highlighted key areas where the construction of offshore wind farms may pose a risk to these birds, particularly for whooper swans migrating to Iceland and for Barnacle Geese that cross the North Sea to Norway *en route* to breeding grounds on Svalbard (see [Griffin et al. 2011](#)). Much less is known, however, about flight-lines taken by birds migrating between southeast England and the Low Countries of Continental Europe. Further satellite-tracking of bird migration was therefore recommended to clarify potential effects of wind farm development for birds moving across this part of the North Sea. Additionally, tracking migratory birds that winter at inland sites helps to identify those designated as Special Protection Areas (SPAs) under EU legislation that may be affected by offshore wind development, which should therefore be taken into account in Scoping Reports and Environmental Impact Assessments on considering the likely significant effects (LSE) of a wind farm on SPAs. Without such studies, the link between inland SPAs and offshore wind farm development would be less well understood.

From winter 2013/14 onwards, the Wildfowl & Wetlands Trust tracked Bewick's swan movements in relation to offshore and onshore wind farms along their migration route, with a particular focus on the birds' flight-paths between Britain and mainland Europe. Eight swans were tagged in the winter of 2013/14 (though some tags had a software problem limiting their data collection) and another 14 tagged in the winter of 2014/15. A total of 52 offshore wind site footprints were encountered, 11 of which were operational and of limited flight height data recorded, most birds flew at <150m, with a mean and modal height in the 0-50m range. The study has served to demonstrate that birds wintering at sites some distance from proposed wind farm developments may encounter these developments during their annual migration, however this relates to a relatively small sample size and more tracking and possibly radar studies could improve knowledge of migration routes, including for other species.

Outputs

Research reports:

Griffin L, Rees E & Hughes B (2016). Satellite-tracking of Bewick's swan migration in relation to offshore and onshore wind farm sites. [WWT Final Report to the Department of Energy and Climate Change. WWT, Slimbridge 55pp](#).

Seabed and water column

Shell Measurements for <i>Arctica</i> Population Study (OESEA-19-102) Identichaet	Project Ongoing
Project overview	
<p>Several marine conservation sites have been designated (at the European and national level) for populations of bivalve <i>Arctica islandica</i>, individuals of which can live for several centuries. Most records of <i>Arctica</i> are made incidentally as part of seabed habitat characterisation or monitoring surveys, with the animals being counted and not measured. This means there is limited information on e.g. the population structure and reproductive success on which to base conservation or environmental management decisions. Regional surveys undertaken across the North Sea in the last decade provide a valuable resource which will potentially allow insights in spatial and temporal patterns of recruitment to the population. This project was to extract the specimens of <i>Arctica</i> from the archived regional survey samples and to measure the shells for subsequent interpretation and reporting. The measurements confirmed that the vast majority of specimens are of juveniles and no dense populations of large, old individuals (which would be of potential conservation interest) were found.</p>	
Outputs	
<i>Project in progress</i>	
British bivalve identification tools (OESEA-15-55) National Museum of Wales	Project Completed
Project overview	
<p>The British Bivalve Website was launched in 2010 to aid the identification of all bivalve species found in British waters at all depths from the intertidal to 5,000 metres. Since then over 20 species have been newly described or found in UK waters and the website has been updated to include these, and adding a series of dichotomous keys to all species, to all deep water species and to several difficult to identify genera or families.</p>	
Outputs	
Project website: http://naturalhistory.museumwales.ac.uk/britishbivalves/	
British bivalve identification tools (OESEA-22-150) National Museum of Wales	Project Ongoing
Project overview	
<p>This project is to extend and update the British bivalve identification website completed under project OESEA-15-55 to add species newly found in British waters and recent science in distinguishing species, undertaking new research on UK deep water species, and to further improve usability of the site.</p>	
Outputs	
<i>Project in progress</i>	
Analysis of seabed samples from 3 single well sites drilled with different mud systems (OESEA-22-146) Fugro	Project Ongoing
Project overview	
<p>This project is to provide another datum point in a 34 year time series investigating the fate and effects of drilling discharges at three single well sites drilled in the early 1980s with different mud systems. The well sites were surveyed in 1987 and 2004, and a collaborative project with Marine Scotland was agreed in 2021 to resurvey the wells. All samples (for sediment particle size, metals and hydrocarbons concentrations, and fauna) were obtained and are presently being assessed. The results are intended to inform assessments of cuttings piles during decommissioning planning, as well as assessments of contemporary water based mud discharges made during renewables, oil & gas, gas and carbon dioxide storage and (potentially) hydrogen storage.</p>	
Outputs	
<i>Project in progress</i>	

Defining the potential influence of internal waves on offshore energy activities on the UKCS (OESEA-15-51 and OESEA-17-73) University of Plymouth with SAMS	Project Completed
Project overview	
<p>The influence of internal waves on the ecology and temporal variability of shelf edge areas is not reflected in current conservation and management models. The project was undertaken in two phases. Phase 1 investigated the feasibility and possible methods of using satellite data to detect internal waves, and Phase 2 built on the first phase by applying the identified methods to produce monthly, seasonal, annual and climatology maps of internal waves for the UKCS, including occurrence and their predicted interaction with the seabed. The study concluded that though this was the first time such an exercise had been undertaken, there were some limitations to the work such as the ability to detect wave amplitude, and recommendations were made for future work which would refine estimates on the impact of internal waves on the seabed.</p>	
Outputs	
<p>Research reports: Kurekin A, Land P & Miller PI (2015) Remote sensing for estimating impact of internal waves on the seabed. Phase 1: Feasibility study. Report for the Department of Energy and Climate Change, 36pp. Kurekin A, Land P & Miller PI (2017). Remote sensing for estimating impact of internal waves on the seabed. Phase 2: Implementation. Report for the Department for Business, Energy & Industrial Strategy, 46pp.</p>	
<p>Peer reviewed papers: Kurekin A, Land P & Miller PI (2020). Internal Waves at the UK Continental Shelf: Automatic Mapping Using the ENVISAT ASAR Sensor. Remote Sensing 12: 2476.</p>	
Behaviour of dense phase CO₂ subsea release (contribution) (OESEA-14-51) DNV with JIP funding from BEIS, Gassnova, National Grid, Petrobras	Project Completed
Project overview	
<p>An OESEA2 recommendation was for improved understanding of the behaviour of dense phase CO₂ releases into the marine environment. Investigations of the behaviours of underwater dense phase CO₂ releases were carried out in tanks at DNV GL's Spadeadam Testing and Research Centre. Phase 1 testing included releases from 0.5mm to 10mm diameters. During Phase 2, 15 tests were carried out with release diameters ranging from 1 mm to 25mm. Three tests were carried out in a water depth of 6m and 12 were carried out in 10m. The results showed that only a small percentage of CO₂ was recorded above the water and the measured concentrations were always below 8% by volume. For comparable nozzle sizes the CO₂ concentrations above the water were lower than those recorded in the tests conducted in the 3m depth in Phase 1. The temperature of the water was seen to decrease but no CO₂ solids were observed in any of the tests.</p>	
Outputs	
<p>Research reports: DNV-GL (2016a). Underwater CO₂ 3m Release JIP Report V4. DNV-GL (2016b). Underwater CO₂ 10m Release JIP Report V6.</p>	
Brahan project (OESEA-13-43) Marine Scotland Science, Heriot-Watt University (ICIT), UK Integrated Monitoring Network, UK Meteorological Office, QUALITAS Remos S.L. & CODAR Ocean Sensors Ltd	Project Completed
Project overview	
<p>Collaborative project to deploy a CODAR SeaSonde HF oceanographic radar system in the Orkney/Shetland sea area commencing in the summer of 2013. Equipment deployment adjacent to the North Ronaldsay Lighthouse on Orkney and at the Sumburgh Lighthouse on Shetland extended to full year through then DECC/BEIS contribution.</p>	
Outputs	
<p>Project website: http://www.thebrahanproject.com/</p>	

Fish behaviour in the vicinity of renewable energy devices (OESEA-10-20)	Project Completed
Marine Biological Association of the UK	
Project overview	
<p>There is a need to determine the movements and spatial use of commercially important species within and adjacent to renewable energy devices to adequately assess their impacts on marine fish abundance and diversity. Long-term monitoring of fish movements in offshore sites is challenging and the project required the design, testing and proving of new seabed lander technologies, as these deployments (up to around 5 years) are far in excess of traditional mooring installations, generally have to be serviced annually. The following output represents work undertaken (for which DECC were a part-funder) which along with the NERC QBEX project have put in place the required long-term fish and shellfish monitoring arrays and developed analysis tools, with a view to future consolidation of data recording and analysis.</p>	
Outputs	
<p>Research reports: The Marine Biological Association of the UK (2013). Understanding commercial fish space use around Marine Renewable Energy sites: novel acoustic array-based fish tracking and monitoring at Wave Hub, Cornwall. MBA Report to DECC, URN 14D/061, 15pp.</p>	

Suspended Sediment Climatologies around the UK (OESEA-15-58)	Project Completed
Cefas	
Project overview	
<p>Ocean colour satellite imagery from 1998-2015 were averaged into 12 monthly means to calculate climatological and monthly climatological averages of non-algal suspended sediment concentrations, and yearly anomalies between years in the dataset studied. The largest observed feature was the Anglian Plume, which extends from the Thames Estuary eastwards across the Southern Bight and the Danish coast, with sediment concentrations often >30mg/l and a seasonal signal displaying lower concentrations in summer months. Estuaries in the UK (Thames, Humber, the Wash, Severn and Liverpool Bay) all showed concentrations above 10mg/l, as did the European rivers of the Elbe, Rhine and Meuse.</p> <p>The calculated monthly average data for 1998-2015, and for individual years, has been made available through the Cefasdatahub.</p>	
Outputs	
<p>Research reports: Cefas (2016). Suspended Sediment Climatologies around the UK. Report for the UK Department for Business, Energy & Industrial Strategy Offshore Energy Strategic Environmental Assessment programme. 39pp.</p>	

Cultural, Socio-Economic and Other

<p>Acoustic techniques for measurement, monitoring and verification of marine CCUS storage facilities (OESEA-23-156) University of Southampton and National Physical Laboratory</p>	<p>Project Ongoing</p>
<p>Project overview</p>	
<p>Carbon Capture, Utilization and Sequestration (CCUS) is considered a key technology for enabling the transition to a low-carbon future. Measurement, Monitoring and Verification (MMV) of carbon storage sites to demonstrate their integrity over time is a key consenting requirement, and remains a challenge. Two types of monitoring include active and passive acoustic methods and both may have a role based on their respective advantages and limitations relating to quantifying release, and spatial and temporal coverage. This PhD studentship will research and advance active and passive acoustic methods for MMV of CCUS sites. The studentship is jointly funded by the OESEA programme and NPL.</p>	
<p>Outputs</p>	
<p>Research reports: <i>In progress.</i></p>	
<p>Seascape and Visual Buffer study for Offshore Wind Farms (OESEA-19-101) White Consultants</p>	<p>Project Completed</p>
<p>Project overview</p>	
<p>This project focusses on the seascape aspects of offshore wind to inform future SEAs and to provide up-to-date strategic level information to leasing/licensing authorities and individual developers. The work builds on previous work undertaken for OESEA (2009) and OESEA3 (2016) and includes: a review of the planning policy context and seascape and visual impact guidance from a UK and International perspective, analysis of windfarm seascape visual impact assessments (SVIAs) to understand distances at which medium to low magnitudes of effect occur for wind farms and cumulatively with other wind farms, and wireline assessments for a variety of wind turbine sizes and at various viewing distances and elevations. The assessment recognises the scales used in the most recent applications for wind farms in the UK (up to 370m). The study also includes a review of information on marine visibility modifiers and impacts from lighting requirements that can alter the visibility of wind turbines.</p>	
<p>Outputs</p>	
<p>Research reports: White Consultants (2020) Review and Update of Seascape and Visual Buffer study for Offshore Wind farms. White Consultants, 121pp + appendices.</p>	
<p>Use of Chemicals in Offshore Wind Farm Construction and Operation (OESEA-20-116) Cefas</p>	<p>Project Completed</p>
<p>Project overview</p>	
<p>The project was to improve the UK wide evidence base on chemical use in existing offshore windfarms (OWFs) and the likely future usage based on the projected scale of OWF developments to attain net zero. A list of the chemicals including their type of use, frequency, and quantity, where known, were collated together with any risk assessments to determine their use in OWFs. Over 300 different chemicals were declared for use in the construction, operation, and maintenance of OWFs, the most commonly used being grout and cementing chemicals. Predominantly, chemicals used in very large quantities were found to be within closed systems with no intentional discharge to the marine environment. The review of windfarm licence conditions noted some variation and a lack of consistency in approach. The likely scale of future OWF developments has the potential to increase chemical use and discharge, but estimation of future use is difficult without accurate operator chemical data for current designs of structures being used. Floating windfarms are less likely to use concrete at sea and are less likely to require drilling fluids.</p>	
<p>Outputs</p>	
<p>Research reports: Blake S, Moran, C, Perry J and Phillips C (2022). Use of chemicals in Offshore Wind Farm Construction and Operation. Contract C8288, 78pp.</p>	

**PhD Studentship on Bayesian approach to cumulative effects assessment for offshore energy activities (OESEA-18-96)
University of Aberdeen**

Project Ongoing

Project overview

This PhD studentship is jointly funded with the University of Aberdeen and aims to develop a Bayesian approach to cumulative effects assessment (CEA). CEA is challenging at project, industry and strategic levels, and is an active area of research. There are multiple UK and international studies/initiatives/fora on how CEA can be applied to the marine environment and providing suggestions/tools for more effective processes. However, CEA is complex and significant challenges remain in terms of developing methods for its effective implementation and the understanding of effects, in particular how different stressors may interact (see e.g. the US National Academies of Science 2018 report) and the influence of a changing climate. The overall aim of the studentship is to investigate the potential for use of Bayesian approaches to CEA (as a way of overcoming the main challenges identified in the NAS 2018 report) and of linked models. The results are expected to have applications to strategic assessment and consenting of offshore energy activities.

Outputs**Research reports:***Project in progress***Peer reviewed papers:**

Declerck M, Trifonova N, Hartley J & Scott BE (2023). Cumulative effects of offshore renewables: From pragmatic policies to holistic marine spatial planning tools. [Environmental Impact Assessment Review 101: 107153](#).

DESNZ Offshore Energy SEA

The SEA process aims to help inform licensing and leasing decisions by considering the environmental implications of a plan/programme and the activities which could result from its implementation. Since 1999, the Department has conducted a series of offshore energy SEAs, the latest covering wind, tidal stream and tidal range, carbon dioxide and hydrocarbon gas storage, and oil & gas.

Since the first SEA, the associated research programme has targeted key information gaps on the marine environment and potential industrial impacts, to inform the SEA process, developers, consenting bodies and others. Research priorities are discussed with the SEA Steering Group and a range of other stakeholders.

For more information on the OESEA programme, visit the offshore SEA web pages on <https://www.gov.uk/> or email oeep@energysecurity.gov.uk