Introduction – Marine Renewables and Birds

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The drive for renewable energy is a increasingly prominent theme in the policies of the UK Government and of the Devolved Administrations. The Scottish Government gives particular emphasis to renewables in its economic strategy, recognising that Scotland possesses certain environmental advantages over some other countries, and has correspondingly ambitious targets for electricity generation and carbon emissions.

Marine renewables will be an element in the emerging mixed base for power generation. Offshore wind is clearly the most mature technologically, but wave and tidal energy projects have the potential to exploit different aspects of the marine energy resource, and add diversity to the marine sector.

The role of Government is to set clear objectives, and to establish policies, instruments and procedures to enable development to meet these objectives. Development must take into account existing uses of the sea, and a wide range of other national and international obligations. In other words, must progress along sustainable lines. Ornithological interests, particularly those related to protected locations and species, are one of the considerations setting the landscape for sustainability.

The Scottish Government has stated that future marine renewable energy developments should plan-led, sustainable, occur within a commercially attractive and facilitative setting, and bring economic benefits to Scotland's people. To these ends, the marine planning authority in Scotland, Marine Scotland, has developed a sectoral planning approach to the renewables industries with the ultimate aim of increasing the efficiency of the licensing process.

Ornithological information is required at several stages in the process from plan initiation to licences being determined. As experience is gained in use of the planning and licensing processes, it has been possible to identify key gaps in knowledge, and various players have become more prominent in commissioning survey and research work. Current needs include:

1 Early Scoping Study stages of planning
- National scale maps of the distributions of protected species at sea
- National scale understanding of the relative importance of different sea areas
- Sensitivity maps of the sea

2 Strategic Environmental Assessment, and associated HRA
- Understanding of the capacity of marine space to accommodate development

- What limits to growth, at national or regional scale, are presented by marine ornithology?

3 Plan refinement

- On a regional or more local scale, can more sensitive areas be identified where development might be particularly harmful (in addition to Natura sites)? c.f. the Zonal Appraisal approach
- Is there scope to review the application of the Birds and Habitats Directives to better reflect current national aspirations

4 Licensing

- Up to date information on the use of sea areas by birds. ESAS?
- Continued improvement for models of collision risk and of the consequences of displacement
- How much displacement actually happens?
- Behaviour of diving seabirds in tidal streams and their reactions to underwater turbines
- Improved, validated models of seabird population dynamics.
- Better quantification of collisions and more reliable estimates of avoidance
- Better targeting within the EIA and HRA process to concentrate on significant risks

This list is inevitably incomplete. However, it is important that critical evaluations are made of the gaps that need to be filled to allow regulators to have sufficient confidence in their recommendations to Ministers. Renewables will inevitably alter the pattern of use of the sea. The ultimate balance of interests within the new pattern has yet to be made clear.

Ian Davies is the Marine Renewable Energy Programme manager at Marine Scotland Science in Aberdeen. Originally trained as a geochemist, he has wide experience of marine environmental science. He now leads on the scientific aspects of renewable energy development for Scottish Government through Marine Scotland, linking science, policy and planning together for sustainable development of renewable energy in Scottish waters.

Potential population-level consequences of marine renewables

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Offshore wind farms may affect seabird populations through collision mortality, barrier effects, or displacement. Research so far, mostly carried out at Danish offshore wind farms Horns Rev and Nysted, suggests seabirds are generally able to avoid collisions, barrier effects are trivial, and few species are displaced. However, given pressures to develop offshore wind and the rapid establishment of many offshore wind farms in European waters, there is an urgent need to assess population-level impacts on protected seabirds. We review an approach to assess the conservation importance of Scottish seabird species and aspects of their ecology that influence their vulnerability to wind farm impacts. Flight height appears to be a key factor influencing collision mortality risk but improved data on flight heights of seabirds are needed. Collision index calculations identify populations of gulls, white-tailed eagles, northern gannets and skuas as of particularly high concern at offshore wind farms in Scottish waters. Displacement index calculations identify populations of divers and common scoters as most vulnerable to population-level impacts of displacement, but these effects are likely to be less evident than impacts of collision mortality. The collision and displacement indices developed for Scottish seabird populations could be applied to populations elsewhere, and this approach will help in identifying likely impacts of future offshore wind farms on seabirds.

Tidal turbines and wave energy devices may also affect seabird populations through collision mortality, or displacement from foraging habitat. With a lack of deployed tidal stream or wave devices to monitor in areas of importance for seabirds, we can only infer likely interactions with tidal and wave devices based on knowledge of seabird ecology. We outline aspects of ecology that are likely to influence seabird population vulnerability to tidal stream and wave device impacts in Scottish waters. Black guillemot, razorbill, European shag, common guillemot, great cormorant, divers and Atlantic puffin are the species that appear most vulnerable to adverse effects from tidal stream turbines in Scottish waters. Divers are the species that appear most vulnerable to adverse effects from wave energy devices in Scottish waters.

Wave energy devices seem likely to represent lower hazard to seabirds than tidal stream turbines, and both forms of energy capture seem likely to represent lower hazard to seabirds than offshore wind farms. The indices developed for Scottish seabird populations could be applied to populations elsewhere, and this approach will help in scoping likely impacts on seabirds of renewable energy developments.

Bob Furness is a seabird ecologist at the University of Glasgow and Principal Ornithologist at MacArthur Green Ltd. MacArthur Green contracts on strategic assessment of impacts of marine renewables on seabirds include work for The Crown Estate, Marine Scotland, and SNH in Scotland, Vattenfall and the Danish Government in Denmark, and the Bureau of Ocean Energy Management in the USA.

Wind farm displacement studies from Nysted, Denmark Monique

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The Rødsand I offshore wind farm was established in the Danish part of the Baltic Sea in 2002. It comprises a total of 72 turbines, covering 24 km^2 at water depth of 6 to 10 m. The Rødsand II offshore wind farm was established only three kilometres west of the Rødsand I wind farm in 2009. It comprises a total of 90 wind turbines, covering 34 km^2 at water depth between 6 and 12 m.

The abundance and distribution of Long-tailed Duck *Clangula hyemalis* was monitored from 2000 to 2011, covering the more than 1000 km^2 around both wind farm sites with the aim to evaluate potential displacement of ducks from the wind farm sites. This data was modelled in its entirety but potential changes in duck distribution and abundance were considered between three phases: the baseline period, post-installation of Rødsand I and post installation of Rødsand II.

The data available for analysis comprise transect data over a number of survey days providing count data (corrected for imperfect detection), which are likely to be spatially and temporally auto-correlated. More traditional GLM/GAM methods require independence in model residuals and violation of this assumption can result in falsely identifying impact effects (since the resulting *p*-values are typically too small when this correlation is positive). For this reason, Generalized Estimating Equations (GEEs) were used to generate reliable 95% confidence intervals in order to assess where any significant differences might be (between baseline period and installation of Rødsand I and Rødsand II) and 'best-case' and 'worst-case' values for the size of any differences at the geo-referenced locations. The uncertainty in both the detection function and surface fitting stages was considered when generating these geo-referenced confidence intervals.

Careful attention was paid to the model selection process. Models which are too smooth for the underlying surface can miss impact effects, however models which are too flexible can falsely identify impact effects. For this reason, spatially adaptive models were fitted to these data and model flexibility was targeted into areas of the spatial surface (and areas of the depth relationship) in greatest need. This is achieved using a Spatially Adaptive Smoothing Algorithm (SALSA) for the one dimensional covariate (Depth) and the two dimensional spatial surface governed by cross-validation for correlated data.

There was good agreement between the input data and the fitted models post-installation of Rødsand I and Rødsand II. A significant redistribution of sea ducks in the survey area post baseline away from the windfarm was evident for both Rødsand I and Rødsand II. Specifically, the sea ducks were seen to move away from Rødsand I into shallower waters farthest from the wind farm while the ducks also moved away

from Rødsand II into shallow waters adjacent to Rødsand I (which were popular with sea ducks in the baseline period but fell out of favour post- Rødsand I and pre- Rødsand II).

Abundance in the survey area appeared to slightly increase post- Rødsand I and decrease post- Rødsand II when compared to baseline numbers, however these changes in estimated abundance were not statistically significant when considering all the relevant uncertainties: parameter uncertainties in the surface and detection function fitting and adjustments for the temporal autocorrelation in model residuals and extra-Poisson variability.

Monique Mackenzie is a statistician working at the University of St. Andrews who also regularly consults to industry and UK government bodies. She is a developer of spatially adaptive (mixed) modelling methods for one dimensional covariates and two dimensional surfaces and regularly applies these developments to bird (and marine mammal) data in both a monitoring and impact assessment framework.

Ib Krag Petersen has worked with seabird distributions for more than 20 years. He is in charge of the Danish national monitoring programme for marine birds. Understanding the relationship between bird distribution and the factors that governs them has been part of this work. The evaluation of impacts from offshore wind farms on seabird distributions has been another core issue.

Displacement effects model for central place foraging auks with the Forth/Tay as the case study

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Offshore renewable developments have the potential to impact on seabirds by displacing individuals from foraging habitats. The impact of displacement is particularly important for breeding seabirds that, as central place foragers, are constrained to obtain food within a certain distance from the breeding colony. The current worst case scenario is that displacement causes 100% mortality, so there is a need to model more realistic consequences of displacement. Displacement is likely to result in changes to daily energy and time budgets. Such changes may impact on the body condition of adult breeders which, in turn, can affect breeding success, adult survival and, ultimately, population size. Additionally, breeding success may be affected directly if provisioning rates alter significantly. We present a displacement model for adult common guillemots *Uria aalge* rearing chicks on the Isle of May (part of Forth Islands SPA) in relation to proposed offshore wind farms within the Firth of Forth area. The model estimates the consequences of displacement and barrier effects on the time/energy budget of breeding birds.

Our model incorporates several novel features resulting in a step change in the degree of realism captured in terms of incorporating how guillemots use their foraging landscape and in how their fish prey are distributed within it. The model compares the time/energy budgets of 1,000 breeding guillemots over a 24-hour period in the absence or presence of a wind farm. From this, an estimate of the time/energy budget for the entire chick-rearing period can be inferred. The model is based on assumptions regarding behavioural change in response to a wind farm and explores a range of scenarios simulating different displacement effects (e.g. only 50% of birds foraging within the wind farm are displaced), different prey densities (e.g. 25% of the prey density is reduced) and different levels of intra-specific interference competition among guillemots feeding in the same patch. The cumulative effect of multiple wind farms in the area is also explored. All scenarios tested have implications for marine spatial planning issues.

In all scenarios, the addition of the wind farm resulted in an increase in the average costs of foraging. This result is significant since it suggests that displacement effects could be important and therefore merit further consideration.

Claire McDonald is a research associate in statistical ecology at the Centre for Ecology & Hydrology. This role involves analysing and modelling large environmental datasets with particular focus on examining interaction effects and spatial problems. Claire completed a PhD at the University of Leeds examining insect trace fossils from Antarctica and comparing this evidence of insect life with modern analogues in Chile. Claire has undertaken fieldwork in a variety of places such as Greenland, Iceland, Svalbard, Svalbard, Greece, the Azores, Thailand, Kenya and Tanzania.

Habitat use by seabird species in high-velocity current flows: investigating the potential effects of tidal-stream renewable energy developments

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Scotland is in an advantageous position with some of the best resources for generating renewable energy from the marine environment in the world. Scotland also holds internationally important populations of many seabird species. Many of these seabirds breed within Special Protection Areas (SPAs) and so are protected by conservation legislation. This legislation requires that developments do not negatively affect protected species and that populations remain in a favourable conservation status. Currently, there is a lack of information regarding the potential effects of marine renewable energy developments on seabirds,

particularly tidal-stream renewable energy installations. A better understanding of the use of high-velocity current flow environments by seabirds is urgently required to identify which species may be most vulnerable to potential effects.

Using vantage point observations of a channel with high-velocity currents, we aim to identify which species use this dynamic habitat. Observations were carried out in a proposed tidal-stream development site in the Inner Sound of the Pentland Firth, on the north coast of Scotland. Distributions of individual birds and associated behaviour were recorded according to a grid assigned to the study area, which was designed to encompass a range of current flows and small-scale oceanographic features, such as eddies and turbulence.

The identification of species using high-velocity current environments will help inform the allocation of monitoring resources for compulsory Environmental Impact Assessment (EIA) to those species most likely to be at risk from the potential effects of tidal-stream renewable energy developments. Assessing differences in habitat use according to season and tidal phase could inform the degree to which seabirds and development activities may interact. In addition, by identifying how seabirds use small-scale oceanographic features we aim to increase our knowledge of how seabirds target visual surface cues. This information could be applied elsewhere to help predict the potential effects of tidal-stream devices at other proposed sites.

Helen Wade is a final-year PhD researcher at the Environmental Research Institute, at the University of the Highlands and Islands. Her current research uses tracking technology and vantage point observations to improve our understanding of the potential effects of marine renewable energy developments on seabird populations.

Are auks the ideal birds to study offshore wind farm impact on seabirds?

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Offshore wind farms may impact local seabirds, both directly through lethal collisions, and indirectly by displacing birds from built-up sites. On the population level, the latter is probably insignificant at present given the relative small sizes of current wind farms, but this is likely to change in the near future given current plans for offshore wind farm development. Important issues are whether or not birds are displaced and to what extent, and whether or not wind farm design might influence displacement. This calls for methods to measure displacement and from this, to compare different sites and wind farm designs. Two recently constructed wind farms, built closely together in Dutch North Sea waters and of a different design

were used to address these questions. One site (named OWEZ) is rather open, having 36 turbines of 3 MW in an area of 27 km^2, while the other site (PAWP) has a much higher turbine density: 60 2MW turbines within 14 km^2. There is about 5 km of open sea between the two sites and ambient conditions in the two parks are similar. We used ship-based surveys to record seabird distribution and density, using a series of 10 transect lines covering an area of circa 12x15 NM with the two wind farms in the centre, and two sets of survey lines running parallel to the main isobaths in the general area, covering only the two sites and the immediate vicinity. Distribution patterns were studied one year pre-construction and four years post-construction. Data from many seabird species did not allow meaningful statistical analysis of the potential impact of the wind farms. Divers, grebes and seaduck mostly occurred between the wind farms and the shoreline while Northern Fulmars generally occurred further offshore; either distribution pattern resulted in marginal densities at wind farm longitudes. Analysis of the impact on gulls was hampered by the fact that fishing was banned from the wind farms. As a result, all post-construction concentrations of gulls around fishing vessels occurred outside park limits. Auks, particularly Common Guillemots) occurred throughout the entire study area (winters only) and in numbers that allowed meaningful statistical analysis. Guillemots are not attracted to fishing vessels and showed significant avoidance of the parks but were also seen to swim within park limits, so avoidance was less than 100%. The vast majority of Guillemots were recorded swimming, rather than flying, and thus are true “users” of the study area, including wind farm sites, rather than mere passers-by. They did avoid the wind farms to some extent, one park more than the other. As Guillemots occur in good numbers all over the North Sea and adjacent seas, these birds appear to be the ideal study objects to compare the impacts of various wind farms and wind farm designs in seabird avoidance studies.

Mardik Leopold has studied North Sea seabirds since 1987. This work has resulted in an Atlas of Seabirds in the SE North Sea (with Kees Camphuysen) and in the designation of Natura-2000 sites for seabirds in the Dutch part of the North Sea: the Frisian Front, for Common Guillemots and large strips of coastal waters for Common Scoters and divers.

Avoidance behaviour and flight intensities of birds in an offshore wind farm in the Netherlands

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Flight patterns of birds were studied in the framework of a three-year effect study in the Dutch Offshore Wind Farm Egmond aan Zee (OWEZ). A combination of visual observations and continuous radar observations were carried out between 2007 and 2010, to assess flight intensities, flight altitudes and flight paths. Visual observations provided information at species level. A combination of horizontal and vertical

radar with automated data recording provided continuous data on flight patterns, also at night time and in adverse weather. In our presentation we show results on occurrence of macro- and micro-avoidance behaviour, based on flight paths of birds through the wind farm area. We also show results on the number of birds at risk of colliding with the turbines, based on flight intensities and flight altitudes of birds in the wind farm area.

Flight patterns of many different species were registered visually. Interspecific variation in reactions was considerable, while intraspecific variation was low. Reactions of the birds to the wind farm could be separated in four categories. Local birds either did avoid the wind farm (e.g. seabirds such as gannets) or did not (e.g. cormorants attracted to the wind farm from the main land). Similarly, migrant birds either did (e.g. geese) or did not avoid the wind farm (e.g. terns, nocturnal thrushes).

Seasonal and diurnal variation in bird activity were recorded in both flux and flight altitudes from sea level up to 1.5 km. High altitude passages were mainly of nocturnal migratory birds including waders and thrushes. Movements during the day at lower altitudes primarily included gulls, as well as other local seabirds.

This study was commissioned by 'NoordzeeWind' (a joint venture of NuonVattenfall Endorsement FC and Shell Wind Energy).

Karen Krijgsveld is a behavioural biologist, working in applied research and consultancy since 2002, as a researcher and project manager. She has been in charge of the multi-year radar study of bird flight patterns at the OWEZ offshore wind farm, for nearly a decade. Apart from wind farm studies onshore and offshore, she studies the effects of human disturbance on birds.

Seabirds and marine renewables: Are we asking the right questions about indirect effects?

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When we start putting in hundreds and then thousands of marine renewable devices in large arrays of areas of 10s of km^2, then we will start to change something fundamental in the marine environment and that is the level of physical mixing. The marine environment is actually less variable and more predictable than the terrestrial environment and hence most marine species rely on the predictability of daily, biweekly and seasonal currents to drive their foraging, fleeing and reproducing behaviours. Seabirds

foraging is most likely tied into those predicable temporal variations, and perhaps only at specific locations. To understand the indirect effects of marine renewable developments we must shift the focus of research onto a more fundamentally mechanistic understanding of seabird foraging.

What is known for certain is that the indirect effects of changes in mixing will influence the amount, species types and locations of elevated primary production (frontal and productive regions). The research on potential environmental interactions between marine renewables and seabirds needs a much clearer ecological focus which incorporates hypothesis testing rather than just the production of distributional abundance maps.

This presentation will cover three main issues of indirect effects of renewables which influence seabird foraging, which are: 1) identifying reasons for locations of, and the potential mechanisms producing foraging areas, 2) the knowledge gained about foraging habitat use by understanding the limits of foraging energy expenditure and 3) the need to explore underwater foraging behaviour. The presentation will also cover how new surveys techniques can incorporate ecology based hypothesis testing approaches. As well, recommendations and examples from current research projects, including the new upward facing acoustic instrument (Multi-frequency and Multi-beam sonar) for exploring seabird and fish underwater interactions at the EMEC tidal sites will be presented.

Beth Scott is a Senior Lecturer at the University of Aberdeen. I have a multi-disciplinary background in marine ecology, oceanography and fisheries. My approach has been to focus on the functional linkages between fine scale bio-physical oceanographic processes, flexible individual life history traits and population dynamics of a range of fish and seabird species. This allows identification of critical marine habitats where predator and prey species overlap.

Short- and long-term effects of an offshore wind farm on three species of sandeel and their sand habitat

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Offshore wind farms are being constructed at a high rate due to a high demand, both economically and politically, for sources of renewable energy. We investigated the short term and long term impact of the Horns Rev I wind farm off western Denmark, established in 2003, on three ecological key species of sandeel (*Ammodytes marinus*, *Ammodytes tobianus* and *Hyperoplus lanceolatus*). Since sandeels display a distinct preference for sand habitats with a low weight fraction of fine particles, we expected changes in

habitat quality to provide a causal explanation for the potential impact of the wind farm on the sandeel community. A Before-After-Control-Impact (BACI) test-design was applied. The results revealed a positive short term effect on the densities of both juvenile and adult sandeels, which was consistent with a reduction in the fraction of silt+clay in the sediment. In the long term a negative effect on juvenile sandeels was found. The negative long term effect was, however, neither consistent with the survey data from September 2009 nor the fraction of silt+clay in the sediment.

Mikael van Deurs has a background in fisheries research (former Danish Institute for Fisheries Research). During his PhD (University of Copenhagen) he adopted a process-oriented approach focusing on life-history strategies and trophic interactions between copepods and planktivore fish in seasonal environments, with emphasize on sandeels. I am today concerned with bridging basic ecological science and applied science (Technical University of Denmark).

Connectivity between seabirds SPAs and windfarms: Overview from the FAME project

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The UK holds almost one hundred internationally important coastal and offshore seabird colonies which are designated under UK law as Special Protection Areas (SPAs) according to the EU Birds Directive. The UK has an international responsibility to safeguard the future wellbeing of the 25 seabird species which depend on these colonies for breeding, and also ensure adequate protection of the adjacent and offshore marine areas upon which they rely for food. Proposals for new marine installations are required to assess the likely impact on such designated features. Whilst at-sea surveys can provide valuable information on where important aggregations of seabirds occur, such surveys cannot establish the provenance of individuals, which is of crucial importance in establishing connectivity between the impacts of offshore developments and SPA seabirds. Information from seabird tracking studies may be of value in establishing the mean and maximum foraging ranges of individual species, and species-specific values may then be used to infer the likely colony origins of at-sea concentrations of seabirds. Here we present an overview from the RSPB's Future of the Atlantic Marine Environment (FAME) and allied projects, which have to date tracked 844 individual seabirds of 5 species from 20 colonies across the UK. The data collected show that some species are capable of travelling much further from the colony than previously reported and that there is considerable inter-colony variation in foraging ranges for some species. It remains unknown how these patterns change over longer time scales, but we demonstrate both stability and variation in foraging locations over three years of tracking. This new information provides an improved evidence-base for understanding connectivity between offshore developments and designated seabird colonies. For those

colonies where tracking has been carried out, clear information on connectivity is now available. However, for the majority of SPA colonies and species, for which empirical data are not currently available, a modelling approach is required. In its simplest terms, such a model relies solely on species-specific foraging information, which may poorly represent actual foraging behaviour for many colonies. Incorporation of colony-specific attributes and information on oceanographic features in the surrounding waters may increase our ability to accurately predict foraging locations in such cases.

Ellie Owen leads the RSPB's seabird tracking work in the UK, including the Future of the Atlantic Marine Environment (FAME) project, one of Europe's largest seabird tracking programs. She specialises in seabird movement and foraging ecology and has worked with a variety of species around the world.

Connectivity between seabird features of protected sites and offshore wind farms: Lesser Black-backed Gulls and Great Skuas through the breeding, migration and non-breeding seasons

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The UK Government has a commitment to obtain 15% of the country's electricity from renewable sources by 2020, of which wind energy is likely to form a major part. Many seabirds that are feature species of Special Protection Areas (SPAs) might potentially be affected by these developments, as their breeding season foraging ranges and migratory routes may overlap with proposed offshore wind farm 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. Assessing movements throughout the year (breeding, migration, non-breeding) is pivotal in the understanding of population-level impacts. We fitted 11 and 14 GPS tags to Lesser Black-backed Gulls *Larus fuscus* at Orford Ness, part of the Alde-Ore Estuary SPA, during 2010 and 2011 respectively. A further four and 10 tags were fitted to Great Skuas *Stercorarius skua* at the Foula SPA in 2010 and 2011 respectively, and 10 tags to Great Skuas at the Hoy SPA during 2011. During the breeding season, some gulls never ventured offshore, whilst others spent more than half their time away from the colony at sea. For Lesser Black-backed Gulls that spent substantial periods of time at sea, there was considerable temporal (up to 7% and 12% of time budgets)

and spatial overlap (up to 48% and 33% of total area usage) between their ranges and consented Round 1 and 2 wind farms (in this case, sites which are under construction), as well as with proposed extensions and Round 3 development sites. The distances that birds foraged offshore and the amount of time spent offshore also differed between years (up to 159 km in 2010, 91 km in 2011). There was also temporal (up to 11% and 6% of time budgets) and spatial overlap (up to 31% and 31% of total area usage) between the ranges of Great Skuas from both Foula and Hoy and medium term renewable development options in Scottish Territorial Waters. All of six gulls for which we obtained data for the 2010/11 non-breeding season wintered in southern Spain or Morroco. On their migrations, three birds crossed existing or proposed wind farms. This study shows the value of GPS data in assessing connectivity and potential interactions between SPA features and offshore wind farms.

Chris Thaxter is a Research Ecologist in the BTO's Wetland and Marine Research Team, with a background in marine ecology. Chris has undertaken a range of projects since joining the BTO in 2008, focused on marine protected areas, climate change, and Environmental Impact Assessments. Chris is currently investigating the potential interaction between seabirds and offshore windfarms using GPS telemetry.

Potential impact of offshore wind farm collisions on the gannet population of the British Isles explored using PVA

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Offshore wind farms around the coasts of the British Isles have the potential to provide significant amounts of energy, and in addition to installed wind farms, there are large areas earmarked for further development, extending into deeper waters farther from the coast. However, these developments have the potential to impact on birds, in particular through collisions with moving turbine blades.

Their large size, flight height and far-ranging habits put Northern Gannets *Morus bassanus* at potentially high risk of collision. The British breeding population of gannets represents over 70% of the European population and over half of the world population.

A population model was developed for this population in order to explore the potential impacts that mortality resulting from collisions could have on the population. This work was funded by The Crown Estate through the Strategic Ornithological Support Services (SOSS). The model used a matrix formulation and included environmental and demographic stochasticity. Two forms of the model were developed with adult survival modelled as either density dependent or density independent.

In the absence of additional mortality, the baseline model prediction was for an average population growth rate of 1.28% per annum, which is close to the rate of 1.33% observed between 1995 and 2004. The risk of the British Isles gannet population declining by more than 5% within 25 years was predicted to be very low; 0.5%.

Collision risk modelling (CRM) was conducted using the recently revised methods for offshore wind farms (SOSS-02). All existing and consented offshore wind farms (Rounds I and II) were included in the calculations. Mortality was apportioned amongst gannet colonies to reflect current understanding of movements and foraging ranges for each breeding colony. Collisions were estimated using an avoidance rate of 98%, in line with current SNH guidance. This is considered to be a precautionary level and is used for those species where specific rates have yet to be studied and agreed.

Based on observed gannet densities at offshore wind farm sites, annual collision mortality of 2,603 adult and 1,056 immature gannets was estimated for existing and consented wind farms around the British Isles.

The population model predicted that, on average, gannet numbers would continue to increase with additional mortality up to a threshold of approximately 10,000 additional birds killed annually. At this level of additional mortality, 50% of simulations would have negative population growth. A much lower level of risk, with 95% of simulations maintaining positive population growth, was achieved with additional mortality of up to 3,500 birds per year.

Threshold annual mortalities which could be sustained by each UK Special Protection Area (SPA) colony in the study area were estimated using the model. This indicated, for example, that the Bass Rock population would continue to grow on average until additional mortality exceeded 2,000 birds per year.

Mark Trinder has established a strong reputation for the delivery of assessments of potential impacts on bird populations, based on statistical analysis and population modelling. He has developed novel analytical modelling approaches for the assessment of impacts of offshore renewable developments and has undertaken work for the renewable industry, statutory agencies and The Crown Estate.

Individual-based population viability modelling as a tool to quantify the effect of wind farm collisions

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We will describe ViaPop, an individual-based simulation approach to population viability modelling. The advantages and weaknesses of individual-based models compared to matrix-based models will be explored, as will a range of outputs to capture the nature and impact of population decline. Using examples from a number of seabird populations, we will discuss the role of probabilistic assessments of population change in particular. The interpretation of these different output measures and the appropriate timescales upon which to base critical decisions will also be discussed.

Aulay Mackenzie is an population and evolutionary biologist who has used mathematical and simulation modeling tools to explore a variety of ecological and evolutionary scenarios, including speciation, extinction and the drivers behind population fluctuations. A senior lecturer in ecology at the University of Essex, Aulay has worked on a wide variety of species, including aphids and other insects, fish and seabirds.

Martin Perrow founded ECON Ecological Consultancy in 1990 to bridge consultancy and research. The trademark of the company remains the scientifically rigorous and holistic approach to ecological work, driven by the needs of sustainable development and biodiversity. As its Director, Martin has considerable experience of managing projects for clients, whilst also maintaining a reputation as an academic ecologist, with ~50 peer-reviewed papers, proceedings and book chapters as well as the acclaimed two-volume Handbook of Ecological Restoration to his name. In recognition of this body of work Martin is an Honorary Research Fellow at University College London. Martin is committed to renewable energy and particularly offshore wind, as part of the solution to global climate change, whilst recognising that smart solutions are required to avoid conflict with biodiversity, especially seabirds.

POSTER ABSTRACT

A review of boat-based seabird survey methodologies in the UK

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Attempts have been made to standardise boat-based seabird surveys for the offshore renewables industry in the past, by Camphuysen *et al*. (2004) and Maclean *et al*. (2009). However there are still several methodologies currently in use in the UK and European waters.

This paper compares and evaluates the different methods used for boat-based seabird surveillance. An assessment of key differences in methods and discussion on the best protocol for future surveys is offered, with emphasis on data quality and data collection suitable for Cumulative Impact Assessments.

POSTER ABSTRACT

Predicting the impact of wet renewables on seabirds using simulation modelling.

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As a contribution to meeting targets pertaining to climate change and renewable energy, there has been increasing interest in the development of offshore marine renewables in Scotland. The world's first leasing round for the wave and tide industry occurred in the Pentland Firth and Orkney Waters strategic area and various projects are being developed. Orkney and the north of Caithness also hosts ten Special Protection Areas (SPAs) which have been designated due to the presence of significant numbers of important seabird species. Two of the development areas overlap with SPAs, and most SPAs are in close proximity to lease sites. So it is likely that birds in the region currently use areas of sea where development might occur. Along with the possibility of injury from collisions, the developments may result in changes to commuting distances *via* exclusion from habitat due to avoidance behaviour, or modifications to the availability of prey. Effects on prey populations or bird behaviour could lead to alterations to a bird's rate of energy acquisition and expenditure, which may impact breeding success and adult condition.

An individual-based model was developed for the common guillemot (*Uria aalge*), which predicts the behavioural and physiological state of both parents and chicks. In the model, the decisions of adult birds are directly linked to the state of both their partner and chick, and the cumulative impact is simulated over the whole chick rearing period. The model was used to predict the probability of successfully rearing a chick to fledging mass, the amount of time chicks were left unattended and the change in adult body condition over the season, under different scenarios of foraging range and prey conditions. The model predicts that, under average conditions, adults can forage about 40 km from the colony and successfully fledge over 90% of chicks; however this range varies non-linearly with prey abundance and calorific content. This suggests that developments further than 40 km from a colony are less likely to be encountered by successfully breeding guillemots, and the impact of developments will be dependent on colony specific changes to commuting distance and effects on local prey conditions.

The results from this modelling study can be plotted onto real space for colonies in the Pentland Firth and Orkney Waters. This allows a prediction of which development areas may have the greatest impact on which SPA colonies, given certain prey conditions, and therefore has the potential to inform Marine Spatial Planning.

POSTER ABSTRACT

A review of the potential use of sonar to observe the underwater behaviour of diving birds near tidal energy devices

Joanna Loughrey, Mark Trinder & Rhys Bullman
RPS Group

The aim of this feasibility study was to review the functionality of the relevant sonar technology, review examples of it's use in the scientific literature and consider the results from current trials. The study includes:

- A review of relevant and available sonar (and underwater video camera and strain gauge) technologies, considering benefits and limitations, availability, cost and methods of attachment.
- A summary of past examples from the scientific literature of the use of .sonar to observe the underwater behaviour of diving birds.
- A summary of current trials in the use of sonar for biological monitoring .near tidal devices.
- A description of the underwater conditions characterising high-energy .tidal currents, waves, turbidity and air bubbles, and how these variables will affect the use of sonar.
- A review of scientific literature relating to the underwater behaviour of .diving bird species occurring around the Pentland Firth and Orkney Islands, with an emphasis on dive depth, dive duration, dive profile and swimming speed, to aid in the potential classification of birds' sonar signatures.

RPS undertook a trial to assess the possible applications and limitations of using boat-mounted Echoscope sonar to track the underwater movements of diving birds. The Echoscope is a sonar device capable of producing real-time three-dimensional images of underwater environments. This trial was undertaken on the Forth Estuary and tracked the underwater movements of two razorbills.

POSTER ABSTRACT

Selection of modelling techniques for bird analysis undertaken for Robin Rigg offshore wind farm, Solway, Scotland

Gillian Lye[1], Dr Sarah Canning[1], Chris Pendlebury[1], Sally Shenton[2] & Richard Walls[1]
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[2] EON Climate & Renewables, UK

Robin Rigg in the Solway was Scotland's first commercial scale offshore wind farm development, operational from April 2010. This presentation will provide specific details of the analysis used for the long-

term ecological monitoring (circa 10 years) undertaken as part of the Marine Environment Monitoring Program (MEMP).

In particular, this presentation will focus on the techniques used to determine the changes in bird numbers and distributions at the site, comparing the situation pre-construction, during construction and then during the two years of operation. The key species that the analysis has been undertaken for are Guillemot *Uria aalge*, Razorbill *Alca torda*, Gannet *Morus bassanus*, Red-throated Diver *Gavia stellata*, and Cormorant *Phalacrocorax carbo*.
This presentation focuses on the issues of autocorrelation and zero-inflation in offshore seabird data. The aim will be to show how models have been selected for each species.

POSTER ABSTRACT

Integrated Ecological Monitoring Plans (IEMP) for Offshore Wind Projects

Chris Pendlebury, Gillian Lye & Richard Walls
Natural Power Consultants, UK

A structured approach for ornithological baseline surveys for offshore wind farms has previously been proposed in order to build up an appropriate understanding of the site during the impact assessment process. As such an Integrated Ornithological Monitoring Program (IOMP) would use a selection of complimentary techniques targeted towards the range of species highlighted as being at potential risk. This presentation updates the approach using examples of offshore wind projects in the UK. The techniques discussed include: boat-based and/or aerial surveys; complimentary remote methods such as radar, and tracking studies; and then modelling approaches such as collision risk, population viability analysis and cumulative impact assessment.

POSTER ABSTRACT

Birds and Wave & Tidal Stream Energy; An Ecological Review

McCluskie, A.E., Langston, R.W.L. & Wilkinson, N.I.

The RSPB has reviewed the potential effects on birds of wave and tidal stream renewable energy generation. This review is a response to the lack of knowledge on how these emerging technologies will impact on seabirds, as well as some other potentially affected species, and it uses an ecological approach to understand the potential nature of these impacts.

Currently, there is very limited experience of operational wave and tidal stream devices at sea, and hence very little information about their impacts on marine birds. It was therefore necessary to make inferences about potential impacts from a theoretical background, based on review of current technological and ecological knowledge.

While the risks to seabirds from wave and tidal steam devices are largely undefined, this review took the approach of examining the component parts of such devices and to drawing structural parallels with existing human activities, including, for example, vessel movements. In addition ecological aspects of the receptors, marine birds, were also examined. Here we give examples, of guillemots, razorbill, gannets, cormorants and shags, to demonstrate how this approach can be a solution to a poor knowledge base, though while it can inform answers it cannot always fully answer questions.

POSTER ABSTRACT

Preliminary insights into the avoidance behaviour of Sandwich Terns at Sheringham Shoal offshore wind farm as illustrated by visual tracking

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The license conditions of Sheringham Shoal require validation of collision risk for Sandwich Terns. Visual tracking of individuals en-route across the site was selected to detail the response of the birds before, during and after construction. Prior to and during construction of the site (2009-2011), the tracks of *n*=898 individuals showed a predominant northeast to southwest flight path in accordance with direct movement of the breeding colony some 20 km distant. Some avoidance of turbine bases was noted at an early stage of construction in 2011. In 2012, when the first turbines came into operation, a high proportion of the *n*=378 individuals tracked showed avoidance of the entire site, with others selecting routes amongst non-operational and incomplete turbines. Further details of changing behaviour are presented and the implications for collision risk are discussed.

POSTER ABSTRACT

Comparison of two different collision risk models used in the offshore environment: Band vs Folkerts

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Collision risk modelling is a critical tool for the assessment of the impact of wind turbines upon birds. Unlike onshore, in the offshore situation, data is typically gathered on a moving platform in which only a small area is continually surveyed. Collision risk models developed for use onshore in which the entire or a known fixed proportion of the site is surveyed are not suitable. Two models are currently available for the offshore situation in which density data is converted to a passage rate to allow collision risk to be assessed. In this exercise, we compared the performance of the 'Folkerts' and 'Band' models with a dummy data set broadly based on a real situation. We selected four species: Northern Gannet, Black-legged Kittiwake, Herring Gull and Arctic Tern, with different patterns of occurrence, peak density and flight characteristics. Although the models produced different results the differences amongst species were small at between 10-15%. We concluded that although the models differed in their basic principles, either could be used with reasonable confidence.

POSTER ABSTRACT

Are newly fledged shags at risk from marine renewable devices?

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The coastal nature of many marine renewable devices means they pose a potentially serious risk to seabirds that forage close to shore. Juvenile birds are typically more naïve than adults and thus may be more susceptible to collision. Increased juvenile mortality as a result of collisions could have population level consequences due to reduced numbers of recruits. The European shag (*Phalacrocorax aristotelis*) is an inshore species with a declining UK population. While numerous logger studies have been carried out on adult shags, little is known about the diving abilities of juveniles. This study used an observational approach to quantify the diving behaviour of adult and newly fledged shags at a breeding colony at the Isle of May, Scotland with the aim of estimating differences in potential encounter rate with marine renewable installations and how this may change during the first eight weeks post-fledging.

Consecutive dive and recovery times were recorded for individual shags using binoculars and a stopwatch. A total of 382 dives were observed between 1st and 12th July 2012 (30 adult and 72 juvenile dive series). A further 247 dives were observed between 26th July and 8th August (19 adult and 51 juvenile dive series). Observations were made at two sites where mean water depth differed slightly (10 m and 15 m respectively).

In the first observation session adults dived for longer than juveniles at both sites. Site related differences were observed with adults diving for longer at the deeper site but no differences recorded for juveniles. However in the second session, juveniles had increased their dive durations with longer dives (36.68±13.27 seconds) than adults (28.21±12.21 seconds) in the shallower site and similar dive durations for both age classes in the deeper site (36 seconds). In the first session, adults spend a greater percentage of time underwater (70%) than juveniles (53%) at the deeper site while at the shallower site little difference was recorded (57% and 54% respectively). In the second session little difference in percentage of time underwater was recorded between the age classes at both sites with adults and juveniles spending 66% and 59% respectively of their time at sea underwater at the deeper site and 57 % and 54% at the shallower site.

While newly fledged shags did not dive as long as adult shags initially, these data indicate that with time their diving ability changes, possibly related to increasing independence from adults and improvements to diving physiology allowing longer dives whilst honing prey capture skills. Site differences may be linked to depth, prey distribution and capture rates. There may also be variation in the length of time spent at depth between the age classes. These data demonstrate that the encounter rate for juvenile shags with marine renewable devices could increase in the eight weeks post-fledging as dive duration and percentage time

spent underwater increases. This study provides useful information on the diving abilities of newly fledged shags and adults in the coastal zone to aid in collision risk modelling for this species.

POSTER ABSTRACT

Implications of marine bird behaviour in a fast tidal stream for interactions with wet renewable energy schemes; a Shetland case study

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Wet renewable energy schemes, i.e. wave energy devices and tidal stream turbines, have the potential to place a new anthropogenic pressure on seabird populations. This can be through collision risk, disturbance and habitat loss. The diving behaviour, foraging patterns and seasonal distributions of a species are all likely to affect if and how they might interact with devices, and their vulnerability to any negative impacts. To understand which marine bird species are more likely to interact with tidal-stream turbines we have undertaken behavioural observations from three vantage points along the length of Bluemull Sound, Shetland, prior to the deployment of a tidal stream device. We aim to establish the key marine bird species utilising this high-energy tidal environment and explore if their behaviour and spatial distribution varies under different temporal and environmental conditions. The most frequently observed diving species during the breeding season were black guillemot, European shag, Atlantic puffin, common guillemot and northern gannet; while black guillemot and European shag were the most frequently observed species during the non-breeding season. We describe the key patterns of foraging activity and spatial distribution of this fast-flowing tidal stream and compare the potential for these species to interact with a tidal-stream turbine.

POSTER ABSTRACT

Radar monitoring of migrating pink-footed geese – behavioural responses to offshore wind farm development.

I.C. Simms, P. Plonczkier & J. Milborrow

The Food and Environment Research Agency (Fera) Sand Hutton, York, UK

In the context of growing demand for offshore wind energy production in recent years, much effort has been made to determine the collision risk that offshore wind turbines pose to birds. Currently only limited species-specific data on migrating birds' avoidance rates and associated mortality at offshore windfarms

exist. During a four-year study, bird detection radar was used to monitor behavioural responses and flight changes of migrating pink-footed geese in relation to two offshore wind farms during and after construction. Radar recorded a total of 979 goose flocks migrating through the whole study area, of which 630 were visually confirmed as 43,249 pink-footed geese *Anser brachyrhynchus*. Overall, we calculated that 97.25% of all flocks recorded by radar, in 2009 and 2010 combined, migrated without any risk of additional mortality associated with the constructed wind farms. We identified a growing tendency of geese to avoid the wind farms and calculated that, for 2009 and 2010 combined, avoidance was exhibited by 94.46% of the original 292 flocks predicted to enter the wind farms.

This study demonstrated that migratory geese responded to offshore wind farms by adopting strong horizontal and vertical avoidance behaviour. For the first time, wind farm avoidance rates have been recorded for this species, these rates will allow more robust impact assessments to be undertaken both of this species and waterfowl in general. Remote sensing techniques should be used to undertake long-term impact assessments at offshore wind farms to provide evidence-base for assessing the mortality risk for migratory birds.

POSTER ABSTRACT

Individual consistency in the foraging behavior of Northern gannets: Implications for interactions with offshore renewable energy developments

Louise Soanes, Roland Gauvain, Phillip Atkinson & Jonathan Green

With recent EU directives requiring that Europe must achieve 20% of its energy from renewable sources by 2020 the development of offshore wind, tidal and wave technologies is gaining momentum, increasing pressure on our already vulnerable marine systems and organisms. All EU countries are required to have Environmental Impact Assessment (EIA) guidelines in place for such developments and whilst tracking studies of marine predators have been recommended to aid EIAs, they are as yet not a requirement. This study tracked Northern Gannets breeding on Les Etacs, a stack immediately offshore Alderney, Channel Islands, to determine their use of both local and international waters and examine the consistency between an individual's foraging trips. The 15 Northern Gannets that made at least two foraging trips foraged in three different territorial waters and their combined home-range area overlapped with nine potential offshore marine renewable energy developments. Repeatability between the first and second foraging trips made by an individual was apparent when considering the direction travelled and the maximum distance travelled from the colony, but not when considering the percentage overlap in core foraging areas, trip duration, or the total trip distance suggesting individuals did not appear to be dependent on specific foraging areas. Our findings highlight the need to consider all important seabird colonies which forage in the range of potential offshore developments and to use tracking technology to determine which colonies may be affected by such developments and the colony's dependence on these

areas**.** Tracking studies of birds from important seabird colonies should form an integral part of the EIA process for marine renewable developments.

POSTER ABSTRACT

Different method different results: the importance of survey choice when estimating spatial overlap between deep diving seabirds and tidal stream turbines

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The risk of collisions between deep-diving seabirds such as auks *Alcidae sp* and cormorants *Phalacrocorax sp,* and the blades of tidal stream turbines is a major concern. Despite this, it remains unknown whether collisions represent real and significant risks to these species. One component of assessing collision risks is identifying spatial overlap between the foraging distributions of vulnerable species and the locations favoured for tidal stream turbine installations. However, the importance of habitats characterised by high tidal currents as foraging locations remains largely unknown. To answer this question, we need to accurately record the distribution of foraging seabirds within these habitats. Here we present and compare the results from two different survey methods that were conducted at the European Marine Energy Centre (EMEC) test site in the Fall of Warness, Orkney, UK: These were (1) Land-based surveys that have occurred almost daily for the previous 6 years and (2) ship-based surveys from a recent 2 day research cruise. We show interesting differences in the results of these two studies. Results from the land-based survey suggest that most species foraged primarily within areas characterised by eddies and shallow water at the edge of main tidal currents; areas that are unsuitable for tidal stream turbines. In contrast, the sea-based surveys suggest that most species forage intensively in areas characterised with strong and mostly unidirectional currents in deep water: areas that are more suitable for tidal stream turbines. We suggest that interactions between bathymetric features and strong water currents within areas suitable for tidal stream turbines create rough and uneven water surfaces, and that this reduces seabird detectability from the more distant land-based observation points. Consequently, land-based surveys may underestimate seabirds' use of these areas. This study highlights the importance of method choice for answering key questions. We suggest that land-based surveys conducted on a regular basis may be best suited for understanding seasonal and annual changes in the abundance and species of seabirds within these habitats. However, ship-based surveys may be needed to determine the fine-scale distribution of these species therein.
