

ORAL PRESENTATIONS

Breeding later at higher latitudes: seabird phenology along a latitudinal gradient from the Norwegian to the Barents Sea

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Phenology links species to their physical and biological environments. Because environmental conditions vary by location it is expected that the timing of annual events would vary over a large geographic region, both within and between species. Seasonality generates a latitudinal gradient in environmental conditions to which we expect seabird adaptations to have evolved. This study investigates timing of breeding of four seabird species (*Fratercula arctica*, *Rissa tridactyla*, *Uria aalge*, *Uria lomvia*) from multiple colonies covering a latitudinal gradient along the Norwegian coast to Svalbard (65–79° N). A linear mixed-effects model with a random year effect revealed that hatching times within species were significantly delayed with latitude for all species (the two *Uria* species were treated together as *Uria spp.*) with mean hatch date delayed by 1.7, 2.1, and 1.5 days per latitudinal degree for *F. arctica*, *R. tridactyla*, and the *Uria spp.*, respectively. The intra-annual breeding synchronicity also significantly increased with latitude for *R. tridactyla*, but not for the other species. We discuss potential explanations for the observed patterns, including the phenology of lower trophic levels. Spatial patterns in timing need to be quantified in order to recognize potential risks to successful breeding and monitor change.

Extreme weather and seabird demography: factors influencing productivity and survival of European shags following a severe winter wreck

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Climate warming is predicted to be associated with increased climate variability and hence frequency of extreme events. Such extreme events may have immediate and downstream effects on seabird productivity and survival, yet these impacts have rarely been studied in detail. Here, we focus on a severe wreck of European shags (*Phalacrocorax aristotelis*) on the north-east coast of the UK in winter 2012-13 associated with two prolonged periods of strong onshore winds and rain in December and March. The exact cause of mortality was unknown, but such weather may prevent birds from finding sufficient food. We analysed the impact of the wreck on the marked bird population from the Isle of May, a population with individual-level data on overwintering location and breeding performance. We investigated whether overwinter location or intrinsic factors such as sex, age and breeding effort the previous breeding season were linked to survival. We also investigated the impact of the wreck on subsequent breeding probability, phenology and success, and disruption of established pair-bonds through mortality and divorce. Our results demonstrate immediate and downstream effects of extreme weather on seabird demography, and highlight the implications of future increases in the frequency of extreme weather events on seabird populations.

Foraging ecology drives contamination by persistent organic pollutants and mercury in the wandering albatross

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Persistent organic pollutants and mercury (Hg) reach remote locations through long-range atmospheric transport and deposition. Top predators such as seabirds integrate significant quantities of biomagnifying pollutants *via* food intake. Several intrinsic and extrinsic factors may drive inter-individual variation in seabird contamination, but this has rarely been studied. Here we measured 10 organochlorine pesticides, 7 polychlorinated biphenyls and Hg in blood of 169 individuals of wandering albatross *Diomedea exulans* from the Crozet Islands, southern Indian Ocean. Thanks to an exceptional long-term dataset, the effect of individual traits (sex, age and breeding status) and feeding ecology (inferred from stable isotope ratios of carbon and nitrogen) on contamination was assessed. The albatrosses carried important loads of contaminants, with strong inter-individual differences. In several cases, contamination differed between sexes, which could result from sexual-specific physiological dynamics of contaminants. However, feeding ecology was the main factor explaining variation between individuals. In particular, feeding habitat had a strong effect on contaminant levels, with individuals feeding in warmer subtropical waters carrying higher loads of Hg, but lower loads of pesticides, than those feeding in colder subantarctic waters. In conclusion, this work stresses the critical role of individual foraging specialisation in shaping contaminant loads in the wandering albatross.

Consistency in the foraging niche of seabirds: possible causes and ecological implications

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Intra-specific variation in individual foraging strategies of seabirds can be large. The extent of such intra-specific relationships among seabirds within the same population was assessed in three different seabird species (Wandering albatross *Diomedea exulans*, Cory's shearwater *Calonectris diomedea* and Yellow-legged gull *Larus michahellis*) during the breeding season, from 2009 to 2012. Together with conventional dietary methods we use a combination of stable isotope and individual movement data to document the existence of individual consistency and examine its relative incidence and ecological implications.

Patterns of individual consistency were found in all studied species (although in different levels), highlighting individual feeding preferences of these species and potentially of related species. This study supports the hypothesis that individual variability within a seabirds' population may be regulated by intra-specific competition, geographic location and environmental characteristics. Inter-annual differences in the foraging behaviour of birds during the breeding season were associated with the availability of food resources around the colonies. Overall, our results suggest a high ecological heterogeneity among individuals within a colony in terms of foraging ecology. Therefore, the inter-individual variation in resources use may have a higher impact on ecological processes and population dynamics of several seabird species, from different marine environments.

Foraging plasticity of breeding black-legged kittiwakes (*Rissa tridactyla*) along a latitudinal gradient

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During the past decades, the population size of kittiwakes along the Norwegian coast has decreased dramatically and it is now listed as “endangered” on the Norwegian Red List. The decline is mainly related to reduced food availability caused by altered environmental conditions. Kittiwakes are medium-sized, surface-feeding seabirds. Being central place foragers, adults are limited to forage close to the colony to maintain chick feeding. The adults feed on highly patchy food resources, and plasticity in foraging behaviour and diet may be crucial in securing successful reproductive outcome.

In this study we used GPS-loggers to explore foraging behaviour of breeding kittiwakes during three successive breeding seasons at three colonies representing different oceanographic conditions in the central- and northern Norwegian Sea and the Barents Sea. Our aim was to identify foraging plasticity in relation to oceanographic conditions and food availability. The study demonstrated different responses in feeding behaviour between the colonies when the birds experienced a temporal change in food availability. Kittiwakes in the colony situated in the northern Norwegian sea switched diet and feeding sites within close proximity to the colony, whereas kittiwakes at the two other colonies adopted extremely long feeding trips and what appeared to be a bimodal foraging strategy.

The importance of demographic indicators for monitoring seabird populations

Aonghais Cook, Daria Dadam, Ian Mitchell, Viola Ross-Smith, Rob Robinson

With increasing anthropogenic pressures on biodiversity, effective indicators need to be specific and sensitive to pressures in the ecosystem concerned, simple enough to be interpreted by non-experts and straightforward enough to facilitate routine monitoring. Seabirds are under increasing pressure as a result of anthropogenic activities and environmental variation. Traditionally, indicators have been based on abundance at breeding colonies, but as many species delay sexual maturity these may fail to capture the ecological complexity of the system concerned.

We constructed two indicators of the state of nine species breeding along the UK coast of the North Sea: (i) Seabird abundance at breeding colonies, and (ii) Seabird breeding failure rates. These were significantly and strongly correlated with each other, but the abundance indicator typically lagged the breeding failure indicator by two to three years. We then considered a third indicator, comparing kittiwake breeding success to levels expected given environmental conditions. The abundance indicator also lagged this by three years, but indications were that changes may have been apparent earlier than when considering breeding failure.

Focussing on demographic parameters and correcting for underlying environmental conditions meant potentially-important population level changes could be detected at an earlier stage than by focussing on abundance alone.

The influence of oceanography on the foraging behaviour of the Northern Gannet *Morus bassanus* at the Wave Hub renewables site, North Cornwall

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Understanding how seabirds utilise their environment and interact with prey is essential for the effective protection and management of the marine environment. Research suggests that a number of oceanographic features, such as fronts (the boundaries between differing water masses), specific stratification levels and tidal currents influence the foraging distributions of seabirds through increasing either directly, or indirectly, the availability of their prey. However, over fine spatial and temporal scales, there exist only a small number of studies that have incorporated such detailed measurements of both seabird behaviour and *in-situ* oceanography, limiting our current understanding of such links.

This study aims to identify the oceanographic processes underlying gannet *Morus bassanus* foraging events around a seasonally occurring front at the Wave Hub renewables site off the North Cornwall coast. Data was collected via two seabird observers, an undulating CTD (conductivity, temperature, depth) and a hull mounted ADCP (acoustic Doppler current profiler) during at-sea surveys over two years; Aug 2012 and Aug 2013. This allowed for parameters of tidal current speed and direction, shear, thermal stratification, frontal index, and sub-surface chlorophyll production to be created. Results are presented from statistical analysis of relationships between these oceanographic parameters and foraging bird distributions. The implications of such findings are discussed with relevance to increasing anthropogenic activities within the area.

The Tystie and the Ice Sea: Black Guillemots respond to a melting Arctic Ocean

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Mandt's Black Guillemot (*Cepphus grylle mandtii*) is one of the few seabirds adapted to exploiting the fish and invertebrates of the cryopelagic ecosystem associated with arctic sea ice. A long-term study of Black Guillemots in northern Alaska found that from 1975 to 2002 parent guillemots relied almost exclusively on Arctic Cod (*Boreogadus saida*), the primary fish species associated with arctic sea ice, when provisioning nestlings. Since 2003, when the extent of summer ice retreat and sea surface temperature increased, a decrease in arctic cod availability has caused guillemots to rely on lower quality prey, such as sculpin and other nearshore demersals, with concurrent decreases in nestling quality and survival. In addition to the reduction of prey near the breeding colony, sea ice reduction has also decreased guillemot breeding success through facilitating the northward expansion of a nest competitor, the Horned Puffin (*Fratercula corniculata*), and forcing the southern displacement of a nest predator, the polar bear (*Ursus maritimus*). Overwinter survival of adult guillemots has not declined in the last four decades, indicating that decadal changes in the thickness and annual formation of ice have not affected prey availability during the nonbreeding period.

Dispersion, Route Fidelity and Within-Pair Coordination: the Mysterious Migration of the Atlantic Puffin

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Atlantic puffins *Fratercula arctica* are a key species of UK breeding seabirds, however their migratory movements have remained mysterious because traditional study methods have provided scant data. Using miniature archival light loggers, we have established a long-term tracking program of puffins on Skomer Island (Wales) to investigate their migratory behaviour. Here, we realise a detailed study of the migration routes of individuals for up to six years, focusing on route fidelity and timing. We also investigate potential sex-specific and pair-specific effects on the puffins' migratory strategy.

The first results are intriguing. Puffin migration is dispersive, with individual birds showing remarkable diversity in overwintering destinations. Yet, individuals are highly conserved in their routes and destinations. Furthermore, we found some evidence that partners follow similar routes, at least during part of the winter, suggesting potential social interactions within pairs during the non-breeding season. These results cannot be explained by genetic or cultural inheritance of the migratory route, the two usual theories about navigational control of migration. Our study should not only be a crucial test of a novel theory of migratory navigation but should also bring invaluable information for conservation planning, since UK puffin populations are in decline.

Age-related variation in reproductive traits in the wandering albatross

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Age-related variation in reproductive traits is widely recognised among iteroparous species, and has significant consequences for population and evolutionary dynamics. However, a number of difference processes may be responsible for age-related variation observed at the population level. Over an individual's lifetime, changes in competency and reproductive investment will both contribute to variation in reproductive performance. In addition, because quality effects and trade-offs are likely to result in associations between survival and average breeding success, changes in the phenotypic composition of the population among age classes may also contribute to age-related variation. We use a 30-year study of the wandering albatross, *Diomedea exulans*, breeding at Bird Island, South Georgia, to disentangle the processes underpinning age-related variation in reproduction. Whilst highlighting the importance of breeding experience, we reveal senescent declines in performance are followed by a striking increase in breeding success at the final breeding attempt.

How important are polynyas for the distribution of Arctic seabird colonies?

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Polynyas are limited areas of permanent or recurring open water in otherwise seasonally ice-covered marine waters. They can be created by tidal currents, upwellings, or persistent offshore winds. It has been suggested that proximity to these open-water areas may be important in determining the location of Arctic seabird colonies. I test this hypothesis by examining the distribution of polynyas and seabird colonies in the Eastern Canadian Arctic. Although the timing of break-up of winter ice-cover is undoubtedly important in determining the extent to which breeding seabirds penetrate the Canadian Arctic waters, there is little indication that polynyas themselves are important factors in the choice of colony locations for Northern Fulmars or Thick-billed Murres (Brünnich's Guillemots). They may play a role for Black-legged Kittiwakes.

Environmental conditions shape intra-brood variation in the impacts of parasitism on nestling shags

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Parasitic infection during early life has the potential to shape an organism's development, which can have life-long fitness consequences. However, individuals may not be affected equally by parasites. Within a brood, siblings often differ in their susceptibility to poor environmental conditions, and may similarly differ in how they are affected by parasitism. We investigated how parasitism and environmental conditions interact to affect the development of nestling European shags, *Phalacrocorax aristotelis*, a species with a pronounced brood hierarchy in which last-hatched chicks have higher mortality rates. We treated broods of three chicks with an anti-parasite drug across four years of variable breeding success and measured the effects on nestlings' growth rate and behaviour. The growth of last-hatched siblings was more heavily impacted by parasitism than that of older siblings, but this effect varied with prevailing environmental conditions, with a greater difference between siblings in less productive years. Treatment also affected competitive behaviour between siblings, suggesting that the consequences of parasitism could be modulated by intra-brood conflict dynamics. Overall, this study indicates that environmental conditions interact with parasitism to influence development in different ways for different individuals, with complex implications for population processes.

Understanding the impact of climatic change on the migration of the broad-billed prion (*Pachyptila vittata*)

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Migration is an adaptive strategy adopted by many seabirds in which individuals move between breeding and wintering areas that provide favourable, but seasonal, climatic and foraging conditions. Recent anthropogenic climatic change has resulted in widespread and rapid shifts in the distribution of many marine species, particularly those at lower trophic levels such as oceanic copepods. These shifts in the distribution of key resources may create problems for dependent predators, requiring changes in foraging behaviour or migration strategies. In this study, we examine the wintering behaviour of a migratory seabird, the broad-billed prion (*Pachyptila vittata*) tracked from a breeding colony on Rangatira, Chatham Islands, New Zealand. Combining the deployment of miniaturised light-loggers with stable carbon and nitrogen isotope analysis, we first characterise the environmental conditions experienced by tracked individuals during migration, before exploring how these areas may have changed through time. Finally, we compare contemporary distributions with historical information on bird movements inferred from isotopic analysis of feathers from museum specimens. Using this information we determine the extent to which these birds may adjust their migratory behaviour to match changes in the spatial distribution of their primary prey source.

Patterns and consequences of individual variation in wintering location in European shags

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In temperate partially migratory systems, individuals from single breeding populations experience a range of winter environments, potentially causing variation in individual life histories and creating demographic heterogeneity. The ultimate impact of this variation on population dynamics depends on individual consistency in location both within and among winters, and whether segregation between locations is random or structured among individuals. Furthermore, there can be carry-over or delayed effects on future reproductive success and survival, and therefore long-term population consequences.

We used large-scale field resightings of colour-ringed European shags (*Phalacrocorax aristotelis*) breeding on the Isle of May, Scotland, to identify temporal and spatial variation in individual location during winter, and associated effects. In total, 3797 resightings of 882 individuals were amassed over three winters, representing over 50% of the breeding population and spanning 622km of coastline, including the Isle of May. These data demonstrate substantial among-individual variation in winter location and high within-individual site fidelity both within and among winters. The population is therefore partially migratory, with structured segregation between locations in relation to factors such as sex and cohort. We quantify links between individual location and subsequent breeding success, and discuss the implications of the observed patterns and consequences for population dynamics.

Current reproductive collapse and diet of Icelandic Atlantic Puffins: A cyclic temperature dependent mechanism?

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Current Atlantic Puffin *Fratercula arctica* chick production and diet was studied in 12 colonies around Iceland in 2010-2013 and in Vestmannaeyjar archipelago since 2007, using IR-illuminated video probes and digital photography respectively. The results reflect Iceland's two oceanic regimes: the Atlantic seawater southern region (with 75% of the population); and the Arctic seawater northern region. Chick production was good in the north and sandeel *Ammodytes marinus* the main prey. In contrast, south has had poor reproduction and famine for 11 years terminating its immature population. Diet of breeders from both regions was examined in 2012 using stable isotope analysis (¹⁵N and ¹³C) from summer and winter tissues and nestlings. Preliminary results will be introduced as available. Puffin harvest in Vestmannaeyjar 1880-2010 shows a strong relation to sea temperature. The temperature pattern reflects the AMO (Atlantic Multidecadal Oscillation) cycle, with a ~3°C difference between the warm and cold periods in March. A critical sandeel size threshold (L_{th}) was calculated for Vestmannaeyjar 1880-2012 [1]. The threshold specifies the minimal body length required for survival (and baseline for reproductive energy investment) given the heat profile the sandeels experience during their first winter. An impressive inverse relationship between L_{th} and Puffin harvest is revealed suggesting that L_{th} might be a key mechanism of relating sandeel population changes to temperature changes.

1. Mikael van Deurs, Martin Hartvig, og John Fleng Steffensen. Critical threshold size for overwintering sandeels (*Ammodytes marinus*). *Marine Biology* **158**: 2755-2764 (2011)

Estimating force vectors produced by wings during flight and swimming in rhinoceros auklets

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Alcids propel themselves by flapping wings both in air and water, despite the different properties of the two media. To discover the regulation of wing propulsion, we measured the force vectors (sum of lift, gravity, thrust and drag) produced during flight and swimming. We attached data-loggers, incorporated a 3-axis gyroscope, a 3-axis accelerometer and depth sensor, on the back of four rhinoceros auklets, *Cerorhinca monocerata*. The data-loggers recorded 3-axis angular velocity and acceleration at 200 Hz, and depth at 1 Hz. We detected the periods of flight and swimming behavior from acceleration and depth data, and reconstructed the dynamic acceleration and gravity-based acceleration from both the acceleration and angular velocity data. Heave and surge dynamic acceleration were then combined to estimate the force vectors during flight and swimming at 200 Hz. We found clear cycles of force vectors in flight and swimming, force orientations concentrated vertically upward in flight, while downward in swimming. These findings suggest that accelerometers and gyroscopes can offer a valuable technique for investigating the biomechanics of free-ranging birds.

BirdLife's seabird data resources: where to find them and how they are used

Ben Lascelles, Maria Dias and Cleo Small

Over the past decade BirdLife International's Global Seabird Programme has helped compile and centralise a range of data relating to seabird distribution, abundance, threats and actions. This talk will outline the data sources available and highlight some of the ways in which they have been used. The talk will focus on 4 resources, highlight how to access them, request and/or contribute data and showcase some of the conservation outputs that have resulted from them.

The 4 resources to be covered are as follows

1. Marine e-atlas – contains details on over 3000 sites that qualify as Important Bird Areas (IBAs) due to the seabird populations they contain
2. Tracking Ocean Wanderers – the global seabird tracking database now houses data on over 65 species
3. Foraging factsheets – literature reviews and summaries of species ecology, foraging distances, habitat preferences and preferred prey items
4. Red List forums – the globally threatened bird forums are used to gather information related to species specific threats and actions that inform the IUCN Red List decisions and classification

Combining multiple tracking systems reveals at-sea behaviour and a pattern of annual variation in breeding season movements of a critically endangered seabird.

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Our understanding of the at-sea movements and behaviour of pelagic seabirds has increased dramatically in recent years. However, for many species, fundamental questions remain relating to when, how and why individuals move through the marine environment as they do. For the Balearic shearwater, a pelagic procellariiform currently facing threats both at breeding colonies and at sea, an improved understanding of the species' movement ecology is urgently required. To address this need for information, we have undertaken a comprehensive multi-year study based upon a range of biologging systems (GPS loggers, geolocators, time-depth recorders) and stable isotopes.

Initial results from 2010 to 2013 reveal three main foraging strategies employed by the species during the incubation phase, and highlight variation in foraging movements between years. Birds were found to exhibit strong diurnal patterns of behaviour, and to be highly efficient at orienting themselves towards their destination at distances of hundreds of kilometres.

We present fine-scale information on how this species partitions its behaviour in space and time, explore the orientation capabilities of the Balearic shearwater and discuss how the at-sea movements of the species relate to the wind field. In addition, we will briefly demonstrate how these new data are collectively being applied to conservation management of this critically endangered seabird.

Storm-petrels can smell, but what can they see?

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The long duration and long range of Procellariiform foraging trips indicate that finding food over the ocean is not an easy task. Data on seabird feeding ecology have accumulated over years, however little is known about the sensory aspects of foraging behaviour. Olfaction has been shown to play an important role in finding prey, but Procellariiform visual ecology gained little attention. We investigated how well Leach's storm-petrels (*Oceanodroma leucorhoa*) can see small objects and distinguish faint contrasts in different light levels. Feeding method and prey size suggest that storm-petrels do not need acute vision for seizing prey. Our behavioural experiments show that at light levels corresponding to late afternoon they have a spatial resolution of only ~ 1.5 cycles/degree, the lowest value reported for any avian species. Storm-petrels detected contrasts of $\sim 10\%$, similar to most other birds. However, anatomical data indicates that at higher light levels visual acuity might be better. At light levels corresponding to a starlit night storm-petrels had visual acuity of ~ 0.125 cycles/degree. Taken together, our results suggest that Leach's storm-petrels cannot rely solely on vision to recruit to foraging flocks, however their visual capabilities are sufficient for seizing prey at moon-lit nights.

Resolution of Navigational Conflict in King Penguin Chicks

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Conflicts may arise within a moving animal group if its members have different preferred destinations. Many theoretical models suggest that in maintaining group cohesion conflicting preferences can have an overwhelming influence on decision-making. However, empirical studies, especially on wild animals, remain limited. We introduce a new study system for investigating collective decision-making: king penguins. Their gregarious life style, the colony's organization into subgroups, and group travel make king penguins especially interesting for studying collective movements. Chicks spend their first year of life in groups with other chicks (crèches), and if displaced, will return to their crèche. We examined how different levels of navigational conflict affect such homing, by comparing the performance of pairs of chicks from the same crèche with pairs from different crèches. The majority of chicks in both treatments travelled at least part of the journey together; when doing so they were more efficient and faster than individuals travelling alone. Chicks took turns in leading and following. Chicks with a common destination (same-crèche pairs) were more precise at homing and less likely to split up than those with a conflict over preferred destinations (different-crèche pairs). Our data support some, but not all, predictions derived from theoretical models.

The effects of an extreme summer storm on seabird breeding success at a North Sea colony

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Many climate models predict an increase in the frequency of extreme weather events which may have a dramatic impact on seabird populations. We quantified the effects of a severe westerly summer storm on the breeding success of four cliff-nesting seabird species at a North Sea colony which occurred in late May 2011 during incubation. Razorbills were more severely affected than European shags, black-legged kittiwakes and common guillemots. Although a proportion of failed pairs relaid after the storm, success was much lower than pairs that survived the storm. Thus, relaying did not compensate for losses during the storm. We found that shag and kittiwake nests located on the exposed west side of the island were more significantly affected. We also found that pairs of guillemots, but not razorbills, at a greater height above sea level were less significantly affected. We estimated that breeding success in the absence of the storm would have been 11.2% 12.2%, 10.6% and 36.6% higher for European shags, black-legged kittiwakes, common guillemots and razorbills, respectively. Our results demonstrate the importance of extreme weather on seabird breeding success and highlight significant variation among species and among individuals within species in relation to species' ecology and nest site exposure.

Quantifying intra-population variation in migration strategies in a tropical, pelagic seabird

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Understanding the level of intra-population variation in over-winter migration routes and wintering grounds in seabirds is an essential component of their ecology and important for facilitating their conservation and the designation of protected areas. Here we present a novel analytical approach for quantifying intra-population variation in migration strategies, using the first tracking data on the overwinter migration of the tropical Round Island petrel. We used data recovered from 116 geolocators, deployed between November 2009 and November 2012 at the breeding colony (Round Island, Mauritius) and the package 'TripEstimation' in the software R to generate 136 overwinter migration tracks. During their overwinter migration Round island petrels ranged over most of the Indian Ocean north of 40°S, with the exception of the Mozambique Channel and the western section of the Somali basin. To quantify the amount of between-individual variation in migration tracks across six Indian Ocean regions, we used a bespoke, Bayesian mixtures analyses. Our analyses identified 21 unique mixtures, each containing between three & ten tracks, highlighting substantial intra-population variation in overwinter migration strategies with groups of petrels congregating in different regions of the Indian Ocean. This approach could be relevant to quantifying between-individual variation in non-migration tracking data.

Foraging distribution of two tropical seabird species with different population trajectories after invasive predator eradication

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Many seabirds are threatened by invasive predators, and eradication of invasive species generally leads to seabird population recovery. Where seabird populations do not recover following predator eradication, research into factors that may limit recovery is needed. In 2004, feral cats were eradicated from Ascension Island (South Atlantic). Masked Boobies (*Sula dactylatra*) rapidly recovered, but no population recovery of Ascension Frigatebirds (*Fregata aquila*) was apparent until 2012. We tracked both species using GPS loggers to investigate whether differences in foraging strategies may explain different population trajectories following eradication. We used a hidden markov model to identify behaviours during foraging trips, examined whether locations classified as 'foraging behaviour' overlapped between the two species, and which oceanographic and weather variables explained differences between foraging locations of the two species. Both species travelled long distances from the colony and employed restricted area search behaviour anywhere within a 300 km radius around the island. Masked Boobies appeared to forage in higher wind speeds than Ascension Frigatebirds, but we found no separation of foraging areas at sea. We speculate that Ascension Frigatebirds may travel farther from the colony to reduce competition with Masked Boobies, which may in turn affect their reproductive output.

UK-wide tracking shows dramatic variation in seabird foraging ranges

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Tracking foraging animals from their breeding site can reveal critical constraints on foraging. The distances over which seabirds forage are important because this information is regularly used to define the focal area for impact assessments of industrial developments. Despite the common use of foraging ranges, values for many seabird species are commonly estimated from indirect methods or based on studies in only one location. Miniaturisation and commercialisation of GPS technology has allowed seabird species to be accurately tracked in greater numbers. Here we provide foraging ranges from multi-site, multi-species seabird tracking in the UK. Using GPS tracking data from 875 birds at 20 colonies involving 5 species and across 3 years we found that maximum foraging ranges were up to three times greater than previously observed. Furthermore, foraging range varied by up to a factor of ten between colonies. Our results demonstrate that seabirds have different constraints depending on where they nest and that a single estimated value for foraging range per species may not be sufficient. We anticipate these results will advance assessments of the environmental impact of developments at sea and improve our understanding of seabird declines in UK colonies.

Comparative albatross demography; species-specific responses to changing climate and fishing pressure

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Capture-Mark-Recapture models are a great tool for disentangling relationships between the demographic characteristics of wild populations and their changing environment. The current prognosis for many populations of albatrosses is particularly alarming, given their extremely slow life-cycles, high levels of incidental mortality in marine fisheries. In addition, many albatrosses breed or feed in Polar Regions, where the rates of environmental changes are amongst the highest in the world. In this study, we analysed an extensive, long-term (>30 year) dataset on three species breeding at South Georgia, with contrasting life-histories: the wandering, grey-headed and black-browed albatrosses. We constructed a multi-event model that allows the investigation of time-dependent variation in key demographic rates and stages of the 3 populations. Climatic and fisheries covariates were collated for the foraging zones used during the breeding and non-breeding seasons by each species. We addressed 3 main questions: are the trends in survival, return, breeding, and success probabilities associated with climatic covariates? Is there an impact of effort in particular longline and trawl fisheries on survival and breeding success? Do the species differ in their responses to changes in fisheries and climate?

Senescence rates are strongly influenced by personalities in wandering albatross

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Longitudinal studies in the wild reveal the widespread presence of declines in fitness with age, or senescence. However, despite individual differences in the rate and onset of senescence, and evidence that individual differences in behaviour, or personalities, correlate with life history strategy, there has been no attempt to test whether personality explains variation in senescence. Here we examine how personality, measured as boldness in response to human approacher, correlates with differences in reproductive success and foraging behaviour across the life time of individual wandering albatross. We demonstrate strong sex-specific differences on the interaction between boldness and age on the reproductive success. We found that bold males showed a decreased decline in reproductive performance with age, demonstrating a slower rate of senescence, whereas no such effects were found in females. This is matched by evidence that older males make longer foraging trips, with bolder males gaining more mass per trip. We discuss these results in light of theoretical predictions which suggest that bolder birds should invest more heavily in current versus future reproduction. Together these results demonstrate personality mediated senescence for the first time in a wild animal, and suggests that foraging behaviour provides the mechanism under which such differences arise.

Foraging patterns of Leach's storm-petrels, *Oceanodroma leucorhoa*, during incubation

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Knowledge of foraging movements during the breeding season is key to understanding energetic stresses faced by seabirds. Using archival light loggers (geolocators) and stable isotope analysis, we compared foraging movements of Leach's storm-petrels (*Oceanodroma leucorhoa*) during their incubation periods in the 2012 and 2013 breeding seasons. Data were collected from two colonies, Bon Portage and Country Island, which are 380 km apart along the coast of Nova Scotia, Canada. Based on allometry for procellariiform mass, predicted foraging ranges for Leach's storm-petrels are 200 km; however, observed maximum distances from the colony were 3 to 5 times that: 613 ± 167 km for storm-petrels from Bon Portage Island, and $1,015 \pm 238$ km for storm-petrels from Country Island. Average distances travelled in a return trip were $1,303 \pm 351$ km and $2,287 \pm 603$ km for Bon Portage and Country Island, respectively. Within islands, there were no differences between years in cumulative distances travelled. Stable isotope analyses indicated that, during the breeding season, prey items from Country Island were from higher trophic levels and had higher energy content than those from Bon Portage Island, perhaps explaining the more distant and longer foraging trips for Country Island birds.

Intra- and inter-colony differences in winter foraging strategies in the northern fulmar

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As natural and anthropogenic changes in marine resources potentially influence foraging in many species, it is imperative we identify differences in key areas of usage between and within populations. We tracked 100 fulmars from two colonies (Scotland and Ireland) and assessed 300 individual fulmars with multi-elemental analyses from five North-east Atlantic colonies to investigate individual and colony differences in fulmar winter foraging. We assessed their potential influence on population dynamics, as measured by breeding success. Consistent individual differences in winter distribution existed within a North Sea colony, with more females than males utilizing the West Atlantic region, compared to local North Sea waters. Older individuals were more likely to remain within North Sea waters than travel further from the colony. In all colonies, a consistent sex difference in winter diet was noted. Irish fulmars had isotopic signatures potentially indicative of a stronger reliance on fishery discards than Scottish fulmars. Winter foraging strategy affected average reproductive success such that in the most successful pairs, males wintered closer to their breeding colony and females wintered outwith the North Sea. This study demonstrates that differential non-breeding foraging strategies exist in a wide-spread marine top predator and that these differences can influence reproductive success.

Kittiwakes on the cliff edge: identifying the driving force of a steeply declining arctic population.

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In rapid declining populations one need to identify which demographic traits are driving the populations in order to find the correct management plan. In general the population growth rates of long-lived species are most sensitive to changes in adult survival rate. However, this can prove inappropriate if ignoring the significance of the variability of less sensitive traits. In this study we analyzed data from long-term time-series (1990 to 2011) on the population growth rate of black-legged kittiwakes breeding on Hornøya, Northern Norway. Between 1990 and 1999, the population was rather stable, but since 2000 it declined steeply (7.3 % p.a). Adult survival was slightly lower during the late period compared to the early period (0.859 vs 0.878 respectively), whereas the breeding success was nearly halved during the period of decline (0.47 vs 0.86). Using a deterministic demographic approach, sensitivity analyses and a retrospective life table experiment (LTRE), we showed that poor breeding success was the most important driver of the population decline, accounting for 55% of the variation, while the variability in adult survival accounted for only 28%. Many kittiwake populations in Norway are in danger of extinction. We stress the importance of identifying causes of poor breeding success and discuss how future management plans can be targeted.

Dual-foraging strategy can also emerge during incubation: the case of Cory's Shearwaters (*Calonectris borealis*) in Canary Islands.

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In pelagic seabirds, food availability and distance of feeding grounds can modulate foraging decisions and ultimately influence reproductive success. In this regard, studies on foraging ecology have mainly been focused on the dual-foraging strategy. This strategy is essentially based on the need to feed the chicks frequently by performing several short foraging trips on relatively poor feeding grounds close to the breeding site but regularly intercalated with one long foraging trip to distant but productive areas to replenish body reserves of the parents. Here, we hypothesize that a facultative dual-foraging strategy can also emerge through changes in local resource availability, regardless of the chick needs. Combining tracking, behavioural and isotopic analyses, we compared foraging strategies during the incubation period of Cory's Shearwaters breeding in Canary Islands in 2011, 2012 and 2013. Over this period, we found a low, a high and intermediate proportion of short trips, respectively. Proportion of short versus long trips was related to the occurrence of a highly dynamic eddy near the colony. Since long foraging trips during incubation can jeopardize egg survival through mate desertion, we suggest facultative dual-foraging strategy during incubation can also emerge just as an adaptive response to face environmental stochasticity.

Diving and foraging behaviour of seabirds in a high-energy tidal stream: implications for encountering tidal-stream devices

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Diving seabirds may encounter and collide with tidal turbine installations while foraging underwater. Some may be killed or injured. Others may avoid the devices, or harness prey associated with them, with implications for their foraging efficiency. These consequences have the potential to impact on seabird populations. There is a legal requirement to assess these impacts through an Environmental Impact Assessment (EIA) and Habitats Regulations Appraisal (HRA).

For birds with foraging preferences within high-energy tidal streams (HETS) the devices may have important behavioural and ecological implications. Our knowledge base on this is very limited. Our study seeks to develop our understanding of seabird foraging and diving behaviour under different tidal conditions within a HETS. Focal observations were undertaken from vantage points along Bluemull Sound, Shetland. Diving birds observed included shags, gannet and auks, with data collected during the 2011 and 2012 breeding seasons. We present results on diving frequency under different tidal conditions, and determine if there is a correlation between dive frequency/direction and tidal speed at different depths. This study is identifying under which tidal conditions species may be more likely to encounter tidal turbines. This should lead to a more accurate assessment of the impacts of marine renewable developments.

Inter- and intra-year variation in foraging areas of breeding kittiwakes (*Rissa tridactyla*)

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While seabird conservation efforts have largely focused on protection from threats at the colony, attention is increasingly being given to implementing protection measures for foraging areas at sea. Although numerous studies have examined seabird foraging behaviour, information is lacking on variability in area utilisation within and among breeding seasons. GPS devices were attached to adult kittiwakes breeding at a North Sea colony during both incubation and chick-rearing in 2012 and during chick-rearing in 2011, to determine whether foraging areas remained consistent and to identify the oceanographic characteristics of areas used for foraging. The type and size of prey items consumed at different stages of the breeding cycle were also examined. During incubation, kittiwakes foraged substantially further from the colony and fed on larger sandeels than when feeding chicks, and there was significant inter-annual variation in foraging areas used during the chick-rearing period. Foraging areas were characterised by cooler sea surface temperatures and areas of high chlorophyll *a* concentration, although association with specific oceanographic features changed within the breeding season and between years. These results emphasise the importance of considering how foraging areas and reliance on specific oceanographic conditions change over time when seeking to identify important marine areas for seabirds.

Mesoscale fronts as foraging habitats: composite front mapping reveals oceanographic drivers of habitat use for a pelagic seabird

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Remotely-sensed oceanographic data are increasingly used to contextualise at-sea behaviours of vagile marine vertebrates. However, conventional sea-surface temperature (SST) and chlorophyll-a (Chl-a) imagery holds questionable value for defining foraging habitats of high-trophic level predators such as seabirds. A diverse array of marine vertebrates are known to associate with mesoscale (10s-100s kms) oceanographic fronts, physical discontinuities between water masses, along which bio-physical coupling can drive the formation of pelagic foraging hotspots. Front mapping via remote sensing is, therefore, a useful tool for identifying potentially important pelagic habitats.

Here, we use composite front mapping and high-resolution GPS tracking to determine the significance of mesoscale fronts as drivers of foraging habitat selection in northern gannets *Morus bassanus*. We tracked 66 chick-rearing gannets from Grassholm over two years, using first passage time (FPT) to identify area-restricted search (ARS). Thermal and chlorophyll-a fronts were mapped at two different temporal scales – (a) contemporaneous fronts and (b) seasonally persistent frontal zones. Using Generalised Additive Models with Generalised Estimating Equations (GEE-GAM), we found that gannets do not adjust their behaviour in response to contemporaneous fronts. However, ARS was more likely to occur within spatially predictable, persistent frontal zones, indicating an important learnt component to gannet foraging.

Homing behaviours of breeding shearwaters investigated via displacement experiments

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As in most seabirds, the streaked shearwater (*Calonectris leucomelas*) breeds on islands and makes repeated foraging trips to the sea during breeding seasons. During these foraging trips, they often travel hundreds of kilometers from their colonies and must navigate in an apparently featureless environment. In this study, we investigated their long-distance homing behaviours via displacement experiments. The experiments were carried out in 2011 and 2012, using birds breeding on an island in the northeast part of Japan. Fifteen chick-rearing birds were caught at the nest each year and translocated by ship to the open sea about 120 km away from the island. To record return paths, GPS data loggers were attached on their back. In 2011, each of three groups consisting of five birds was released from the same place at different times of day (midday, sunset, and night). In 2012, each group was released at three different areas (southeast, east, and northeast from the island). After release, fourteen and fifteen birds were recaptured at the island in 2011 and 2012, respectively. In our presentation, their homing strategies will be discussed with respect to temporal and spatial aspects by analyzing return paths and differences among groups.

Breeding phenology and foraging behaviour in Manx Shearwaters: patterns and relationships

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Late breeding normally occurs in years of poor resource availability in many populations of marine predators, but the proximate mechanisms underlying the individual variation in timing of breeding (phenology) within a given year is poorly understood. Here we combined the position (GPS) and activity (TDR) data in chick-rearing birds with their breeding parameters in both parents and chicks. Our study focused on a population of Manx Shearwaters, *Puffinus puffinus*, at Skomer Island, UK in 2013. The total duration of breeding varied considerably among individuals and was negatively linked with chick hatching date (e.g., earlier birds raise young slower). What are the mechanisms responsible for this negative relationship? Foraging trajectories and foraging trip time varied considerably, but we show the existence of a spatial segregation between long and short trips. Critically, we show that foraging intensity (number of dives) and efficiency (food load) is significantly higher in short-tripped birds. This suggests that shearwaters use a dual foraging to feed their young with a short trip and to maintain their body conditions with a long trip. In this presentation, we discuss a potential link between phenology and foraging in shearwaters.

Observing seabirds from “bird radars” onboard French tropical tuna purse seiners

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Because of the difficulty in observing seabirds at sea, understanding how they interact with their surroundings, in particular with other predators, is extremely challenging. Other predators are conspecifics or heterospecific and may involve humans. In some cases the seabirds-humans interactions induce changes in the food resources availability and eventual risks of mortality through bycatch or collisions with human-made structures.

Using data collected in the Indian Ocean by French tuna purse seiners equipped with radars specifically dedicated to observe seabirds, we present some methodological advances as well as some preliminary results specifically chosen to show the huge source of information that radar-technology can provide for the study of seabirds.

Results include estimates of seabird densities per area, relationships between seabirds, interactions with fishing vessels. We show at which distances all these interactions might happen, which gives some precious estimation about the biases induced by ship-based seabird observations.

We show how radar technology can help us understand the susceptibility of seabirds to some human activities at sea.

Considering that tuna purse seiners fish in all tropical oceans using bird radars, accessing to this data represents a unique opportunity for scientists to analyse large databases covering large spatio-temporal scales.

Are trip attributes auto-correlated and what does it tell us?

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While auto-correlation in animal trajectory data has been frequently investigated at the scale of individual fixes, hardly any results have been reported on correlations at coarser scales (e.g. relations between foraging trips versus nest bouts). We think that there may be interesting information relating to e.g. carry-over effects and animal memory at this scale as well. In this study we analyse trips by 44 lesser black-backed gulls during their entire breeding period. The individuals were tagged with GPS-sensors and during the research period their breeding stage was monitored. We concentrate on auto-correlation in trip duration, duration of visits to different habitats on land and sea per trip and travelled distance; as well as the relation to the duration of nest-bouts. We identify autoregressive moving-average models to describe the structure of these trip-attributes over time. There appears to be a consistent relation between duration of nest bouts and trip length, as well as an alteration between long and short trips whereby short-trips appear in clusters. The presented method is applicable to any sequential data set that can be segmented and we encourage others to apply it to learn about the coarse-scale relationships in their data.

Integrating behaviour with epidemiology: could the socio-spatial structuring of immature and breeding common guillemots influence the transmission of a tick-borne virus?

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Increased transmission of parasites and pathogens is thought to be a major cost of coloniality. However, infection risk can be modified by the behaviour of individuals within the colony. We are investigating how the social structure of a colonial seabird, the common guillemot (*Uria aalge*), may influence the transmission of a tick-borne virus.

Guillemots show well defined socio-spatial structuring. Adults breed on cliff ledges at high densities and show strong site fidelity, while immature prospecting birds typically congregate around the colony edges. Immatures also make repeated attempts to enter the breeding areas and this behaviour is a key part of the recruitment process. Our epidemiological model suggests that this movement of immatures has important consequences for virus transmission, because the rate of infection is higher in younger birds. To investigate this, spatial time budgets of immature guillemots were recorded in four sub-colonies on the Isle of May, to quantify the proportion of time spent within the breeding areas and hence in close proximity to breeding birds. Although this behaviour was rare, a sub-colony dependent effect was found. The implications of the immature birds' behaviour for tick-borne virus transmission will be discussed in the light of recent changes in environmental conditions.

Out of sight but not out of harm's way: human disturbance affects reproductive success and nestling growth of a cavity-nesting seabird, the European storm petrel

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The effects of human disturbance on diurnal surface-living animals have been widely investigated, but few authors have considered potential effects on animals occupying cavities or burrows. Procellariiform seabirds are among the most globally-threatened avian taxa and include many species that nest underground. Human disturbance is one of the main threats they face, yet breeding colonies attract increasing numbers of tourists. Despite remaining out of sight, we show that the cavity-nesting European storm petrel *Hydrobates pelagicus* is negatively affected by human disturbance associated with tourism. Nestling survival was significantly lower in areas exposed to high levels of visitor pressure. Furthermore, disturbed nestlings that survived to fledging displayed depressed growth rates. Plasticity in developmental pathways enabled nestlings to mitigate for poor growth conditions by prioritising energy allocation to structural components and extending the growth period. While this growth plasticity can be adaptive, there may also be long-term costs associated with this strategy. Despite the reduction in individual fitness, colony productivity was reduced by only 1.3% compared with that expected in the absence of visitors. This study presents good evidence that, even when humans do not pose a direct mortality risk, animals may perceive them as a predation risk and respond accordingly.

Movements and at-sea activity of Boyd's Shearwaters (*Puffinus boydi*) using geolocators and stable isotope analysis

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Tracking studies increasingly focus on small seabirds, but those breeding in tropical and subtropical regions are still little studied. Boyd's Shearwaters (*Puffinus boydi*), a Procellariiform seabird endemic to Cape Verde Islands (Macaronesia), are thought to disperse over the central Atlantic but ship sightings are scarce and unreliable. We used geolocation-immersion loggers to track 32 birds from 2007 to 2012. Salt-water immersion data provided information on at-sea activity. We also analyzed C and N stable isotopes in the 1st primary, 1st and 8th secondary and 6th rectrice feathers of tracked birds. After breeding, birds migrated 1,000 to 2,600 km to the west from April to June, remaining in the central Atlantic Ocean for 115 days on average until August to October. Prenuptial migration lasted for 7 days on average. Changes in stable isotope values suggest animals moult their 1st primary in different areas from both 1st and 8th secondary feathers. Birds spent a greater proportion of time resting on the water in the non-breeding than the breeding period. By using tracking devices and stable isotope analysis we could describe for the first time detailed changes in distribution and activity pattern of this small oceanic seabird over its entire annual life cycle.

POSTER ABSTRACTS

Seasonal separation of storm petrels in the South Atlantic

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Sympatric speciation can occur in storm petrels if breeding populations nesting on the same island shift their breeding phenology until they are temporally isolated. We investigated whether Madeiran Storm Petrels (*Oceanodroma castro*) nesting on a small predator-free island in the South Atlantic exhibit sufficient temporal and morphological separation to be potentially considered as separate species. We captured 1730 storm petrels on Egg Island (St Helena) during the cool (June) and hot (December) season in 2013. None of the 675 birds captured during the cool season were re-captured during the subsequent hot season. Hot season birds had marginally longer wings and shorter tarsi, and birds from both seasons had significantly longer bills than Madeiran Storm Petrels breeding in the Azores with which they are currently considered conspecific. We estimated population size as 4512 (95% CI: 3686 – 5595) individuals during the cool season, and 7145 (6085 - 8466) individuals during the hot season. Given the phenological and morphological separation of the two seasonal populations we consider it likely that the cool season population may qualify as a separate species new to science. This new species would be endemic and globally threatened due to a small population size and extent of occurrence.

Seabirds exhibit differential large-scale foraging responses to fishing vessels based on boat activity.

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The production of discards by commercial fisheries has been shown to have broad-scale impacts on seabird demography and behavior. However, understanding the factors underlying decisions to forage in association with fishing vessels remains elusive. We use high-resolution GPS tracks of Northern gannets *Morus bassanus* to determine behavioural states, and link this with Vessel Monitoring System data to investigate the scale at which fishing activity influences seabird behavior. Multi-state Markov modelling reveals that gannets are increasingly likely to change from commuting to foraging behavior within an 11km radius of fishing vessels. Importantly, our results demonstrate that these behavioral changes are not only a result of spatial proximity to vessels, but that such interactions vary with specific types of fishing activity. Individual birds are significantly more likely to move into foraging states around trawlers than non-trawlers, particularly when these vessels are potentially discarding. These results demonstrate that gannets can differentiate between vessels with respect to foraging opportunities, and even limited fishing activities can have large effects on the distribution and behavior of these wide-ranging marine predators.

Foraging ecology of terns in Brittany, France: predominance of sandeels and unexpected occurrence of the Atlantic saury as a regular prey

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The foraging ecology of three species of terns (sandwich, common and roseate) was studied during the breeding period in south-western Brittany, France, on one of the main French mixed tern colony (programme Skrapesk 'foraging terns' 2012-2014). Results mainly concerned sandwich and common terns as too few data were obtained for roseate terns. Specific boat surveys were conducted to localize the marine areas exploited by terns and type of prey, and feeding frequency of chicks was studied on the colony. The terns bringing back food were photographed in flight when they arrived at the colony and the preys were subsequently identified on the pictures. In both years, sandeels (at least three different species identified) represented the main prey for sandwich tern (about 85%) and common tern (about 50%), this latter having a more diversified diet. In June and July 2012, both sandwich and common terns also regularly fed on the Atlantic saury. It was unexpected because Atlantic saury has normally an offshore distribution associated with warm waters outside the foraging range of terns (about 15 km from the colony), and is effectively rarely caught by local fisheries specialized on pilchard. In 2013, Atlantic saury was absent (only one case recorded) and terns frequently fed on pilchard and mackerel.

17 years of monitoring of the largest French storm-petrel colonies: one efficient team, two hard-working hands, 2,000 burrows inspected annually, 16,500 birds ringed

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The largest French storm-petrel colonies are located in the Mol  ne archipelago, Iroise National Nature Reserve, western Brittany. The first census was carried out in the late 1960s, with about 270 apparently occupied sites (AOS) founded. A ringing programme was launched in the mid 1970s, mainly with mist-netting at night. Additionally, nest-sites were numbered and monitored in the 1980s. After a few years without any survey in the 1990s, annual intensive monitoring started in 1997. All potential nesting sites were carefully inspected at least twice during the breeding season, all accessible chicks were ringed and productivity was monitored in one colony. Moreover, since 2001, breeding adults were controlled on one colony in their nest-sites at the end of the incubation period. Three sessions of mist-netting were organized annually in June, July and August, each during three consecutive nights. The colonies were visited regularly from late March to late October to search for pellets regurgitated by gulls, herons or owls in order to evaluate the intensity of predation, and pellets containing remains of storm petrels were examined to search for possible rings. Number of AOS varied from 375 in 1997 to 845 in 2013. From 1997 to 2013, 16,471 birds were ringed: 12,563 adults and sub-adults mist-netted at night, 528 in nest-sites as well as 3,380 chicks. Over the same period more than 5,000 birds have been killed by predators.

The evolution of spatial dynamics in the expanding Mediterranean gull *Larus melanocephalus* – a flyway perspective

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Mediterranean gull *Larus melanocephalus* has a patchy distribution year-round. Individuals from different breeding populations congregate at traditional wintering sites and offer opportunities to study the species' migratory and wintering strategies. Here, I present info on its winter ecology (population composition, distribution, movements) at various spatial and temporal scales. A probabilistic model using capture-recapture data of first-year birds predicts the initial choice of wintering area in NE Spain as a function of distance. In subsequent years, birds return to the same wintering area, showing high life-long site fidelity (apparent local adult survival = 0.81). On a local scale, within wintering patches, birds move frequently and non-directionally, possibly exploiting multiple resources in wide areas (00s of km). Large night roosts are a significant feature of the winter gullscape and may play a role in shaping distribution. The demographic model also allows predicting the most probable migration route – a combination of large rivers and sea crossings, with one notable exception. *Larus melanocephalus* has expanded its breeding range W and S since the 1970s across much of Europe. By comparing the evolution of the distribution and movements of the breeding and wintering populations, I conclude that the two processes have occurred asynchronously.

Spatial foraging segregation by close neighbours in a wide-ranging seabird

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Little is known about dietary and spatial foraging difference between closely adjacent colonies, particularly for wide-ranging foraging species. The extent of spatial foraging segregation between two sub-colonies in a wide-ranging seabird, the Cory's shearwaters (*Calonectris diomedea*), separated by only 2 km, was assessed on Corvo Island, a small oceanic island in the North Atlantic. During the 2010 chick-rearing period a total of 43 breeding adults of both sexes were sampled at both sub-colonies. A GPS logger was deployed on each individual and birds from the two sub-colonies were tracked simultaneously. Results suggested that spatial segregation was apparent in daily (84.2%) but not in longer (i.e. ≥ 2 days; 15.8%) foraging trips. Birds from different sub-colonies have foraged at different locations, exploring areas with different oceanographic conditions during the daily trips. Interestingly, however, no differences were found in the exploited habitat between birds from both sub-colonies, suggesting that birds concentrated their feeding activity in small concentrated patches of similar habitat. We provide evidence that widely-ranging seabirds from two sub-colonies exhibited colony-specific foraging areas during short trips, most likely to reduce intra-specific competition.

Linking foraging theory and behavioural data: understanding foraging behaviour and the impact of tidal renewable devices

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While there is a rapid increase in energy generated from marine sources, the impact of tidal renewable devices on marine ecosystems and foraging behaviour of diving seabirds is not well known. There is currently a lack of data and general foraging theory that can inform the development of models able to provide predictive capabilities to assess likely impacts and future scenarios.

From a theoretical 2-dimensional model, we gained understanding of the potential differences in foraging efficiency of diving predators characterised by contrasting foraging strategies in complex landscapes. Animal movements, intervals between prey captures and foraging efficiency are likely to critically depend on species' foraging strategies, size and density of renewable devices and their effect on prey distribution. However, diving animals move and forage in complex and highly variable 3-dimensional environments. Our 3-dimensional model simulates predator and prey behaviour, starting from statistical parameters extracted from tracking devices as TDR, GPS, multibeam and multifrequency instruments allowing a clearer analyses of the mechanisms and consequences of movements and subsurface predator behaviour under different scenarios.

The development of this modelling tool represents a valuable starting point for exploring predator response to environmental changes and provides insights on possible future scenarios likely to occur.

Population-level differences in the distribution and habitat characteristics of non-breeding grey-headed albatrosses

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Advances in tracking methods have led to greater knowledge about the at-sea distributions of many seabirds, yet relatively few studies have compared the spatial usage of non-breeding birds from different populations. We tracked 66 grey-headed albatrosses *Thalassarche chrysostoma* with archival geolocator tags for a mean of 426 days from two major breeding colonies in different ocean basins; in the south-west Atlantic Ocean (Bird Island, South Georgia, n=41) and in the south-west Indian Ocean (Marion Island, Prince Edward Islands, n=25). The non-breeding distributions of birds from the two populations showed limited overlap; South Georgia birds foraged mainly within 1500km of the colony or around the Falklands, and to a lesser extent around Marion Island, whereas individuals from Marion Island foraged around their colony, to the east of the Kerguelen Plateau and to a lesser extent in the Drake Passage. Grey-headed albatrosses are biennial breeders and spatial segregation was much more pronounced during the non-breeding summer than the first or second winter away from the colonies, suggesting that non-breeding birds avoid waters near other grey-headed albatross colonies due to potential competition with breeding birds. Habitat preference was modelled to determine if differences in distribution between populations were the result of differing habitat preferences or due to other factors.

Identification of Kittiwake behaviour: a multi-sensor approach

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Modern animal-borne logger technology enables the identification of seabird behaviours, including while at sea when they are otherwise hard to observe. In particular the use of accelerometers has become increasingly common, however being able to attribute signals from accelerometry data to behaviours relies largely upon validated observations, which when identifying at sea behaviours may necessarily be impossible. We deployed accelerometers and salt water immersion loggers on kittiwakes at Puffin Island, North Wales. Remote cameras were also deployed at nests. Data collected from the salt water immersion loggers allowed us to determine when a bird was on the water surface and as a result increased the confidence in assigning signals from the accelerometry data to behaviour types. The cameras allowed us to validate terrestrial behaviours. As a result the following behaviours could be identified: resting at sea, resting at the colony, flight and foraging. Using data from more than one type of logger has effectively given us a qualified calibration of signals associated with behaviours in the accelerometry data, such that we are now able to assign behaviours to birds equipped solely with accelerometers. This approach has allowed us to construct time-activity budgets for study birds. Such information will ultimately be used to identify differences between individuals and how these differences may impact reproductive success.

Central-place foraging flights of lesser black-backed gulls under varying weather conditions

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Flight behaviour of birds is expected to be affected by weather conditions, especially wind conditions. Seabirds typically breed at high density, foraging over a wide surrounding area, i.e. central-place foraging. Here we analyse central-place foraging flights of lesser black-backed gull *Larus f. fuscus* on pelagic marine foraging trips in the Baltic Sea. Using high resolution GPS tracking we followed gulls throughout the breeding period. Foraging flights are analysed with respect to varying environmental conditions (e.g. wind). For example, during the inward flight of a marine foraging trip the gulls are expected to perform goal-orientated movement (i.e. they should return directly to the nest site). However, wind conditions will vary during foraging trips, such that on some flights they may experience cross-winds, in the absence of mechanisms to detect these, longer less direct flights would be performed. If the gulls are able to detect lateral movement resulting from wind-drift, they should perform more direct flights. Our dataset allow us to analyse flights for many individuals under a wide range of conditions. Depending on cues used to detect, and compensate for drift, the extent of wind-drift may also differ under different sky conditions (*inter alia* cloud and fog).

Foraging ranges habitat use at sea and food provisioning of Sandwich Terns studied by GPS-loggers in the SW-Netherlands

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Maasvlakte-2 is the newly build westward expansion in the North Sea of the port of Rotterdam with potential negative effects on birds in Natura 2000-SPA 'Voordelta'. Several compensation measures, like fisheries and recreation exclusion-zones, have been taken to compensate these effects. The presented work was part of a monitoring program aimed at birds, fish and benthic fauna to study their efficacy. Here we focus on the new findings regarding the foraging behaviour of Sandwich Terns with a breakthrough due to GPS-loggers usage.

Fieldwork was conducted between 2009 and 2013 in a Sandwich Tern colony in the Rhine-Meuse-Scheldt estuary. We used a combination of methods to study various parts of the breeding and feeding ecology. VHF-transmitters and GPS-loggers were used to study habitat use at sea, with in addition a surface-net to sample pelagic fish available to terns, enclosures to follow chick growth and breeding success, faeces samples of adults near the nest, and we did observations from a hide to study provisioning rates to the young.

We will give insights into the different results that were collected, and how these are interrelated. Novel findings include how we could link GPS-tracks to fish provisioning to chicks. New data on prospecting behaviour and connectivity between European Sandwich Tern colonies was an interesting 'bycatch'.

Severe wreck of European shag, *Phalacrocorax aristotelis*, in the north-east UK, 2012-2013.

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The sudden mortality of unusually high numbers of seabirds is observed periodically during winter in the North Sea. Such wrecks may be associated with prolonged adverse weather leading to unfavourable foraging conditions. Many climate models predict an increase in extreme weather events and hence wrecks may become increasing frequent in the future. Understanding their impacts on seabird populations is therefore vitally important.

Here, we focus on a wreck of European shags along the North-East coast of the UK during winter 2012-13. Over 650 corpses were recovered between Orkney and East Anglia, with peak concentrations found in Aberdeenshire and along the Firth of Forth coastline. Total counts included 243 individually-marked birds from the intensively studied south-east Scottish colonies. This wreck was more severe than two previous winter wrecks (1993-4 and 2004-5), affecting a larger proportion of the population.

Numbers of recovered birds were significantly correlated with strong onshore wind in the previous week, suggesting that sub-optimal foraging conditions may have led to mortality. Juveniles and males tended to be found earlier on in the wreck, suggesting high vulnerability to adverse weather. Our analyses demonstrate that winter wrecks can affect a significant proportion of a seabird population and affect population structure.

The influence of cetaceans on the distribution of Northern Gannets at sea

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Generalist marine predators rely on techniques to locate and access patchily distributed prey. Processes that increase prey availability are important particularly for foraging avian predators during reproduction. We studied habitat selection and foraging behavior of Northern Gannets (*Morus bassanus*) in the Gulf of St. Lawrence (Northwest Atlantic) during the breeding period with ship-based surveys. At least 15.8% of all Gannets observed (n=2,525 ind.) occurred in groups associated with natural feeding associations. These mostly comprised multi-species feeding associations and/or associations with marine mammals. Cetaceans and particularly dolphins were dominant producers in these associations. The influence of fishing vessels was negligible. The spatial association between Gannets and cetaceans was close and significant. 25% of Gannets occurred within 0.3km, 50% within 2.9km to the nearest cetacean. Cetacean abundance had the largest effect of all significant predictors when modeling Gannet abundance based on a Generalized Additive Model (GAM). These findings underline the role of local enhancement for foraging Gannets. The high abundance of foraging cetaceans which concentrate suitable prey in water depths exploitable by Gannets are likely a key mechanism. The latter might support the large numbers of breeding Gannets in the Gulf of St. Lawrence.

Long term variation in egg sizes of various seabirds breeding in the Faroe Islands

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In the last few decades, the health of seabird populations has been used as a proxy for monitoring the marine environment. Breeding performance has been one such factor of interest, as this has implications for the future of the population at hand. The size of eggs has been found to be a predictor of feeding condition during egg formation, so it may be a surprise that very few studies have evaluated egg size over a long-term period. Contemporary studies have found a long term decline in egg size and relate this to changes in diet. By combining contemporary and historical field data, and from measuring museum eggshell collections of Great Skua *Stercorarius skua*, Fulmar *Fulmarus glacialis* and Guillemot *Uria aalge*, our study explores the long-term variation of these seabird eggs, and relates this to changes in their populations. These three bird populations differ ecologically, and they have had very different fates over the past century. Fulmars are relatively recent colonisers to the Faroes (1839) and are now the most abundant breeding bird in the Faroes. Great Skua populations have increased dramatically since a near extinction through persecution at the beginning of the 20th Century. Guillemots, which have historically been an abundant population, have since the 1970's seen a steady decline. If the population trends are responses to foraging conditions the particular species encounters we predict that we find differential changes in egg size over time with egg size but that this variation in egg size is different for species that are in population decline (Guillemots) and those that are in stable or growing (Fulmar and Great Skua).

The breeding population size of the Atlantic Puffin in Iceland

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The first estimate of the total population of Atlantic Puffins *Fratercula arctica* breeding in Iceland is presented. Estimate was based on aerial photography, burrow density counts and Burrow Occupancy Rate (BOR) measured with IR video probes. Surface area of the colonies was measured from vertical low-level aerial photographs and corrected for slope. Most of the larger colonies were visited for field measurements but regional mean burrow density and BOR were used when local "ground truth" was unavailable. The population survey of this most abundant of Icelandic seabird species is currently being compiled.

Short-term effects of data loggers on behaviour and physiology of the black-legged kittiwake (*Rissa tridactyla*)

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New technology, such as loggers and transmitters, has the last three decades become an important part of the research on free-living animals. Loggers are very useful in seabird studies, as seabirds often travel considerable distances at sea where visual observation is difficult. The potential negative effects of devices on birds have received some attention, but few studies have investigated the physiological effects of instrument attachment.

In the present study, effects of GPS-loggers on black-legged kittiwakes were investigated by obtaining behavioural and physiological parameters of stress (nest attendance, plasma levels of the avian stress hormone corticosterone (CORT), relative leucocyte counts, body mass and reproductive success) during approx. two days of GPS-deployment. Equipped kittiwakes had elevated levels of CORT at recapture and extended the duration of feeding trips compared to controls. Kittiwakes in poor body condition attended nests less than controls, and this pattern was more evident among GPS-equipped birds.

The study underlines the need to take device effects into consideration when instrumenting seabirds. Potentially, effects may become more pronounced in birds with low body condition or in years where food is limited. Device effects should be considered for ethical and conservational reasons, but also in order to assure the quality of obtained data.

Survival in macaroni penguins and the relative importance of different drivers; individual traits, predation pressure and environmental variability

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Penguins have exhibited dramatic declines in population size, and many studies have linked this to bottom-up processes altering the abundance of prey species. The effects of individual traits have been considered to a lesser extent and top-down regulation through predation has been largely overlooked due to the difficulties in empirically measuring this at sea where it usually occurs. For 9 years (2003-2012), macaroni penguins (*Eudyptes chrysolophus*) were marked with subcutaneous electronic transponder-tags, and re-encountered using an automated gateway system fitted at the entrance to the colony. We used multi-state mark-recapture modelling to identify the different drivers influencing survival rates and a sensitivity analysis to assess their relative importance across different life stages. Survival rates were low and variable during the fledging year (mean=0.33), increasing to much higher levels from age 1 onwards (mean=0.89). We show that survival of macaroni penguins is driven by a combination of individual quality, top-down predation pressure and bottom-up environmental forces. The relative importance of these covariates was age-specific. Our results suggest that macaroni penguins will most likely be negatively impacted by an increase in the local population size of giant petrels, and, at least in the short-term, positively influenced by local warming.

Evidence of cryptic sexual size dimorphisms in the feeding apparatus of Brünnich's Guillemots (*Uria lomvia*)

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An active discussion in the seabird literature concerns sex-specific behaviour and the impact of foraging behaviour on the evolution of sexual size dimorphism (SSD). We studied the bill morphology of an apparently sexually monomorphic species, Brünnich's Guillemot (*Uria lomvia*), in which the sexes forage at different trophic levels. We measured 24 females and 23 males from Kippaku, Greenland, using standard morphological measurements and nine non-traditional bill measurements to evaluate possible SSD. A single observer collected all measurements following standardized protocols. We used linear mixed effect models with sex as a fixed effect predictor and individual ring number as a random effect for each measurement to determine significance. The sexes differed ($p < 0.05$) for all bill depth measurements. The nine non-traditional bill measurements gave a unique and detailed description of bill shape that is not available when only standard measurements are collected. With knowledge that sexes of *U. lomvia* forage at different trophic levels the foraging ecology of guillemots could be an influence on SSD in this species. Further research is suggested to determine the implications of bill morphology on guillemot behavioural ecology.

Towards cold water – foraging trips of the High Arctic alcid, the little auk *Alle alle*

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Knowledge of foraging ecology of seabirds is crucial to understand their roles in marine ecosystems. In this study, exact locations of foraging areas and foraging ranges of a small planktivorous alcid, the little auk *Alle alle* were determined using miniature GPS loggers. The study was performed in two main little auk aggregations on Spitsbergen with contrasting oceanographic conditions (Hornsund and Magdalenefjorden representing colder Arctic and warmer Atlantic environments, respectively). Studied little auks foraged in areas with low sea surface temperature (Arctic-type water, marginal ice zone, and frontal zones) with high abundance of the preferred zooplankton species. In colder environment, birds foraged significantly closer to the colony (up to 60 km) compared to up to 150 km in warmer environment. Inter-colony differences in distances covered by chick-rearing little auks did not affect their breeding success or chick body mass. However, chicks in colder environment achieved both peak body mass and fledging age earlier, suggesting faster chick growth and better food quality/quantity compared to warmer environment. The importance for breeding little auks of nearby cold water foraging grounds may make them sensitive to predicted climate change with serious negative consequences for body condition, future survival and breeding success.

Dynamic emergence of metapopulation patterns in seabirds

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Seabirds are important indicators of marine ecosystem health. A detailed understanding of seabird population dynamics is essential for their conservation and for decrypting early warning signals of changes in the marine environment. Although seabird colonies are increasingly recognized as metapopulation networks, we lack an in-depth understanding of the dynamics that establish and maintain these networks. Our work will address these knowledge gaps via an innovative approach that dovetails population- and individual-level processes using the iconic Northern gannet (*Morus bassanus*) as case study. Firstly, we will apply advanced habitat modelling to identify suitable colony locations based on environmental variables. Secondly, we will address colony dynamics at the population level by fitting a dynamic, state-space metapopulation model to a 100-year historical dataset of gannet colony censuses over their East Atlantic breeding range. Complementarily, we will address breeding colony selection at the individual-level by equipping immature gannets with GPS tracking devices. Using the fully-fitted metapopulation model, we will then forecast the effects of scenarios of local and global (e.g. climate) environmental change. These results will enhance our understanding of the long-term responses of important indicator species to anthropogenic environmental change and provide a broad scientific basis for the adaptive ecosystem management of seabirds.

Responses of chick-rearing common murre to food quantity and quality in the Baltic Sea

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Fisheries and climate have a strong influence on marine ecosystems, and changes in forage fish stocks may have significant impacts on top predator seabirds. In the Baltic Sea, a collapse of the cod stock allowed their main prey sprat to reach high numbers. Decreased sprat weight and condition followed, mainly due to intraspecific competition. Development of a sprat fishery, along with a potential cod stock recovery, have reduced sprat abundance somewhat, but weight and condition remain low. Baltic common murre feed their chicks almost exclusively with sprat, and we studied murre chick-rearing in relation to these changes. There was a positive relationship between fledging success and food quality (measured as sprat weight-at-age), but not with food quantity (sprat abundance). Feeding rates were strongly linked to chick age, but maintained between years and during the main part of the chick-rearing period. Average foraging trip duration showed a negative relationship with food quantity, suggesting that murre buffered moderate changes in food quantity with increased effort, similar to responses found in studies elsewhere. No patterns indicating responses to food quality were found when investigating the length of fish brought to chicks.

Census of total and breeding population of Scopoli's Shearwater (*Calonectris diomedea*) colony on Strofades islands (Ionian Sea, Greece)

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Strofades Islands (37° 15' N, 21° 00' E) host a significant Scopoli's Shearwater (*Calonectris diomedea*) colony, the largest in Greece. The total population on these two small islands (Stamfani and Arpyia), was estimated via coastal surveys by counting rafts which can comprise thousands of birds, 1-2 hours before dawn. Fieldwork involved three teams working simultaneously during the breeding seasons of 2009 and 2013. Total population size was estimated to be between 17,000 to 18,000 individuals whereas the population density on Stamfani and Arpyia were 3,068 inds and 2,723 inds per km of suitable nesting coastline respectively. The survey of the breeding population was based on assessing the Apparently Occupied Sites (AOS) in 30 square sampling units of 100 m² each. Stratified sampling was made in 2009 after two nesting habitats of different quality were identified. The total breeding population was estimated from the density of nests (average over the sample units) and the size of the suitable nesting habitat of the colony, and was found about 5,587 pairs (C.I. 95%: 3,518 – 7,649), 3,585 pairs of which (C.I. 95%: 2,256 – 4,909) were on Stamfani Isl. and 2,002 pairs (C.I. 95%: 1.262 – 2.740) on Arpyia Isl.

Identifying key behaviours and migratory carryover effects during the Manx shearwater breeding season using a machine learning approach.

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Gathering information about the breeding behaviour of seabird species often requires long periods of field work and disturbance to the animals. The introduction of bio-logging technology has enabled major advances in our understanding of seabird behaviour at sea. The focus of these studies is often on behaviour far away from the breeding colony, specifically long distance migration. Here we demonstrate that the light and salt immersion data gathered by long term geolocator deployment can also be used to identify different behaviours and key life history events during the breeding season.

Using a Gaussian mixture model we classify each day during the breeding season into different behaviours. This allows us to identify laying and hatching dates, which are then compared to different migratory strategies to look for carry over effects. This techniques was applied to 5 Manx shearwater colonies around the UK for a period of 5 years. We also uncover distinct breeding strategies in birds from different colonies.

Experience matters: a preliminary analysis on the relation between seabird niche and overlap with fisheries during the non breeding season.

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We evaluated individual experience, trophic niche and overlap with fisheries for the Cory's Shearwater, *Calonectris diomedea*, during the non-breeding season. We deployed Geolocators on 7 experienced and 7 inexperienced birds (based on the successful number of breeding attempts during 7 consecutive years) between 2011-2012 at Berlengas Islands, Portugal. Relation with fisheries was estimated through a spatially weighted regression between habitat use (using individual Kernel Densities) and fisheries intensity (using an interpolated raster from ICCAT catch databank). Each individual was classified as belonging to Group 1 or 2 (using high intensity fishing areas and using low and zero intensity fishing areas, respectively). Experienced birds were significantly more frequent on Group 1, whereas inexperienced birds belonged to Group 2. A Stable Isotope Analysis in R (SIAR) revealed that Group 1 had a significantly smaller trophic niche than Group 2. Our results suggest that there might be conflicts between Cory's Shearwaters and fisheries that deserve further studies. Are trophic niche and success of experienced birds a consequence of interaction with fisheries? Experienced birds may benefit their condition and subsequent breeding success by interacting with fisheries, but may reduce their survival rate because they are more exposed to incidental bycatch.

The sexual year-round spatial segregation on an Antarctic population of Southern Giant Petrel

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This study evaluates year-round sexual segregation of Southern Giant Petrels (SGP). We test for gender differences on habitat use and spatial distribution. A total of 30 geolocators were deployed (11 females and 19 males) to estimate Kernel Densities during incubation, chick-rearing and non-breeding Season from January 2011 to February 2012. We found that females are usually northerly displaced in relation to males, even when there was a great overlap during the chick-rearing, hence the probability of occurrence of females answered negatively to male density in all periods. Temperature explained the females' response to male during breeding season, but during non-breeding season, chlorophyll was most important, mainly because females moved north to high productive waters, while males used predominantly the ice-edge near 60°S. Our results confirm former hypothesis of north dislodgement in the Non-breeding season from SGPs from high latitudes. Also, we found clear differential use of habitats during the non-breeding season, and a clear effect of the habitat on the response of females to male, suggesting that there is a potential difference on the factors male and female are exposed during the non-breeding season regarding fisheries and climate changes that could ultimately be responsible for divergent selective pressures on sexes.

Foraging ranges of northern gannets in relation to proposed offshore wind farms

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In each of the three years 2010-2012, adult northern gannets *Morus bassanus* from Bempton Cliffs, on the northeast coast of England, were fitted with satellite tags (battery powered Platform Terminal Transmitters fitted to the central undertail feathers) to investigate their foraging trips during chick-rearing and early post-breeding periods. This was done primarily to establish whether there is overlap with potential development zones for offshore wind energy generation in the North Sea. The three seasons of study, 2010 - 2012, all good breeding seasons, showed considerable similarity in the sea areas used by adult gannets. Distance to colony was the over-riding factor influencing foraging range. Locations of tagged birds coincided with several wind farm proposal areas in the North Sea, the extent of overlap varying temporally. During migration especially, gannets may encounter multiple wind farms. Understanding the connectivity between breeding colonies and foraging areas at sea is an important component towards understanding the potential impacts of offshore wind farms on these pelagic seabirds, and for identifying important sea areas for possible designation as marine protected areas.

Migration routes and winter distribution of razorbills (*Alca torda*) breeding in Southwest Greenland

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The razorbill *Alca torda* is endemic to the North Atlantic; in the Nearctic it breeds from New England via the Labrador coast to western Greenland and is the least abundant auk in this area. Although the razorbill is reasonably well studied in Europe and Canada, hardly any information exists on overwintering areas of razorbills in Greenland. The little information that exists comes from ringing recoveries and suggests that part of the Greenlandic razorbill population overwinter off Newfoundland.

We used geolocators to identify the migration routes and wintering areas of adult razorbills breeding at Kitsissut Avalliit, South Greenland, from 2009-2011. As suggested by ringing recoveries, razorbills migrated to Newfoundland. However, for some birds this was only used as a stopover site before continuing along the eastern coast of the U.S. with one individual overwintering as far south as ~26°N. The individuals with the most southerly overwintering area slowly headed back toward the breeding colony at the end of March, whereas all other individuals left their overwintering areas in late April. All birds were back at the breeding colony in May. The migration pattern identified is interesting in view of the unprecedented appearance of numerous razorbills of Florida in December 2012.

Migration of an endangered seabird, Hutton's shearwater (*Puffinus huttoni*) with GLS tracking

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Puffinus huttoni is an endangered shearwater nesting only at a couple places on the Seaward Kaikoura Range in New Zealand's South Island. For many years we have been only able to outline what the rest of the year was like for this species thanks to individuals washed offshore and sightings and in Australia, yet the picture was scant. In order to clear it, 23 individual Hutton's shearwaters were tagged with light archival tags and saltwater immersion devices for a year in 2010 and 2011. The results show us which are the wintering grounds these birds use and the migratory routes they follow to get there. Besides, we will try to infer what their behaviour is like at the different places they inhabit over the year thanks to saltwater immersion data and also to identify their phenology and behavioural states in space and time. Our results should help shed some light on the biology of this species and by this help in its conservation.

The Mediterranean Storm Petrel *Hydrobates pelagicus melitensis* on Filfla

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Filfla is a small (6ha) offshore island, situated in the Central Mediterranean, 4.5 km southwest of Malta. Over 50% of the known population of the Mediterranean Storm Petrel *Hydrobates pelagicus melitensis* comes to breed in the boulder scree of this island. The population size of the Storm Petrel colony on Filfla was assessed via multiple nocturnal mist-netting sessions during the 2013 breeding season. Population estimates were achieved using capture-mark-recapture models.

In July 2012 and 2013 a total of 74 Storm Petrels nesting on Filfla were equipped with radio-tags. Birds were tracked by means of a small Cessna aircraft and a sailing yacht following different transect routes to determine which area the birds use at sea.

Predation by Yellow-legged Gulls *Larus michahellis* is supposed to be one of the major threats for adult Storm Petrels when they arrive at the colony at night. Yellow-legged Gulls' regurgitates were collected and analyzed for the presence of Storm Petrel remains.

The studies on the Mediterranean Storm Petrel are part of an EU-Life+ funded project to identify marine Important Bird Areas (IBA) for Maltese Seabirds.

Seabird displacement analysis for a UK offshore wind farm: Robin Rigg, Solway, Scotland

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Robin Rigg in the Solway Firth was the first commercial scale offshore wind farm in Scotland, operational from April 2010.

Ornithological monitoring was undertaken using boat-based surveys prior to, during and after construction. Analyses compared baseline, construction and post-construction monitoring (3 years) using Density Surface Modelling techniques incorporating novel statistical methods. These were used to compare the abundance and distribution of seabirds across the phases of development for a range of bird species: guillemot *Uria aalge*, razorbill *Alca torda*, gannet *Morus bassanus*, red-throated diver *Gavia stellata*, and cormorant *Phalacrocorax carbo*.

This approach to monitoring and analysis provided considerable improvements in certainty around potential impacts; this ultimately allowed the potential impacts to be understood in greater detail. The patterns of changes in abundance and distribution of these species in response to the wind farm leads to questions of whether the right questions are being asked during impact assessment for development applications.

Monitoring persistent organic pollutants (POPs) in Antarctic seabirds: infrared spectroscopy as a novel approach to assess adverse effects

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In an era of increasing anthropogenic pressure, even remote regions have become contaminated by highly toxic, persistent organic pollutants (POPs). In spite of the pressing need to properly evaluate their detrimental effects, there are few long-term monitoring datasets from wildlife, and toxicological studies have mainly been laboratory-based.

Recent studies have demonstrated the utility of attenuated total reflection Fourier-transform infrared (ATR-FTIR) spectroscopy as a novel approach capable of identifying alterations in lipids, secondary structure of proteins and DNA/RNA at environmental concentrations of polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) in human cells. In our study, ATR-FTIR spectroscopy was applied, for the first time, to blood samples from Antarctic seabirds, to test if levels of POPs were sufficient to induce molecular alterations in seabirds breeding at South Georgia. With this aim, we analyzed: i) levels of legacy and emerging POPs, i.e. PCBs and PBDEs, respectively, and ii) the ATR-FTIR spectra of blood samples covering a temporal interval of 10 years.

Preliminary ATR-FTIR data indicated both temporal and interspecific differences in structural alterations of lipids, secondary structure of proteins and DNA/RNA; the effect on DNA/RNA was particularly apparent in the species that fed at the highest trophic level, northern giant petrel. The results suggest that ATR-FTIR spectroscopy has exceptional potential as a highly effective, non-destructive approach for monitoring effects of contaminants in seabirds.

Using spatial variation in trends to investigate the effectiveness of alternative traits to identify the state of seabird populations

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Coastal marine environments contain some of the most diverse and productive habitats, yet, despite their importance, pressure on these habitats has increased markedly over the last several decades. As top predators, seabirds have the potential as monitors of the quality of shallow coastal habitats. Currently, data used to monitor the state of populations focuses on counts, which provide invaluable information; however, detecting significant changes in numbers can be difficult. Instead we aim to investigate the effectiveness of an alternative suite of easy to monitor traits to identify the state of seabird populations that may give a greater resolution than population counts. We exploit existing spatial variation in population trends across Northern Ireland and south-west Scotland to validate alternative monitoring tools. Using historic seabird data, spatial variation was identified in three seabird species associated with coastal habitats nationally and within the study area; herring gull *Larus argentatus*, lesser black-backed gull *L. fuscus* and European shag *Phalacrocorax aristotelis*. Exploiting this spatial variation, colonies which are known to have contrasting population trends can be compared to determine which traits help to provide an early warning that a population experiences adverse environmental conditions; enabling management and conservation actions to be considered more immediately.

Predicting movement decisions in seabirds based on GPS and saltwater immersion logger data.

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Animal movements result from decisions that are often constrained by memory and navigational ability of individuals. When investigating mechanisms that govern animal movements, it is important to consider the decision-making process in an ecological context. However, this is often difficult when only remotely collected data are available, which is often the case for wild animals. To investigate whether data from different types of loggers can remotely indicate foraging success and predict movement decisions, we simultaneously deployed GPS data loggers and saltwater immersion loggers on breeding Manx shearwaters (*Puffinus puffinus*). These birds are known to embark on long foraging trips and are particularly interesting for navigational studies. We predict that unsuccessful foraging time will be represented by periods of tortuous search behaviours identified from GPS tracks and non-foraging types of patterns from saltwater immersion data. Consequently, these unsuccessful foraging bouts would precede movement to other foraging locations rather than a return to the colony. Here, we present the analysis of data for approximately 50 individuals collected from Skomer Island in 2012 and 2013. Finding a good indicator of foraging success by merging information from different loggers could be used to investigate whether movement between prey-patches in an apparently featureless ocean is driven by cue-based orientation or memory and navigation.

Seasonal variations in seabird abundance and distribution in the Bay of Biscay and the English Channel

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The recent Marine Strategy Framework Directive encourages Member States of the European Union to achieve 'Good Environmental Status' of their waters; that is to protect and restore marine ecosystems and biodiversity. Fulfilling this objective demands an improved knowledge of marine species' distribution. In 2011/2012, we conducted two 3-months aerial surveys in the English Channel and in the Bay of Biscay to investigate spatio-temporal variations in seabird distribution. A total of 375,015 km² were surveyed, travelling a distance of 66,550 km on effort. Seabird observations added up to 17,620 in winter and 8,271 in spring/summer. Alcids, gannets, kittiwakes and large gulls were the most frequent among all the observed taxa, though considerable variations occurred in densities and abundance between both seasons. This study of an unprecedented scale intends to produce abundance and density estimates of seabird species in the areas and to improve our knowledge on their distribution. The English Channel and the Bay of Biscay are known to be of high importance for seabirds. Here, we confirm that the continental shelf and the slope are mainly exploited by seabirds along the year, although kittiwakes and procellarids visit oceanic waters of the Bay of Biscay.

Let's consider another neighbourhood: intense prospecting movements of failed breeders nesting among failed conspecifics

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Tracking prospecting movements of failed breeders is essential to understand dispersal mechanisms and predict individual and population responses to unfavourable environmental conditions. Yet, studies addressing this topic are scarce because of methodological and technological constraints. Here, we tracked with new GPS-UHF loggers the movements of failed black-legged kittiwake breeders nesting in a failed subcolony of Hornøya, Norway across chick-rearing. After one week of tracking, failed breeders abruptly deserted their nesting cliff and increased prospecting rates. Overall, 91 % of tracked failed birds performed intense prospecting visits to more successful cliffs within their nesting colony. Among them, 40% also visited neighbouring kittiwake colonies 40-50 km apart. Our results provides new elements on prospecting patterns at a fine spatial and temporal scale, and indicate that extensive and repetitive visits to alternative breeding areas could be the occasion for individuals to explore a new neighbourhood and potentially prepare dispersal to a new breeding site for the following year.

Common Scoters in relation to ecological covariates and disturbance by ships in the shallow coastal zone in the SW-Netherlands

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Maasvlakte-2 is the westward expansion in the North Sea of the port of Rotterdam with potential negative effects on birds in Natura 2000-SPA Voordelta. Several compensation measures, like fisheries and disturbance exclusion-zones, have been taken to compensate the loss of potential foraging grounds for scoters. The work presented here was carried out within the framework of a large monitoring program aimed at birds, fish, benthic fauna and impacts of human activities, which was put in place to study the efficacy of the compensation measures. Here, we focus on the ecology of Common Scoters and the potential influence of disturbance by ships on seaduck presence.

Fieldwork was carried out between 2009 and 2012. We used a combination of methods to study the occurrence and ecology of the scoters, including year-round aerial surveys to record numbers and distribution, reconstruction of diet based on shell remains in the stomachs of dead birds, scuba-diving sampling of benthos at places with foraging scoters, large scale benthos sampling, and radar and visual observations of nocturnal behaviour of the birds. Monitoring of shipping as source of disturbance was based on vessel tracking by the Automatic Identification System.

We will give an overview of the different aspects that determine seaduck presence in the Voordelta, and how these are interrelated. For this, we also present the results of an extensive statistical analysis, tackling the zero inflation and spatial correlation of the data using Bayesian statistical methods.

A review of marine bird diving behaviour for use in assessing underwater collision risk with tidal turbines.

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With up to 25% of Europe's tidal power occurring in seas around Scotland, there is a strong desire to harness this energy through tidal turbines. These underwater devices have the potential to impact diving birds, primarily through collision with turbine blades. There is a legal requirement to assess these impacts. Collision risk modeling has been used widely to quantify collision risk to volant birds with wind farms. Intuitively, the same approach can be taken when assessing risk of underwater turbines to diving birds. Such models require data on a bird's foraging and diving behaviour to calculate their likely exposure to a tidal turbine array while foraging underwater. Accordingly, we have reviewed studies from peer-reviewed literature that present estimates for 18 diving parameters for 22 species of marine birds that occur in UK waters (comprising divers, grebes, shearwaters, gannet, cormorants, seabirds and auks). The parameters included dive depth, duration and frequency, descent and ascent speeds and foraging trip duration and frequency. We present a summary of these values for use within underwater collision risk models. This work will provide a key resource to the consenting process as it can be used in the assessment of environmental impacts of marine renewable developments.

GPS-telemetry informs seabird collision risk with offshore wind turbines

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A number of offshore wind farms are now operating in UK territorial waters, with more and larger scale projects planned. Concerns have been raised about the environmental impact of such developments particularly on seabirds, including concerns about mortality caused by collisions with turbines. One of the main factors determining collision risk is the height at which birds fly. Until recently, data on seabird flight altitudes have been scant and largely based on estimates from boat-based surveys, which are restricted to daylight and good weather conditions. However, these shortcomings are being addressed through GPS tracking.

We used GPS tags to investigate flight heights of breeding Lesser Black-backed Gulls and Great Skuas. A Bayesian space-state approach showed that both species primarily flew below the turbine blade height. Flight altitudes were lower than those given in previous published accounts, with implications for the wind farm consent. Lesser Black-backed Gulls spent a smaller proportion of their time flying than Great Skuas, and also flew at higher altitudes. Lesser Black-backed Gulls (but not Great Skuas) flew significantly higher during the day than at night, suggesting the potential for increased collision risk due to poor visibility at night would be offset by low flight altitude.

Egg Volume of the Black Guillemot (*Cepphus grylle mandtii*) in Arctic Alaska is correlated with the Pacific Decadal Oscillation

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Increasing temperatures and decreasing ice extent are causing major physical changes in the Arctic Ocean. However, knowledge of the associated impacts on the marine ecosystem remains limited. Monitoring annual processes of seabirds provides a relatively inexpensive method for measuring those effects. Cooper Island, Alaska hosts a colony of Black Guillemots (*Cepphus grylle mandtii*) that has been monitored since 1975.

Our initial examination of annual variation in egg volume (1978-2012) found an increase in volume during the 1980s and early 1990s, with a decline during the first decade of the 21st Century. Preliminary analyses yielded significant correlations between egg volume and lay date, body mass and breeding experience of the female, and the Pacific Decadal Oscillation (PDO) with a one-year lag. Annual variation in seabird egg size reflects both female condition and pre-laying prey availability. The observed trend in guillemot egg volume may reflect changes in the population's age-structure, with egg size increasing in a maturing population and decreasing in an aging one, or changes in the prey availability during the pre-breeding period. Increases in PDO reflect increasing sea surface temperature in the North Pacific and the positive correlation with egg size may indicate increased availability of prey in warmer years.

Spatial scale and sample size in seabird studies: stories from the Caribbean

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Considerable efforts have been expended in recent years to designate marine Important Bird Areas, for the preservation of seabird populations themselves but also to feed into ecosystem-based marine planning processes. Data from seabird tracking studies have been essential in this process and in our previous work we showed the importance of assessing the size and composition of tracking samples when assessing habitat use by seabird populations. Here we report on an ongoing project which is using seabirds to inform Caribbean marine planning. We expand our previous time-in-area based approach and test predictions about the shape of the relationship between sample size and foraging area of brown boobies (*Sula leucogaster*). We also demonstrate the importance of spatial and temporal scale considerations when matching bird behaviour to marine planning processes. For example, whilst a smaller grid size may be most appropriate for assessing fine-scale habitat use, a large grid cell size may be more appropriate for marine spatial planning processes when only a small sample size is available. Incorporation of these considerations is essential for systems where data are sparse but management decisions have important implications.

Quantifying winter movements of sub-adult European shags: a multi colony approach

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In order to conserve long-lived seabird species it is important to know where individuals of different ages go at different times of year and hence quantify spatio-temporal variation in environments experienced. However, currently little is known about the winter movements of sub-adults, due to spatial and temporal constraints on observation. The ecological dynamics of the critical life-history stage between fledging and recruitment are consequently poorly understood.

Since 2009, 7643 European shags (*Phalacrocorax aristotelis*) across 12 colonies spanning the east coast UK have been ringed with uniquely engraved colour-rings, allowing individuals to be identified in the field. Targeted field surveys and volunteer observations during five winters have generated over ten thousand resightings of 3718 colour-ringed individuals at 78 locations along >1000km of coastline. These resightings show that some individual first and second winter shags move north or south after fledging, while others stay near their natal colony, and that individuals from different colonies occupy large and overlapping geographical ranges in winter. Future analyses will quantify to what extent individual sub-adult shags are philopatric to winter locations, thereby informing marine conservation planning.

Using GPS telemetry reveals the importance of within and between breeding season variation in assessing seabird-wind farm interactions

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The marine environment is increasingly pressured from human activities, such as offshore renewable energy developments. Offshore wind farms may pose direct risks to seabird populations (“connectivity”) at special protection areas (SPAs). However, changes in food availability can influence the habitat used by seabirds, and hence wind-farm interactions, both within a single breeding season and between years. Studies have seldom investigated connectivity over these wider time scales. We used GPS-telemetry to study the within- and between-season movements of great skua from Hoy and Foula SPAs (2010 and 2011), and lesser black-backed gulls from the Alde-Orde SPA (2010-2012). Great skuas foraged mainly in proposed Scottish renewable energy lease sites, spending increasingly more time offshore as the season progressed. Lesser black-backed gulls predominantly used a nearby proposed Round 3 wind farm zone, the use of which was highly ephemeral throughout the season; interaction was almost entirely between late June and early July, corresponding to the early chick-rearing period. Lesser black-backed gulls used offshore wind farm areas more in 2010 than other years. This study highlights the importance of tracking birds over longer time periods, without which environmental impact assessments may incorrectly estimate the magnitude of risks posed to protected seabird populations.

Extensive Arctic Tern chick mortality in W and NE Iceland: influence of dietary composition and provisioning rates

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Many seabirds populations across the North Atlantic have been subjected to declines and breeding failures often due to local or large scale reductions in food availability during breeding. Arctic Terns *Sterna paradisaea* in W Iceland experienced very low breeding success in 2008-2011, primarily driven by low chick fledging success as a consequence of low growth rates and starvation. In order to explore the factors contributing to these poor conditions for chick growth and survival, we quantify the types and size composition of prey delivered to chicks in colonies across the Snaefellsnes peninsula in W Iceland, and relate between-colony variation in prey delivery rates to chick growth and survival. However, as sandeels are only present in the waters of S and W Iceland, we also quantify prey composition, delivery rates, chick growth rates and survival in colonies in NE Iceland, in order to compare success rates in areas with differing prey communities and where anecdotal evidence suggested higher success rates. Prey composition and size varied greatly between the two regions and colonies. In W Iceland, higher delivery rates were associated with greater fledging success, but sandeels were delivered at low rates at all colonies. In NE Iceland, capelin replaced sandeels as the main marine prey, but delivery rates of capelin were either very low or inconsistent, and fledging success in NE Iceland was similarly low, in contrast to expectations. Constraints on the availability of food resources for chicks therefore seem to be driving the recent very low breeding success both in W and NE Iceland, and understanding the causes of changing food availability will be key to reversing these trends.

Great skua (*Stercorarius skua*) movements at sea in relation to marine renewable energy developments and fisheries activity

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In the UK we are witnessing the increasing development of the marine environment for renewable energy generation, and changes to fisheries policy and management. The effects of these developments on seabird populations are largely unknown. We used GPS technology to assess great skua overlap with existing and proposed marine renewable energy lease sites and fisheries activity in Scotland, with the aim of improving predictions of how this scarce endemic species may be affected by renewable energy developments and changes to fisheries management. We tracked 17 adult great skuas from 2 breeding colonies in Scotland for up to 3 months over one breeding season; providing information on over 2000 trips. The maximum distance covered in a single trip was over 2,000km and lasted over 11 days. Our results identify a generally low overlap with proposed and existing renewable energy sites; however, overlap with fisheries activity differed between the two breeding colonies. The results of this work can contribute to improving our predictions of how great skuas may be affected by changes to fisheries policy and management. They could also support marine spatial planning by informing the sensitive designation of sites for development and conservation, and informing requirements for compulsory environmental impact assessment.

Using concurrent predator, prey and oceanographic information to understand seabird foraging distributions at fine spatiotemporal scales

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Within high latitudes it is becoming increasingly apparent that seabird foraging distributions at the habitat scale (10-100km) are often relatively predictable. Favoured habitats are often characterised by persistent features such as fronts, tidal races and stratification: all of which consistently accumulate prey species in certain areas through physical forcing or enhanced primary production. However, seabird foraging distributions at the micro-habitat scale (<1km) within favoured habitats are less predictable. It seems likely that seabirds require very specific physical conditions to make prey species available, with interactions between wind, currents and bathymetry/topography often determining when and where foraging opportunities occur. However, the combination of physical conditions underlying foraging opportunities remains largely unknown. To identify the combination of physical conditions that promote preys availability, concurrent datasets detailing seabird distributions, physical conditions and prey behaviour at fine spatiotemporal scales are required. Here, we outline several projects that aim to understand what processes drive seabird foraging distributions at the micro-habitat scale within favoured habitats. A range of methods have been used to quantify physical processes and prey behaviour including behavioural observations, active acoustics and hydrodynamic modelling. Consequently these projects are truly multi-disciplinary, relying upon oceanographical and engineering expertise to help answer fundamental ecological questions.

Is time spent in area a reliable representation of seabird foraging hotspots?

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The ability to identify important at sea foraging hotspots for seabirds is crucial in marine planning and resource management. Frequently, time spent in a given area is calculated from positional data collected by bird-borne data loggers. This is used as a representation of the foraging area, under the assumption that a bird will spend longer in an area when foraging than when transiting. Here, we compare positional data with behaviour data, extracted from tri-axial accelerometers, and test this assumption by examining the relationship between time in area and foraging rate. Thirteen birds were caught from Les Etacs, Alderney in June 2013 and fitted with both GPS and acceleration data loggers. Data from the nine recaptured birds were used in the analysis. Each bird recorded between two and four trips and only complete return trips were included. We assigned behaviours (flying, floating or diving) based on unsupervised cluster analysis of acceleration signals, using ethographer in software IGOR Pro. This was then refined using logical arguments in R. Preliminary findings suggest strong correlations between time spent in area and seabird foraging rate. These findings support the theory that time spent in area is a reliable mechanism with which to gauge foraging hotspots if only positional data are available.

Using a multi-instrument seabed frame to record underwater interactions between diving seabirds, prey, hydrodynamics and turbine structures

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Rapid developments in biologging have contributed greatly towards our understanding of seabird diving strategies. However, time-depth recorders (TDR) are unable to collect large quantities of concurrent environmental information during foraging events. Therefore, how individuals may adapt their diving strategies towards variations in hydrodynamic conditions and prey behaviour remains largely unknown. Such knowledge could offer insights into how individuals successfully forage within dynamic marine habitats. Such knowledge could also offer valuable insights into whether seabirds are vulnerable to collisions with marine renewable energy installations (MREI). To improve our understanding of diving strategies and collision risks, studies must involve the simultaneous collection of dive profiles, prey behaviour and hydrodynamics during foraging events. Here we present the preliminary results from a multi-instrument seabed frame that uses active hydroacoustics to collect simultaneous information on seabird dives, prey behaviour and hydrodynamics in high energy coastal habitats containing MREI. Concurrent seabird dives, prey behaviour and fine-scale hydrodynamics were successfully collected during 10 weeks of deployments both alongside and away from turbine structures. As well as improving our knowledge of seabird diving strategies within high energy coastal habitats, these studies provide the empirical data needed to accurately assess the risk of collisions between seabirds and MREI.

Identifying important foraging areas of breeding tern *Sterna* species using a habitat modelling approach – a UK scale study

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The four larger tern *Sterna* species that breed in the UK (Arctic, Common, Sandwich and Roseate) are currently protected through a network of breeding colony Special Protection Areas (SPAs). We describe survey and analysis undertaken to identify their important foraging areas, informing the identification of marine SPAs to complement the existing colony-based network. Using the novel 'visual tracking' technique, three seasons (2009-2011) of data collection at selected colonies provided foraging location data from a total of 1275 tracks (Arctic n=185, Common n=407, Sandwich n=628, Roseate n=55) across 18 colonies. Generalised Linear Models (GLMs) were applied through bespoke development of the 'case-control' method, to establish the relationship between foraging locations and environmental variables related to prey availability and distribution. Predictive ability was best using relatively simple models with few covariates, and all but one contained distance to colony. Estimates of relative usage were generated for each species/colony; a total of 60 models across 32 SPA colonies. Addressing the challenges associated with geographic extrapolation of models for hotspot identification at data-poor colonies will be highlighted. This study is the first to undertake habitat modelling for all four tern species at a UK scale and provides an invaluable resource for their marine conservation.

Is there so big difference in primary reproductive investments between males and females in a small seabird (the little auk *Alle alle*)?

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The activity of birds at the mating stage may constitute an important part of parental investments and may influence subsequent parental performance. Detailed behavioral studies of mating performance are scarce, however. Here, we investigated mating behavior (copulations, aggressive interactions), time budgets and body condition estimates (body mass, hematological parameters) in the little auk *Alle alle* breeding in a large breeding colony in Hornsund (Spitsbergen). We found that little auks frequently engaged in copulations, including extra-pair copulations (EPCs). Most of the EPCs were unsuccessful, and that was due to female rejecting behaviour. Nevertheless, the males tried to protect their paternity by aggressively intervening when their mates became involved in EPCs. Compared to females, males also spent more time in the colony pursuing EPCs and guarding nest sites. In the same time, the females forage extensively due to the egg production. Despite the apparent sex differences in the time budget and frequency of aggressive interactions, body condition expressed with various variables was very similar in the two sexes. Our results indicate that initial reproductive investments, although expressed with different currencies, may represent comparable costs for males and females.

Seeing stormies in the dark: thermal imaging of European storm petrels

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The fundamental ecology of many seabird species remains difficult to study, especially if they are nocturnal and prone to human disturbance. Even the most skilled seabird ornithologist can do nothing if their study species simply flies away when a torch is turned on. Imaging technology has the potential to address this difficulty, and is becoming increasingly available in the field. Here I describe the use of a high-performance thermal imaging camera in the study of European storm petrels on Skokholm and Skomer Islands. The technique proved particularly useful to study storm petrels without noticeable disturbance, greatly facilitating the location of nesting sites and revealing behaviour at breeding colonies and even within nests – including what may be the first observation of courtship display in this species. Thermal imaging has the potential to reveal the unseen ecology of this species, and could potentially be developed as a census tool.

Influence of seabirds on local enrichment of the Arctic marine littoral zone

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Studies on the influence of seabirds on the Arctic marine littoral ecosystem usually focused on rather simple analyses of water nutrient content and different organisms' abundances. Isotopic analyses of primary producers and their consumers provide better understanding of the nutrient cycling in this ecosystem. The aim of the present study was to assess the influence of seabirds on local enrichment of the marine littoral zone around Spitsbergen. The samples were collected both from marine environment (algae, benthic invertebrates) and from the land (plants), at two localities: (1) below the colony of Brunnich's guillemots and kittiwakes, and (2) away from the seabirds' colony. Two hypotheses were tested: (i) nitrogen stable isotopes ratio ($\delta^{15}\text{N}$) of marine producer and consumer tissues is higher close to seabird colonies than beyond their impact due to nutrient concentration in the area and multiple nitrogen fractionations during passing through the food chain; (ii) since seabirds deposit guano primarily on land, and the ornithogenic nutrients are assimilated by terrestrial vegetation first and then run-off or/and leached to the sea, differences in organisms' $\delta^{15}\text{N}$ ratio between the seabird-influenced and control areas are less pronounced in marine than in terrestrial ecosystems.