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Population Biology

Predicting the distribution of *Lutra lutra* (Eurasian otter) on the Isle of Anglesey, Wales.

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Eurasian otters (*Lutra lutra*) remain a high priority conservation species despite recent increases in UK populations. Specifically, a marked increase in abundance (50%) was observed on the Isle of Anglesey (North Wales) between 2002 and 2009. Understanding the drivers that act upon the distribution of *L. lutra* will allow for more targeted conservation efforts. In this study, species distribution modelling (MaxEnt) was applied to predict the potential distribution of male and female *L. lutra* across Anglesey. Elevation, and distance to roads and water (m) were found to be the most influential factors in determining the distribution of individuals across all models. The generated models performed better than random and were capable of identifying areas where *L. lutra* could potentially occur across Anglesey (AUC = 0.818). Sex-specific analysis of proposed distribution of *L. lutra* was found to have strong positive correlation between the genders ($r = 0.71$) suggesting that habitat preference may not be gender specific. In further near distance analysis (shortest distance of *L. lutra* presence to feature), no differences were observed between transient males and more residential females ($p = 0.175$). Locations for concentrating future research efforts are suggested through analysis of intraspecific spatial variation, human disturbance effects and population analysis across the study region. This study provides a baseline of *L. lutra* habitation possibility across the Isle of Anglesey and exposes areas for future conservation in habitat management and research efforts.

Modelling disease spread in endangered cetaceans

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The emergence of novel diseases represents a major hurdle for the recovery of endangered populations of gregarious species. Predicting the potential severity of outbreaks is a necessary first step to inform disease management, for which social network models have become a valuable tool. In recent years, epizootics of infectious diseases such as cetacean morbillivirus (CeMV) have emerged as a major threat to cetacean populations, particularly group-living odontocetes. However, very little research has explored the potential consequences of novel pathogens in endangered cetacean populations. In this study, we utilize 5 years of fine-scale data on social contacts in the endangered southern resident killer whale population to inform a stochastic, individual-based model of disease spread to predict the severity of disease outbreaks. We find that this population is highly vulnerable to disease outbreaks, and that CeMV in particular is likely to result in large-scale epidemics. These results can be utilized to better inform population projections for this population to inform conservation efforts.

Drivers of unique social partitioning in a dolphin social network

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Cetaceans are known for their complex social structure. This structure may lead to behavioural diversity not only among populations, but also within a single population, with different subsets of a population exhibiting different types of behaviour. Understanding the mechanisms of these patterns is interesting biologically, but may also help conservation efforts, because not all segments of a population necessarily respond to, or interact with, human activities in the same way, or at the same time. Such differences may provide insight into the impacts of human activities on wildlife, but also into the evolution of novel behaviours, social learning, adaptation to perturbations in the environment and resilience to anthropogenic stressors. Here, we studied the social network of a resident bottlenose dolphin population over 16 years and found it highly structured into distinct social clusters of mixed sexes. Unexpectedly, the two largest social clusters overlapped spatially, but not temporally, as they used the same area at different times of day. Such diel temporal partitioning does not appear to have been documented in cetaceans previously. To understand this temporal and social partitioning, we further investigated several potential drivers of it, including differences in fisheries-related behaviour, diet based on stable isotopes, pollutant levels, and genetic factors. The two clusters differed in ways they interacted with fisheries, as one regularly interacted with trawlers, while the other did not, but this did not explain the temporal partitioning. Stable isotopes indicated differences in diet, in particular differences in trophic level. There were no differences in pollutant loads, with most dolphins exceeding toxicity thresholds, and evidence of maternal offloading of pollutants. Genetic analyses are currently pending. This study demonstrates how different segments of animal populations can behave differently, interact differently with human activities and in turn respond differently to anthropogenic impacts.

Cetacean, seal and sea turtle strandings in Greece: spatio-temporal distributions and correlations with environmental factors

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Stranding data analysis is proven to be an efficient, cost-effective, indirect method for cetacean, seal and turtle monitoring. The present work describes the spatial and temporal stranding patterns that occurred in Greece from 2008 to 2016, and investigates correlations between the patterns identified and environmental factors (sea surface temperature, sea surface height and sea surface current velocity). Amongst the 324 stranding events, 12 species were identified. The species were clustered into 4 groups, according to their body shape and drifting properties: small cetaceans, large cetaceans, turtles and seals. Time series analysis revealed that strandings were significantly more frequent during spring, and have doubled in number since 2008. This increase is partly due to an escalation in sampling effort, but could also be linked to a general increase in mortality rate, due to the expansion of threats for marine mammals and turtles in the Mediterranean Sea. Spatial analysis revealed 7 stranding hot spots in Greece, and each group of species presented distinct spatial patterns. Stranding occurrence was negatively correlated with sea surface height and negatively correlated with sea surface temperature. These results suggest that high waves and high temperatures are likely to accelerate carcass decomposition and increase the probability of carcasses to sink before reaching the shore. No significant correlation was found between stranding occurrence and sea surface current velocity. This work provides an understanding of the stranding process and the influence of environmental factors on carcass drift, and represents a promising step into creating an efficient stranding response network in Greece. Further studies are necessary to strengthen the understanding of correlations between stranding occurrence and environmental factors, with a particular focus on potential lags between the environmental factor series and the stranding series.

Marine Mammal and Human Interactions

Socio-economic models for marine conservation: the illegal wildlife trade in Caspian seal (*Pusa Caspica*) products

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The illegal wildlife trade (IWT) in products from marine ecosystems is a global threat to biodiversity and is steadily escalating. The population of Caspian seals have declined by 90% over a 100-year period, mainly, due to the historic over-exploitation. Even though the commercial hunting has stopped the population of Caspian seals is still not recovering. Conservation biologists are beginning to debate the scale of trade in products from seals and whether it contributes to the process of decline in the seal population. Here I show that a network modelling approach could be used to estimate the quantities of seals, blubber and pelts flowing through the IWT supply chain, and define its structure. I carried out 8 months of field observations in Dagestan (Russian Federation) over 2018, using questionnaire surveys to collect quantitative data on seal bycatch, seal product use and socioeconomic factors from fishers (n=26), middlemen (n=4) and traders (n=105). The survey results suggests the IWT chain structure consists of a maximum of 3 levels of actors for seal blubber and 4-5 for seal pelts. Using network analysis, I identified a “nodes” and “vectors” and type of social network for organizing for supply chain participants. Further data collection will allow estimates of product flows through the network, building on this initial definition of network structure. I anticipate that my study will feed into more sophisticated socio-economic model on studying demand for products from seals, impacting the size of seal population and human related motivations driving IWT supply chain for Caspian seals.

Assessment of anthropogenic disturbances due to ecotourism on a grey seal (*Halichoerus grypus*) colony in the Blasket Islands, SW Ireland

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Wildlife-oriented tourism has experienced a rapid growth in the last decades. While ecotourism aims to promote conservation, its actual impacts on wildlife and populations must be assessed, especially during critical stages of the life cycle. The grey seal (*Halichoerus grypus*) is a protected species in Ireland and therefore, its population is subject to monitoring programs. Consequences of anthropogenic disturbances due to ecotourism are being assessed on a grey seal colony over the breeding and mating seasons in the Blasket Islands, SW Ireland. Here, the tourist season overlaps with part of the pupping period, and consequently the most sensitive time in terms of potential disturbances. Disturbance might adversely affect the fitness of this species by reducing resting and nursing times, forcing them into the sea and leading to abandonment of offspring. Impacts of ecotourism due to presence of tourists and ferries are being evaluated by investigating changes in the behaviour of grey seals between undisturbed and disturbed conditions due to the approaching ferries and walking tourists. Differences in behaviour, proportion of seals entering the water and time spent looking after and feeding the pups are being assessed using focal and scan sampling of seals hauled out on the beach. Response distance of seals to approaching ferries is also taken into account. The results of this study identify whether conservation efforts need to be increased whereby restrictions or limitations should be enforced to reduce the effect of disturbance.

Whale Wise: assessing and mitigating the impact of whale watching encounters on whale populations in north Iceland

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Despite its potential to promote marine conservation, there is now substantial evidence that vessel-based whale watching encounters alter the activity budget of target cetaceans. However, the ramifications of these short-term responses for the long-term health and status of individuals and populations are largely unknown. This PhD aims to address these knowledge gaps, using several methods, in order to mitigate whale watching disturbance. Specifically, we hope to deduce the behavioural, bio-energetic and physiological impact of encounters on humpback whales (*Megaptera novaeangliae*) and blue whales (*Balaenoptera musculus*) in Skjálfandi Bay, Iceland. Behavioural disturbance will be assessed by comparing the activity pattern of individual whales in the presence and absence of whale watching vessels. Moreover, by including vessel number, type and movement pattern as explanatory variables for behavioural response, we will analyse the relative impact of different encounter types. Combined with data from the literature, we will then model the effect of this behavioural change on energy acquisition and expenditure. Furthermore, we will study the impact of encounters on physiological stress through 'blow sampling': unmanned aerial vehicles will be used to collect samples of a whale's exhaled breath before and after prolonged whale watching encounters. The concentration of cortisol (a stress-related hormone) will be measured in each sample in order to estimate the stress induced by vessel presence. In addition to this whale watching impact assessment, we will deduce the influence of future climate change on the distribution of target whale populations. Specifically, as part of iAtlantic- an EU-funded international collaboration- we will model the response of blue and humpback whale populations to projected future oceanographic changes in Icelandic waters. To conclude this PhD, I will incorporate both sets of results into an evidence-based conservation plan, for the existing and future industry, which aims to minimise disturbance whilst allowing profitable, high-quality encounters.

Habitat modelling of deep-diving species in Irish waters, through the use of static acoustic monitoring (SAM)

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A number of deep-diving cetacean species occur within the Irish EEZ and constitute an important part of the Irish marine mega-fauna. These species spend a considerable proportion of their lives underwater which represents a real challenge and little is known about their distribution or habitat preferences. These species include sperm whale (*Physeter macrocephalus*), long-finned pilot whale (*Globicephala melas*) and five species of beaked whales. They rely on sound to communicate, locate prey, avoid predators and sense their environment, which makes them particularly sensitive to a range of maritime human activities which generate noise including military sonar, shipping and seismic surveys. There is increasing pressure on Ireland's EEZ due to the potential for economic development of gas and oil exploration and marine renewable energies, which may pose potential threats to which deep-diving species are likely to be exposed. Understanding the effects of those pressures is essential and the use of acoustic methods to detect these species can provide unique insights into ecology and habitat preferences of deep-diving cetaceans to contribute to mitigation strategies. Based on static acoustic data collected by Woodside Plc in the Porcupine Sea Bight in 2014 and 2016, this project has four main objectives: (1) to provide size-classes estimates for the sperm whale population based on acoustic methods; to model the (2) spatial and (3) temporal distribution of all deep-diving species in relation to environmental covariates in order to create statistical models that could predict their habitat preferences; and (4) to explore the extent of anthropogenic sound sources (most particularly seismic surveys) and their effects on species distribution and habitat use.

Acoustics

Assessing harbour porpoise activity in a conservation Hotspot in North East Lewis, Scotland

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Under Natura 2000, the United Kingdom (UK) was required to designate Special Areas of Conservation (SACs) with harbour porpoise (*Phocoena phocoena*) recognised as the primary conservation feature. As of 2018 only one such SAC had been created. Yet it failed to encompass the UK's most densely populated area; the Minch in Western Scotland. It is necessary to understand which factors are driving fine scale habitat use and site-specific activity of harbour porpoise in order to understand how best to manage them. To address this, passive acoustic monitoring using C-POD data loggers was used to examine acoustic activity of porpoise along the east coast of the Isle of Lewis, Scotland at five study sites for a six-year period. The number of porpoise detections per minute (DPM/hr) and foraging buzzes were analysed at hourly resolutions as well as the ratio of time spent foraging. Detections for dolphin species within the area were also analysed for comparison. Harbour porpoise DPM and foraging buzzes were recorded at levels consistently higher than dolphin. Generalized Additive Models (GAMs) were applied to increase understanding of the covariates; month, year, time to sunset, time to closest highwater, highwater range, site and species presence. All had a significant effect on porpoise activity. Porpoise were present year-round with month being the most influential variable effecting DPM, whereas year was most influential for foraging buzzes. This study has increased understanding of porpoise activity in this area which is clearly ecologically important to the species. Here, support is provided for the designation of an SAC for the protection of harbour porpoise in western Scotland.

Using passive acoustic monitoring to investigate the occurrence of cetaceans in a protected marine area in Northwest Ireland

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In European waters harbour porpoise and bottlenose dolphins are listed as Annex II species requiring Special Areas of Conservation (SACs) for their conservation. However, identifying suitable candidate areas is limited by a poor understanding of the drivers of occurrence in an area including habitat associations. Ability to determine this is often limited by the relatively short time-series of data available to researchers. This study uses nine years of passive acoustic monitoring data paired with environmental covariates to better understand the spatio-temporal dynamics of protected cetacean species using generalised estimating equations-generalised linear models (GEE-GLMs). This extended time-series included periods of increased disturbance due to construction of an underwater gas pipeline in the area, enabling us to investigate the effect of construction on species occurrence. Harbour porpoise and dolphins occurred in every season, with detections peaking in winter, although there was a negative association between dolphins and porpoises. Interannual variation in occurrence was evident, with a cyclical bi-annual pattern highlighted for both species suggesting a more complex migration pattern may be occurring in the area. Construction activity had a significant negative effect on the presence of porpoise but not dolphins. However, no long-term displacement of porpoise was recorded. This study highlights the importance of understanding the drivers of cetacean occurrence as well as the temporal scale of disturbance effects for planning and management of construction activities in coastal areas.

Modelling the Habitat Preferences of Sperm Whales (*Physeter macrocephalus*) off the North-west Coast of Scotland

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The distribution and habitat preferences of solitary male sperm whales (*Physeter macrocephalus*) off the north-west coast of Scotland are poorly understood, despite this bachelor population being classified as 'Vulnerable' by the IUCN. Understanding the factors which drive distribution is critical in understanding the species ecology and has important conservation implications. Therefore, the habitat preferences of sperm whales were modelled in relation to several environmental variables to determine distribution and habitat preferences and define critical areas for sperm whales in the waters off the north-west coast of Scotland. This study used acoustic data collected on Extended Ellet Line (EEL) hydrographic survey in June 2016. Sperm whales make loud, near-continuous echolocation clicks, making passive acoustics the most reliable method of detecting animals. A Generalised Additive Model (GAM) was used to model sperm whale presences and Generalised Estimating Equations (GEEs) were used to account for autocorrelation, resulting from the large distances over which sperm whales can be heard. A range of bathymetric and oceanographic variables including: depth, slope, sea surface temperature (SST) and the distance to, strength and persistence of thermal fronts, were available for inclusion in the model. Results suggest that sperm whales off the north-west coast of Scotland are most likely to be encountered in depths between 1500-2500m and temperatures between 10-14°C; suggesting a preference for prey in a specific area (likely the Gulf Stream). This correlation between environmental conditions and sperm whale distribution suggests this area is an important, and permanent feeding ground. Important areas, which may be used extensively for foraging were also identified. By identifying the factors determining solitary male distribution in this area, this study represents an important first step in the implementation of conservation and management plans, which are required for sperm whales under Annex IV of the European Union Habitats Directive.

The use of Passive Acoustic Monitoring to localise sperm whales off the west coast of Scotland

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Whilst research is occurring worldwide on sperm whales, their fine-scale distribution in many regions is not very well understood. This is particularly evident off the west coast of Scotland, where despite the seemingly abundant presence of male sperm whales in this region, little research has focused on their distribution and abundance. As sperm whales vocalise near-constantly through echolocation clicks whilst diving (which is roughly 80% of the time), they are a prime candidate to track acoustically. Whilst acoustic surveys have been conducted to map the distribution of sperm whales in this region, research has currently not localised individual whales from acoustic recordings. Localising individuals would provide a greater understanding of the number of whales off the west coast of Scotland and their habitat use in that region on a fine scale. Acoustic data was collected during the July and October of 2003-2005 by a research vessel towing a two-element hydrophone array during hydrographic surveys off the west coast of Scotland. Sperm whales were detected using automatic detection software along with bearing to sounds. Using PAMGUARD, distances of sperm whales from the vessel will be estimated. By estimating distance to detection of sperm whales: (i) detection functions will be fitted to estimate the effective strip width; (ii) the number of sperm whales will be estimated. Following this, habitat modelling will be carried out to map the sperm whales' distribution throughout the region. Through the localisation of sperm whales, we hope to gain a better understanding of their abundance and habitat use off the west coast of Scotland. This is highly important in further understanding the species and could aid their future protection through policies and management, in this poorly surveyed region.

**The use of passive acoustics to detect the presence of individual bottlenose dolphins,
Tursiops truncatus, in a coastal population**

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Mark-recapture is commonly used for studying abundance, survival and movements of wild animals. For cetaceans, photographic mark-recapture is often used. Photographs must be obtained during daytime in good weather conditions and involve significant costs and human effort. As well, obtaining pictures is often invasive. Fixed hydrophones located in high-use areas offer a non-invasive alternative to capture individuals using acoustic labels – individually unique signature whistle types (SWTs). Here, we investigated the potential to use passive acoustic monitoring (PAM) to detect individual bottlenose dolphins and analysed the data within a mark-recapture framework. Data were collected from four moored hydrophones located in Walvis Bay, Namibia. To test the influence of recording location and duration, we analysed data from four sites, collected over 22 synchronised recording days; and 124 days of data from one high-use site. SWTs were identified from the recordings using a bout analysis approach (SIGID, Janik et al., 2013). Between-site comparisons revealed high variability in SWT capture, with between 0 and 13 SWTs detected at different sites over the same period. This could be partly attributed to different noise backgrounds affecting detection ranges and/or individual differences in habitat use – highlighting the importance of hydrophone placement. At the high-use site, 31 SWTs were captured over six months. Discovery curves indicate an initial increase in newly detected SWTs, approaching asymptote on day 105, after 15 encounters, in the fourth recording month. Repeat detections of individual SWTs ranged from 4 to 115. This study indicates the potential use of acoustic labels as proxies for individual occurrence which may be useful for investigating individual patterns in habitat range, social structure or generating density estimates through spatial capture-recapture. We also highlight potential sources of bias that may influence study design, which if understood, allow PAM to offer a powerful, cost effective, less invasive alternate to photo-identification.

Physiology and Genetics

Understanding oxygen management in grey seal blubber

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The ability to undergo dramatic changes in body mass and condition is vital for grey seal survival. Biomedical studies suggest that oxygen availability in fat tissue is affected by tissue expansion during obesity and is a potential health concern. However, whether and how blubber remains normoxic under radical adiposity changes is unknown. Grey seals have a similar fat percentage to obese humans; therefore, we hypothesise that oxygen availability in blubber will be affected by increasing tissue depths and adiposity. For the first time, we measured oxygen saturation (SpO₂) and partial pressure of oxygen (pO₂) on the dorsal flank's blubber of sedated and anaesthetised juvenile grey seals (n=12). Blood oxygen saturation, heart rate and breathing rate were monitored throughout sampling. Oxygen saturation and blood flow were recorded using non-invasive Near Infrared Spectroscopy (NIRS) to assess oxygen supply. Simultaneously, dissolved oxygen availability was measured in the same blubber region at different depths, with a non-consuming, temperature compensated optical oxygen probe (NX-LAS-8/OT/E, Oxford optronix). In four cases, two probes were inserted simultaneously 33±3 mm apart to examine inter-site variability. To investigate the influence of adiposity, we estimated fatness by photogrammetry and measured blubber depth using ultrasound. Furthermore, four animals were resampled after weight increases of 6 to 25 Kg. Preliminary results suggest substantial decreases in blood SpO₂ correspond with a lagged decrease in blubber pO₂. Large inter-individual differences have been recorded, however values are similar to those reported in human studies. Surprisingly, pO₂ varies irrespectively of blubber depth or adiposity. Further statistical analysis will better evaluate adiposity effects and vascularity. Our data suggest that blubber is well is not hypoxic, despite its large volume and radical changes in size. Further work on freely diving animals needs to be undertaken to explore changes in oxygenation and potential hypoxia during large changes in oxygen availability.

Stable isotopes in Antarctic fur seal whiskers reveal sexual segregation in foraging distribution

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Patterns in an individual's resource use can be determined by analysing stable isotopes in their tissues. Nitrogen isotope ratios ($\delta^{15}\text{N}$) are used as proxies for diet, while carbon isotope ratios ($\delta^{13}\text{C}$) indicate foraging distribution. Otariid (eared seal) whiskers are ideal tissues to study resource use, as they are composed of keratin (which is metabolically inert), do not shed during moulting, and are assumed to grow at a constant rate throughout life. We aimed to analyse $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in Antarctic fur seal whiskers to determine whether the sexes overlap in diet and foraging distribution. Whiskers were cut from 20 male and 20 female Antarctic fur seals at Bird Island, South Georgia. Samples were cut every 5mm along the length of each whisker, washed in a chloroform:methanol (2:1) solution, then ran through a Isotope-ratio mass spectrometer (IRMS). Synchronous oscillations in $\delta^{13}\text{C}$ values corresponded to annual migrations by both sexes. The $\delta^{15}\text{N}$ values did not differ between males and females, suggesting no sex difference in diet. However, $\delta^{13}\text{C}$ values differed substantially between the sexes, indicating pronounced sexual segregation in foraging distribution. Males had lower $\delta^{13}\text{C}$ values than females, representing a more southerly winter migration. The $\delta^{13}\text{C}$ values of females were divided into two main groups, including 1/3 of females that migrated north of the polar front. These northerly migrating females have a potentially large impact on the South Atlantic marine ecosystem, while male Antarctic fur seals likely compete with penguins and krill fisheries in the Antarctic. Studying stable isotopes in seal whiskers provides a useful tool to gain valuable insights into the cryptic lives of seals over a long time scale with implications for species conservation.

The evolution of cetacean cultural intelligence.

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Many cetaceans have large brains, complex sociality and exhibit complex behaviours. Fox et al. (2017) sought to confirm a co-evolutionary relationship between these factors. They published a large dataset of social, physical, and behavioural measures across cetaceans. This dataset has been extended using more comprehensive data on cultural variation, social organisation, and life-history parameters to establish how culture is distributed across cetaceans, and to understand the “building blocks” for the evolution of cetacean culture. In addition, the relationship between social structure, brain size, and behaviour was further explored. The results allowed for comparisons with primates and made clear that high cultural intelligence has evolved multiple times in both mammal groups. No simple link between social complexity and brain size was discovered, and it is suggested that cultural intelligence drives social complexity in social species rather than vice versa. The primary drivers for brain size and cultural intelligence were found to be a longer developmental period, longer lifespan, and more opportunities for social learning – in line with the predictions of the cultural intelligence hypothesis. These findings help shed light on the evolutionary foundations of human cumulative culture, as well as bridging distinctions between human and non-human capacities for social learning.

Population genetics of seals in Irish waters: a tool for management and conservation

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Abstract: Two pinniped species are inhabiting Irish waters: the harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*). Both species are protected by national and European laws. Information regarding the population genetic structure of Irish seals is limited, representing a major knowledge gap if they are to be effectively conserved. Currently, each species is considered as a single population nation-wide, though for the harbour seal at least, distribution and movement patterns (from tagging studies) indicate some level of sub-structuring within Irish waters. Thus, the present study sets out to investigate potential barriers to gene flow in both species using genetic data. Variation of the mitochondrial control region (d-loop) was investigated for harbour seals (n=38) and grey seals (n=54) obtained from around Ireland (sub-regions for analysis were set to SW, W, NW/NE, SE) and adjacent regions (UK and Germany). 10 harbour and 13 grey seals distinct genetic variants (haplotypes) were identified. Haplotype diversity (h) was high (>0.8) for both species. Genetic variance was highest within rather than among Irish sub-regions for both species. For grey seals, significant genetic differentiation was found between Irish and German samples, but no significant differentiation among Irish sub-regions for this species. In contrast, genetic sub-structuring was found for harbour seals between geographic regions within Ireland. The highest differentiation was observed between the north/northeast and the southwest ($F_{ST} = 0.65385$, $p = 0.018$). This indicates that management on the basis of a single population unit may be inappropriate for harbour seals within Irish waters. Findings of the present study will be corroborated with increased sample sizes and geographic coverage for both species. If the present results are confirmed, these findings will have essential implications for the conservation and management of pinniped species in Irish waters.

Behaviour and Movement

Offshore foraging and resting behaviour of harbour seals (*Phoca vitulina*) as revealed by high-resolution multi-sensor tags.

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An understanding of where and when animals feed and rest, as well as the relative importance of particular sites, is a key element in making predictions about the likely effects of disturbance. Harbour seals (*Phoca vitulina*) are known to travel offshore to find prey without returning to land for several days at a time. Current assumptions on their behaviour during these offshore trips are based on low resolution data which have not been reliably validated. Here high resolution, multi-sensor DTAGs were deployed on harbour seals in the Wadden and southern North Sea to facilitate more reliable inferences regarding behaviour and time/energy budgets during offshore foraging trips, as well as to uncover possible reasons that some individuals do not merely subsist on more readily available prey patches closer to the haul-out. Using a combination of movement sensors (accelerometer, magnetometer, pressure and GPS) we were able to recreate the 3-dimensional movements of each animal, to reveal when and where foraging and resting took place. We found that, contrary to current assumptions, harbour seals forage almost continually both during straight-line travel towards offshore sites and during the more tortuous offshore movements which have traditionally been associated with foraging. This could indicate the importance of continual feeding and therefore vulnerability to cumulative effects of brief disturbances. Diurnal patterns of rest and foraging varied between individuals, perhaps suggestive of individual prey specialisation, which would make it more efficient to rest when particular prey types are harder to access. Finally, preliminary results on the daily time spent resting during offshore trips increases by day, suggesting that an accumulating resting deficit may play a role in the decision to return to land were resting can be more effective. Given that harbour seals in this area already exist in a disturbed environment; these results suggest how we might go about evaluating the impact of additional sources of disturbance on offshore foraging animals.

Behavioural responses of seals to pile driving during offshore wind farm construction

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Offshore wind farm numbers will continue to grow over the coming years, with increased construction and operation of these devices in coastal environments. Environmental concerns for marine mammals come primarily from the intense sounds produced during pile driving, when the foundations of wind turbines are hammered into the seafloor. The habitat use of seals overlaps with many of the areas proposed for development, and so these animals face a number of risks including hearing damage from noise exposure, exclusion from their natural habitat, and potentially long-term impacts on fitness from behavioural changes in response to disturbance. Despite these potential risks, our understanding of how animals may respond to these activities is sparse, hindering future offshore developments and limiting our ability to mitigate possible impacts. Using data on the movement and dive behaviour of seals fitted with GPS-tags, this study aims to investigate the behavioural responses by individual seals to pile driving activity. Here, we present preliminary results from a study of 24 harbour seals (*Phoca vitulina*) at a wind farm in The Wash, south-east England. A Mahalanobis distance-based method was developed to quantify behaviour change over time and identify potential responses to noise disturbance. Predicted noise levels were estimated at each identified behavioural response, and a Bayesian hierarchical model was constructed to estimate the probability of animals responding to noise at different received levels.

The cultural transmission of humpback whale (*Megaptera novaeangliae*) song in the central and eastern South Pacific Ocean

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Some of the strongest evidence for nonhuman culture is found in the complex songs of humpback whales (*Megaptera novaeangliae*). Male humpback whales produce a vocal sexual display called 'song' during the breeding season. Song is a long, stereotyped acoustic signal with a hierarchical structure. All male humpback whales of each breeding population sing the same song at any given time. Each song changes gradually with all singers of the same population updating their song to maintain similarity across the population. While humpback whales can be found in all of the world's oceans, the transmission of song in the South Pacific Ocean is of particular interest to researchers due to the occurrence of song 'revolutions' in which a population discards a current song in favour of a new, and completely different song type. Song types have been found to radiate eastward across the South Pacific breeding areas, as individuals within an adjacent population repeatedly adopt the neighbouring population's song. It is not yet known how this song transmission is achieved. It is therefore important to study in detail how song is transmitted between breeding locations to understand the factors underpinning the phenomenon of song revolutions. This research may also aid understanding in the utility of song as an indicator of population structure, which could be useful in protecting the diversity of the endangered Oceania subpopulation. My PhD research will address two key areas: firstly, how the Cook Islands function in the transmission of song to neighbouring populations and secondly, how song is transmitted as we move further eastward, past French Polynesia, towards Ecuador. I will address these research gaps by analysing and comparing long term datasets of songs recorded in the Cook Islands, French Polynesia and Ecuador.

Marine top predator inter-specific interactions in a dynamic environment

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In my PhD I aim to investigate the inter-specific interactions of four marine top predator species and the role that oceanographic and hydrodynamic processes play in these interactions. I am interested in understanding how hydrodynamic features affect the way we study marine mammals, and how they influence the habitat use and foraging ecology of top predators. The first objective of this study is to use temperature data, collected by GPS tags deployed on over 60 seals, to describe hydrodynamic features, such as water column mixing and stratification. Characteristics of water masses affect sound propagation in water, hence we hypothesized that changes in the water column structure are affecting the detection ability of hydrophones and thus trends and patterns observed in the acoustic data. The second objective is to describe the distribution overlap, both in space and time, between two odontocetes and two pinniped species. Using a combination of datasets for each species, I will describe how these species are sharing their environment. Finally, I will combine the knowledge from the previous two objectives into two more focussed case studies aimed to address the role that hydrodynamic features play in inter-specific interactions and a comparison of foraging behaviours between two sympatric species. I will focus the first case study on a narrow deep channel, used both by bottlenose dolphins and harbour porpoises. I will use new hydrophone arrays, to track the animals in three dimensions, and hydrographic surveys to gather new knowledge on this poorly understood interaction and its association with hydrodynamic features. In the second case study I plan to use oceanographic data to improve our understanding of pinniped foraging ecology and compare the foraging behaviour of two sympatric seal species (harbour and grey seals) competing for resources. This multidisciplinary research will provide a new perspective and understanding of the dynamics between these sympatric marine top predator species and their environment.

Poster Abstracts

Investigating the effect of season and time of day on the behaviour and distribution of Irrawaddy dolphins (*Orcaella brevirostris*)

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This study aims to build on current behavioural and distribution knowledge of Cambodian Irrawaddy dolphins in the Gulf of Thailand, by conducting observational land and boat surveys. Behaviour was analysed using focal scan sampling at regular seasonal and daily intervals to understand the effect of season and time of day on the critical behaviours (feeding, breeding, resting and nursing) of Irrawaddy dolphins. Distribution was calculated by collecting coordinates of dolphins using a theodolite from land and GPS device from boat. Seasonal and daily distribution will be mapped using ArcGIS software; behaviour and season/time of day will be statistical tested for significant relationships using chi-squared tests. Findings will be used to evaluate and make suggestions regarding current regional conservation legislation in the Cambodian region of the Gulf of Thailand, with a specific focus on fishing and tourism activity.

The enigma of humpback whale song: getting to the bottom of complex male mating behaviours

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The songs of male humpback whales (*Megaptera novaeangliae*) are highly stereotyped and hierarchically structured. Although songs change progressively each year through cultural evolution, all males within a population conform to the same song type at any given point in time. Despite a plethora of studies, the underlying function(s) of song and its role within the species' mating system remains unclear, particularly as it shows a high level of both complexity and conformity. This project aims to improve our understanding of the function of humpback whale song by investigating the intra- and inter-sexual drivers of song in the light of male mating behaviours. Firstly, I will evaluate whether associations between individuals are determined by genetic relatedness or song via social network analysis using genetic information, photo-identification data and song recordings. Secondly, considering the possibility that song conveys information on male quality, I will assess whether certain song characteristics increase a male's reproductive success through female mate choice, based on parentage analysis. Finally, focusing on male behaviour (singing or participating in competitive groups), I will explore whether variability in male mating behaviours reflects different individual reproductive strategies and how this may affect reproductive success. To accomplish these aims, DNA profiles, comprising multi-locus microsatellite genotypes (15 loci) and genetically identified sex, will be constructed for samples collected in New Caledonia in the South Pacific. These data will be used to infer paternities and estimate relatedness for ~1,200 whales in this discrete wintering ground. I will analyse song recordings of ~35 genetically identified singers to investigate the potential correlation between male reproductive success and certain song characteristics, such as novelty, complexity and individuality in style and performance. This work will add to our comprehension of cetacean culture through improving our understanding of how cultural behaviour may affect fitness.

A study on cranial variation in Beluga whales (*Delphinapterus leucas*), Narwhals (*Monodon Monoceros*) and their hybrids

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Beluga whales (*D.leucas*) and narwhals (*M.monoceros*) are peculiar toothed whales belonging to the family Monodontidae. Having both a circumpolar arctic distribution, their geographical range overlaps producing hybrids offspring. In this study, we employed geometric morphometrics to explore morphological differences in Monodontidae skulls of 164 specimens (91 *M.monoceros*, 71 *D.leucas* and 2 hybrids) housed at Natural History Museum of Denmark, Natural History Museum of London, Mus   National d'Histoire Naturelle de Paris, and La Specola (Florence, Italy). We recorded 42 three-dimensional anatomical landmarks with Microscribe 2GX to capture main features of skull geometry and size. Generalised Procrustes analysis was employed to extract Procrustes shape coordinates that were subsequently analysed via Principal Component Analysis (PCA). The PCA showed clear distinctions in 3D skull shape between narwhals (characterised by relatively short rostrum and wide zygoma) and Beluga whales (more elongated and narrower skull). Skull size also differed between the two species with the narwhals being significantly larger. Both hybrid specimens occupied intermediate regions of the morphological space even if in one case (NHMD-1353) 3D geometry and size approached more closely the beluga than in the other (NHMD 44.1.4.1963) that resembled narwhal type. This demonstrated that although hybrids could be discriminated from narwhals and beluga they will still retain dominant phenotypic traits of one species or the other, potentially due to different cross breeds of male and female.

Evolutionary Genomics of Lactation Strategies in Pinnipeds

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A key challenge in evolutionary genomics is to understand the genetic basis of adaptation and evolutionary novelty. Pinnipeds are a single group of semi-aquatic marine mammals that include Sea lions, Fur seals, Seals and Walrus. During their re-colonisation of the sea Pinnipeds have evolved radically different changes in morphology and physiology, showing surprising diversity in traits that occur within and between groups, with lactation strategy being one example. These differences are linked with the exploitation of varied ecological niches by different species. I will take a comparative genomic approach to identify genes showing that have been selected for during pinniped evolution. With recent advances in genome sequencing technologies, the analysis of whole genomes from non-model organisms has become an affordable research area. I will sequence the genome of at least one species of seal and, in combination with many other species of Pinnipeds and mammals that have already been sequenced, will identify regions of the genomes that have patterns consistent with positive selection across lineages. This will look to reveal a number of candidate genomic elements, when combined with investigations of life history traits and niche use, could explain the extreme phenotypic diversity observed in modern day species of Pinniped.

Grey seal (*Halichoerus grypus*) pup dispersal in Wales: Spatio-temporal overlap with a tidal stream turbine

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Dispersal plays a fundamental role in population dynamics and gene flow. Natal dispersal typically covers vast areas and has large impacts on individual fitness and population structure. Despite their biological importance, little is known of the early movements of juveniles, which can represent up to half of the total population in long-lived species. This lack of knowledge is particularly pertinent to marine predators, such as grey seals (*Halichoerus grypus*), that move alone, with no information from their parents. Such information is key for understanding and predicting the responses of animals to climate change or anthropogenic activities. We present data from a historical mark-recapture record of grey seal pups in Wales. These records, spanning 1954-1971, document the early movements of 256 individuals from over 1300 originally marked. Movements are recorded for up to a year following weaning offering a novel understanding of natal dispersal. The squared displacement modelling method is used to quantify movement types and relate these to biological and demographic covariates; including sex, colony and environmental conditions. Results show that individuals cover huge ranges during their first few months at sea; travelling as far as Northern Ireland, France and Spain. There is large inter-individual variation and differences in strategies of pups from different colonies. By combining model predictions of dispersal with recent pup count data from three Welsh colonies, we derive the time window of spatio-temporal overlap risk with marine renewables. Our results can inform marine renewable energy industries to devise strategies to minimise risk for marine spatial planning.