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ABSTRACT BOOKLET

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ACOUSTICS

Getting below the surface: density estimation methods for deep diving animals using slow autonomous underwater vehicles

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Underwater gliders can provide an alternative cost-effective platform for passive acoustic monitoring surveys, compared to boat surveys, for abundance estimation and to collect high resolution environmental data for habitat studies. Gliders are usually equipped with one acoustic sensor, which limits the methods available for abundance estimation from acoustic data. Estimation of parameters used in distance sampling methodology, such as the detection function and cue rates, must be estimated separately from the glider deployment. A methodology for deriving the acoustic detection function of vocal animals is demonstrated with a combined biologging and passive acoustic experiment. The methodology consists of distance estimation of the clicks produced by the tagged animal and detected at acoustic receivers placed at different depths, using surface bounce detections to estimate range. In addition, different detection algorithms were tested for the detectability of Blainville's beaked whales. Detectability was found to vary with depth for Blainville's beaked whales in the area of El Hierro (Canary Islands). The depth dependent detectability for this species was tested further with a wider dataset from two different geographic populations of Blainville's beaked whales, those of El Hierro and the Bahamas. Differences in detectability were found using depth and animal movement data as recorded on the DTAG in a simulated network of receivers placed at different depths. In addition, sequences of clicks, called click scans, were tested as an additional "cue" for cue counting methodology. The high directionality of beaked whale regular clicks leads to reduced detection ranges for receivers close to the surface or for receivers placed much deeper than the foraging depths of the whales and this reduction translates into varying lengths and numbers of detected click clusters as a function of distance and receiver depth. A method for estimating density of animals from underwater gliders is presented in a simulated glider survey using different distribution and density scenarios using clicks and click scans as cue for density estimation.

Where's the air? A novel way to find out how wild echolocating whales manage air for sound production in deep dives

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Whales use air to produce sound underwater presenting challenges for species that echolocate for food in deep dives; air volumes reduce with depth following Boyle's law with only 1% of the surface volume available at 1000 m. How whales manage this supply to produce clicks throughout long dives remains an open question. Clicks are produced pneumatically as air is passed from the nasal passage to the vestibular sacs via the phonic lips. Here we show that resonances of these air sacs when excited by clicks can be detected in on-animal sound recordings. We hypothesized that resonant frequency should be inversely related to the air sac volume which will change with ambient pressure and click-by- click air movement. To test this, we applied a model for the resonant frequencies of fish swim bladders to predict air sac volume in 33 short-finned pilot whales *Globicephala macrorhynchus* tagged with DTags. We found that (i) the vestibular air sacs increased in volume during a click train with each click adding roughly 50 μL of air, and (ii) vestibular air sac volume decreased by a factor of more than 10 during occasional short (1-2 s) pauses in clicking indicating that air is recycled back into the lower nasal passages. Thus, pilot whales must pause to recycle air every few hundred clicks, but the timing of this can be chosen to minimize the impact of these silent periods on biosonar-based foraging. Air volume is also related to click amplitude and so air usage can be reduced by decreasing the intensity of clicks and therefore the detection distance of prey. Although air sac resonances are particularly apparent in pilot whales, similar patterns in other tagged toothed whales suggest that this mechanism of gradual air movement during clicking and recycling during pauses is a central driver of echolocation behaviour.

Sperm whale localisation using passive acoustic monitoring

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In many parts of the world, shipping traffic is thought to increase in the near future. In the Northwest Providence Channel in the Bahamas, this is likely to be the case as a result of four-fold global increase in commercial shipping, the expansion of a container port in Freeport and the proposed construction of an oil refinery. However, this particular site has been shown to play an important part in the life-cycle of several sperm whale individual, whose site-fidelity has been confirmed through photo-identification. Potentially, the increase in shipping traffic could have adverse effects on the local population.

Two SoundTrap sound arrays placed on either side of the channel will be recording at ten-minute intervals over the course from mid-November to mid-April. The acoustic sound file will then be processed using PAMGUARD. The aim of this project is to use different localisation techniques using passive acoustic monitoring in the Northwest Providence Channel to determine sperm whale presence and use of the Channel, with a descriptive spatial model of sperm whale habitat use as a final objective. This information could then feed into governmental programs aimed at reducing the impact of human activity on and potentially identify key regions of the sperm whale population.

Fine scale foraging behaviour of harbour porpoises (*Phocoena phocoena*)

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The harbour porpoise (*Phocoena phocoena*) inhabits cold water ecosystems in the Northern Hemisphere, and due to their small size, must eat frequently to maintain their internal body temperatures. Studies have shown that harbour porpoises in the water of the Kattegat between Denmark and Sweden are foraging nearly continuously with up to 500 prey encounters per hour and are making both short shallow dives and longer deep dives. Since 2012, 14 DTags have been deployed on fisheries bycatch harbour porpoises in the Kattegat, and echograms, which are a high-resolution representation of each porpoises' acoustic scene of what is being detected from the animal's outgoing echolocation sounds, can be created from DTag acoustic recordings. This project will aim to interpret these fine-scale predator prey interactions to infer both porpoise foraging behaviour and prey behaviour.

MARINE MAMMAL & HUMAN INTERACTION

Long-term Static Acoustic Monitoring of harbour porpoise (*Phocoena phocoena*) at the Galway Bay Marine and Renewable Energy Test Site in Ireland

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Potential environmental effects of Wave Energy Converter (WEC) installations and operations on small coastal cetaceans are, to date, poorly documented. Since the wave energy industry is still in its infancy, pilot-scale projects may be used as baseline to assess responses of harbour porpoises to WEC structures. Since 2006, individual WECs have been intermittently deployed and functioning at the Galway Bay Marine and Renewable Energy (MRE) Test Site, in Ireland. Galway Bay supports an important population of harbour porpoises (*Phocoena phocoena*). Over a 10-year period, three research projects (in 2006-2007; 2009-2010 PReCAST project; 2014-2016 SmartBay project), used Static Acoustic Monitoring which employed self-contained click detectors (T-PODs and C-PODs). Archived data from these different projects were used to investigate variations in harbour porpoise temporal occurrence and foraging activity in the vicinity of the MRE Test Site and to relate potential changes in these patterns to the WEC deployment and operation. Harbour porpoises exhibited strong seasonal patterns with a peak in the frequency of occurrence in summer during the breeding season and in winter in which foraging activity increased. Diel and tidal patterns were highly variable between seasons. Observed diurnal and nocturnal patterns in harbour porpoise presence and foraging activity highlighted the complexity of their diel rhythmic behaviour. Harbour porpoises used the site under specific tidal conditions. Changes in these natural patterns were observed throughout the WEC deployment and functioning period. Harbour porpoises were less present at the site after the WEC deployment period than before, implying they exhibited long-term displacement and avoidance behaviour regarding anthropogenic disturbances. Their foraging behaviour however increased in the vicinity of the WEC suggesting a local enhancement of the feeding ground with higher prey availability. This long-term study therefore provides fine-scale baseline information to help design and enforce effective mitigation measures.

The effect of water turbidity on seal-fishery interactions

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Seal depredation (damage to fish catches) and accidental bycatch in fishing gears have been reported in fisheries worldwide, with regular calls from the fishing industry for management of seal populations. However, the mechanisms or factors influencing these interactions are poorly understood; limiting our ability to guide management decisions. A two-year time series of a set-net fishery from the south of Ireland was analysed to investigate the underlying causes of seal-fishery interactions. Fisheries data included GPS locations of hauls, gear type, catch, bycatch, and depredation of catch by seals. While rates of seal bycatch peaked in winter months, depredation peaked in summer, suggesting seasonal factors could be affecting both. I investigated the possible influence of visibility on rates of depredation and bycatch using earth-observation data of water turbidity. Level three turbidity rasters were generated from the European Space Agency's Coastcolour project at 1-month temporal resolution and 1km 2 spatial resolution, and averaged across the length of the net for the duration of each soak time. Hauls in which seals were bycaught occurred in water that was on average twice as turbid than when bycatch did not occur. Conversely, hauls that were depredated by seals occurred in clearer waters than hauls which were not. This suggests that the ability to see the net plays a role in both seal bycatch and depredation and that bycatch and depredation may occur independently of one another. By accounting for the water turbidity when and where nets are left to soak, fishing practises could be adapted to reduce seal depredation and bycatch.

Analysis of North Atlantic right whales (*Eubalaena glacialis*) behavioural responses to playbacks using DTAGs

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The North Atlantic right whale (NARW) is the most endangered baleen whale, and ship strikes are the main cause of excess mortality. This study aims at improving the understanding of the hearing range and behaviour of NARW to help designing strategies to preserve them from ship strikes. Previous studies found that alert playbacks caused the whale to break its dive and surface quickly which increased the risk of ship strikes. The main objectives of this study are to estimate the frequency range of NARW hearing, and to evaluate the impact of anthropogenic noise on its behaviour. The behavioural and acoustic data used for this project were collected from 14 NARW using DTAGs in the Bay of Fundy in July and August 2005. Three different playbacks including silence (n=11), high-frequency signals (6 tonal signals from 32 to 10 kHz, 6 sweeps from 32 to 5 kHz, and 6 downswept frequencies from 19 kHz to 500 Hz, 3 of each presented for 1 minute followed by a 1-minute pause for a 20-minute exposure, n=12), and an alert signal (1 2-second downsweep signal from 4000 to 500 Hz presented for 2 minutes followed by a 15-second pause for a 15-minute exposure, n=12) were presented to the tagged whales. The estimated hearing range should match the hearing range predicted in previous studies (10 Hz-22 kHz). The behavioural analysis will focus on heading changes rather than changes in dive behaviour since preliminary analysis of the latter found few changes. If any recordings of natural calls are detected, the associated behaviour will be analysed as well. Whales are expected to swim away from alert playbacks and toward conspecific calls. Estimating their hearing range and analysing their behaviour is important to understand the impact of anthropogenic noise on NARW and reduce these impacts.

Behavioural responses by seals to offshore energy activities

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Over the past 50 years, human offshore activity has led to an increase in the range and intensity of man-made sounds that animals are exposed to. The number of marine renewable energy developments (offshore wind farms and tidal energy devices) will grow rapidly over the coming years, with increased construction and operation of these devices in coastal environments. The habitat use of seals overlaps with many of the areas proposed for development, and so these animals face a number of risks including collision with moving turbine blades, 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.

This project aims to investigate the behavioural responses by individual seals to offshore energy activities. Data on the movement and dive behaviour from harbour seals (*Phoca vitulina*) fitted with GPS-tags will be used to investigate their responses to three different sound sources: pile driving during offshore wind farm construction, tidal turbine noise, and acoustic deterrent devices. The aim is to quantify the effect industrial activity has on seal behaviour, and to what extent its impact can be mitigated by the use of acoustic deterrents.

Experimental determination of a mortality threshold for collisions between marine mammals and tidal turbines

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University of St Andrews

There are significant concerns about potential mortality from collisions between marine mammals and rotating tidal turbines. Collision risk models (CRM) are used to estimate the potential rates of encounters and collisions with moving turbine blades. Converting these to estimates of mortality has been based on the assumption that all collisions will result in fatality. This is unlikely to be true given the range of turbine rotation rates over a tidal cycle and the fact that impact speed varies along the blade, decreasing to zero at the hub.

We tested this assumption by subjecting seal carcasses to collisions with a model turbine blade travelling at a range of speeds. We assessed the resulting structural damage using x-rays, computerised-tomography(CT) scans and necropsies. Significant skeletal damage, which would represent fatal injuries, occurred consistently at speeds above 6 m.s-1. In contrast, no damage was observed in any seal struck at or below 5.6 m.s-1. This suggests a threshold for catastrophic skeletal trauma lying between 5.6 and 6m.s-1. Dramatic herniation and organ rupture was noted in the liver and lungs of several cases from high speed collision but not from collisions below 5.6 m.s-1. However, soft-tissue damage is difficult to resolve in previously frozen carcasses so the possibility of deferred, fatal, soft-tissue trauma at lower speeds remains. In terms of skeletal and gross soft-tissue damage these results suggest that ~40% of predicted collisions would be unlikely to be immediately fatal. Additional trials with fresh carcasses and a wider range of species will provide more robust estimates of the likelihood that a collision will kill the animal involved. Such corrections should be implemented in future CRMs to improve estimates of potential mortality rates due to interactions with renewable energy installations.

Exposure of diving grey seal pups (*Halichoerus grypus*) to shipping noise in the Celtic Sea

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The commercial shipping industry increasingly generates low frequency underwater noise. This noise is recognised as a pollutant, and evidence suggests it is associated with a number of negative ecological effects. Consequently, policymakers must consider and mitigate the risks of shipping noise. However, these decisions are constrained by a lack of data relating to the noise levels experienced by marine life. The grey seal is a protected species with hearing sensitive to the dominant frequencies of shipping noise. In particular, grey seal pups are naïve when they go to sea and must develop an effective foraging strategy alone, potentially making them vulnerable to disturbance.

Using AIS vessel tracking data, a ship source model and a range-dependent acoustic propagation model, this study predicts the cumulative sound exposure level (cSEL) of grey seal pups in the Celtic Sea using location and dive data from GPS/GSM devices. The results show the exposure of pups in relation to their spatial use of the environment, including variation as they dive throughout the water column. The potential auditory damage of each seal was calculated using published M-weighting criteria and functions for the onset of temporary threshold shift (TTS).

Results for 6 grey seal pups show broadband (10-1000 Hz) 24hr weighted cSELs are between 107 and 173 dB re 1 µPa2-s. These levels are not great enough to result in TTS. The results help to inform marine spatial planning, and contribute to our understanding of the anthropogenic pressure on seal populations in areas where their distribution overlaps with shipping traffic.

The purpose of porpoises around Scottish fish farms

Texa Sim

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The harbour porpoise (*Phocoena phocoena*) has a widespread coastal distribution throughout the northern hemisphere, where there is potential for interaction with anthropogenic activities. In Scotland the species may interact with an expanding Atlantic salmon (*Salmo salar*) aquaculture industry. Scottish salmon farms are mainly situated on the west coast, northern and western islands which also have some of the highest harbour porpoise densities in Europe. Possible impacts to the species have been brought further into focus through the recently proposed Inner Hebrides and Minches Candidate Special Area of Conservation (cSAC). This protected area will cover 13,539km² of porpoise habitat and has significant overlap with existing salmon farm sites.

The impacts of salmon farms on the harbour porpoise are not well understood, and study efforts mainly focus on the effect of Acoustic Deterrent Devices (ADDs) deployed to prevent seal depredation. These may induce habitat displacement in harbour porpoises, or conversely cause habituation where individuals have been exposed to long-term use. However, the extent of these impacts on porpoises in Scotland is presently unclear. The significance of other factors, such as wild fish aggregations, has also received limited attention to date.

To address these knowledge gaps, the present study will use Passive Acoustic Monitoring (PAM) to identify whether harbour porpoise occur near Scottish salmon farms, and if so, establish temporal variation in usage patterns. Additional PAM will investigate evidence of behaviours such as foraging. Potential attractants such as wild fish aggregations will also be assessed using a combination of video and acoustic techniques. Finally, the effects of ADDs on porpoise occurrence and behaviour will be assessed, providing further understanding of the West of Scotland population. The study will ultimately present multiple small-scale, site-specific examinations on the relevance of salmon aquaculture to harbour porpoises in Scotland, with an aim to inform activity management within the cSAC.

Quantifying the impact of marine renewable energy devices on harbour seals: a multifaceted approach to plugging knowledge gaps on fine-scale habitat use in a tidally active environment

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UK marine renewables energy (MRE) is currently being developed to meet targets set by various governing bodies. Assessing environmental impacts of MRE device are important for the health of ecosystems as well as complying with the EU habitats directive. Harbour seals (*Phoca vitulina*) are a protected species that may be at risk from MRE devices. The project will utilise a 4D mathematical collision risk model (CRM) developed within a physics engine with the aim of quantifying the risk. With a long-term dataset collected by DAERA around Northern Ireland and by collecting new individual-based data we will input empirical evidence into the CRM. Collision probabilities enable a better understanding of MRE device impact on harbour seals. This tool can be used to better inform environmental impact assessments and help ensure the protection of harbour seals.

Fantastic Beasts and Where to Find Them: modelling the distribution of deep diving cetacean species in the North Atlantic

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Beaked whales, and other deep diving cetacean species, have generally long dive times and may spend only relatively short periods of time on the surface between dives. This can make them difficult to detect on visual line transect surveys because they are unavailable for detection by observers for large proportions of the time. As a result, there are often very low numbers of detections from large scale surveys resulting in insufficient data to investigate the spatial distribution of animals in an offshore habitat. Passive acoustic monitoring is an alternative data collection method for some of these species, but the number of detections is still typically small.

Surveys from platforms of opportunity are subject to the same constraints but there are many more data from such surveys meaning that an efficient approach to investigate the distribution of these cryptic species could be to combine data collected from the many different platforms of opportunity with those from designed cetacean surveys. This maximises the data available for analysis, allowing investigations that would not be possible in isolation.

This study combines deep diving cetacean data collected on the SCANS-III cetacean survey conducted in July 2016, with those collected from more than 30 years of seabird surveys carried out throughout the North Sea and European Atlantic. Initial distribution models include a range of static environmental variables to investigate which of these best explains variability in the data for beaked whales, sperm whales and pilot whales. Future work will include additional visual datasets from the north-eastern North Atlantic and PAM data from European Atlantic waters, and additional dynamic oceanographic variables in the modelling.

Predicting grey seal pup (*Halichoerus grypus*) stranding events along coastal Irish waters

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Pupping season is a high-risk time for newborn grey seals (*Halichoerus grypus*) in Ireland, with many pups stranding and subsequently succumbing to starvation, illness, or injury. This study aims to predict grey seal pup stranding risk along Irish coastal waters. Using Seal Rescue Ireland's inhouse stranding data for the years 2013-2017, we will identify and test variables influencing grey seal pup stranding. Secondly, we will determine the optimal resolution, scale, and geographic region of potential stranding predictions to optimise coordination of Seal Rescue Ireland's extensive stranding volunteer network of over 700 individuals. We will perform a stepwise logistic regression analysis to develop a presence/absence predictive model for stranding events. We hope to address the primary variables influencing pup stranding and mortality to more efficiently identify high likelihood rescue areas in the future.

Photo-identification of Azores Sperm whales (*Physeter macrocephalus*)

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Sperm whales (*Physeter macrocephalus*) are key to the whale-watching industry of the Azores, an archipelago of nine islands on the Mid-Atlantic Ridge. Although this species is sighted throughout the year, little is known about the population and social structure. This study aims to use photo-identification to gain an insight into these aspects. Since 2008, sperm whale fluke photographs have been collected by the whale watching company Dive Azores during commercial excursions in the vicinity of Faial and Pico, central islands of the Azores. A database of over 500 identified sperm whales has been created over the past 10 years. The trailing edge contour and markings on the flukes are being used as the identifying features of individuals. Whilst some individuals have been sighted in the Azores once, others have been re-sighted multiple times. Preliminary findings indicate individual sperm whales are being re-sighted at approximately the same time of the year as originally sighted. Social units are also perceived when individuals are re-sighted on the same day together. Re-sighting rate is expected to estimate the population size after further analysis (c.f. mark-recapture). However, this data is limited by the spatial extent of the sampling during the whale-watching excursions and cannot apply to the whole archipelago. Many Azores whale-watching companies have been collecting photos of sperm whale flukes and expanding this study to work with other researchers would correspondingly increase the value of this approach. Migration patterns could also be discerned if this research was expanded globally.

Assessing the Potential for Photogrammetric Assessments of Pregnancy in Free-Living Harbour Seals (*Phoca vitulina*) and Bottlenose Dolphins (*Tursiops truncatus*)

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Assessing the fecundity rate of a group of individuals is imperative to better understanding their population demographics, however this is notoriously difficult to estimate in wild populations. An important part of assessing fecundity rate is the ability to predict whether a female may be pregnant, and whether the pregnancy produces successful offspring. Historical techniques to estimate pregnancy status in free-living animals can be invasive and stress the animal. This study aimed to investigate the potential to use measurements taken from remote photographs to estimate pregnancy status in free-living bottlenose dolphins (*Tursiops truncatus*) and harbour seals (*Phoca vitulina*).

Aerial photographs were taken of bottlenose dolphins and harbour seals in two locations in North East Scotland using a pole-cam and an unmanned aerial vehicle (bottlenose dolphins n=14, harbour seals n=71). Measurements from photographs were then taken using computer program ImageJ, to measure length, various body widths and angles, and total area of an individual. Using linear regression models, evidence of proportional dimorphism between sex and between pregnancy states was found for both species.

 This provides evidence that aerial photogrammetry has the potential to successfully estimate pregnancy status and/or sex for both study species. This technique may thus provide a novel way to estimate the pregnancy 'success rate' for a population, i.e. how many offspring are observed in comparison with the number of 'pregnant' mothers observed earlier in the season. Such information would offer a new insight into the demographics and pressures of a population. Management procedures could then be more informed to maximise pregnancy success rate.

Spatial ecology and population biology of Mediterranean sperm whales (*Physeter macrocephalus*) in the Balearic archipelago

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Found in the pelagic waters of every ocean, the sperm whale (*Physeter macrocephalus*) has an extensive geographic range, from the tropics to latitudes of around 70°. Regional sub-populations of sperm whales are also known to exist. Notably, in the Mediterranean, where sperm whales are isolated geographically, genetically, and in terms of their repertoire of codas, from their Atlantic neighbours. Moreover, this is also the only sub-population with a distinct conservation status – classified as 'Endangered' in IUCN's Red List, based on the elevated anthropogenic threats to sperm whales inhabiting the enclosed and heavily exploited Mediterranean Sea, and on estimates that fewer than 2,500 individuals remain. Following the recent IUCN Joint SSC/WCPA 'Marine Mammal Protected Areas Task Force' announcement, that the Balearic Islands Shelf and Slope has been assigned "Important Marine Mammal Area" (IMMA) status, the campaign to establish robust protection for this endangered sub-population is gathering momentum. While IMMAs have no legal standing they can be used in conservation planning, and with sufficient quantitative data, can be used to justify the creation of biologically significant areas. This alone, is unlikely to result in the establishment of a Marine Protected Area for a migratory species, such as the Mediterranean sperm whale but it could be used to justify better Marine Spatial Planning, leading to improved monitoring and potentially a reduction in the risk of anthropogenic threats. Since 2003, the Balearic Sperm Whale Project, which is a collaboration between the University of St Andrews and the Spanish NGO, 'Asociacion Tursiops', has been collecting data on the abundance, habitat preference and behaviour of sperm whales around the Balearic archipelago. Using this data, in combination with ongoing fieldwork, the aim of this proposed research is to study the spatial ecology and population biology of the unique Mediterranean sperm whale sub-population, to support and inform management actions in this area.

Not just fat: Investigating the proteome of cetacean blubber tissue

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Mammalian adipose tissue is increasingly being recognized as an endocrine organ involved in the regulation of a number of metabolic processes and pathways. It responds to signals from different hormone systems and the central nervous system, and expresses a variety of protein factors with important paracrine and endocrine functions. This study presents a first step towards the systematic analysis of the protein content of cetacean adipose tissue, the blubber, in order to investigate the kinds of proteins present and their relative abundance. Full depth blubber subsamples were collected from dead-stranded harbour porpoises (*Phocoena phocoena*) (n = 21). Three total protein extraction methods were trialled, and the highest total protein yields with the lowest extraction variability were achieved using a RIPA cell lysis and extraction buffer based protocol. Extracted proteins were separated using 1D Sodium Dodecyl Sulfate Polyacrylamide Gel Electrophoresis (SDS-PAGE), and identified using nanoflow Liquid Chromatography Electrospray Ionisation in tandem with Mass Spectrometry (nLC-ESI-MS/MS). A range of proteins were identified (n=295) and classed into eight functional groups, the most abundant of which were involved in cell function and metabolism (45%), immune response and inflammation (15%) and lipid metabolism (11%). These proteins likely originate both from the various cell types within the blubber tissue itself, and from the circulation. They therefore have the potential to capture information on the cellular and physiological stresses experienced by individuals at the time of sampling. The importance of this proteomic approach is two-fold: Firstly, it could help to assign novel functions to marine mammal blubber in keeping with current understanding of the multi-functional role of adipose tissue in other mammals. Secondly, it could lead to the development of a suite of biomarkers to better monitor the physiological state and health of live individuals though remote blubber biopsy sampling.

Assessing resilience of beaked whale populations to human impacts: population structure and genetic diversity in impacted and semi-pristine areas

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As members of the family Ziphiidae, beaked whales (BWs) are one of the most speciose and least-studied cetacean groups. Globally distributed, these animals have come into the public eye due to their exceptional diving behaviour and dramatic behavioural responses linking certain anthropogenic sounds to mass stranding events. The recognized susceptibility to noise pollution and substantial knowledge gap regarding abundance and population structure, strongly highlight that more information is required for effective management and conservation of these species.

This project brings together a global collaboration of 64 researchers in 26 countries to study two sympatric BW species commonly found in mass stranding events, Blainville's and Cuvier's (*Mesoplodon densirostris* and *Ziphius cavirostris*, respectively). Using genomic methods and samples collected from across the species' ranges, we will investigate BW global population structure, connectivity and genetic diversity. To determine the viability of populations under anthropogenic disturbance, comparisons of genetic diversity and social structure will be made between acoustically 'semi-pristine' and 'disturbed' populations in three geographic locations. Little is published about BW populations on local or global scales and the few known populations are small and isolated, thus susceptible to genetic erosion. Understanding these populations is critical to identifying population-level effects of mass stranding events.

Non-invasive isolation of pinniped DNA from scat and moulted hair

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Grey (*Halichoerus grypus*) and harbour (*Phoca vitulina*) seals are protected under European legislation requiring amongst other obligations the restoration/maintenance of a Good Environmental Status. In Irish waters, implementation of EU legislation is hampered by lack of samples and knowledge gaps regarding population structure. Management Units suggested thus far are based on geographic areas and limited telemetry data, which is sub-optimal. This project aims to assess population genetic structure and long-term changes in genetic variability for both species (I) in Irish waters and (II) in relation to seals from other European countries. A number of tissue types are used for genetic analysis including non-invasive samples (e.g. scat, moulted hair). To identify effective protocols, validation experiments in semi-controlled environments were carried out investigating DNA degradation in scat samples over a four weeks period. Two conditions were tested, including untreated and sea water-treated scat left sheltered and exposed, respectively. Results have shown that DNA can reliably be obtained from scat after a four-week period, enhancing sampling opportunities in the field. However, it was demonstrated that factors such as dryness of the scat will impact DNA yields suggesting that an initial assessment of scat samples must be carried out in the field. Further tests were carried out on moulted hair samples collected from both adult harbour seals and grey seal pups. DNA from moulted hair of grey seal pups has successfully been extracted allowing for lanugo samples of late stage IV and stage V pups. Further results will be presented on probabilities of cross-sample contamination and probable variation of DNA isolation success in relation to hair categories (e.g. lanugo vs adult hair, a few separate hairs vs large lanugo aggregations). This study shows that non-invasive samples are a reliable source of DNA for the study of pinniped genetics.

Assessing the mitochondrial phylogeography of long-finned pilot whales (*Globicephala melas*) stranded around the British Isles, with evidence of new haplotypes

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Long-finned pilot whales are a gregarious species with complex social bonds, commonly encountered in mass stranding events. Opportunistic non-invasive biological samples from stranded individuals provide genetic sequences to assess population diversity and structure. Previous haplotype analysis determined diversity in the North Atlantic was very low, with only six documented haplotypes. The current consensus haplotype length only encompasses the first domain of the control region. Here, we investigate if this haplotype length is representative of control region variation and look for maternal population structuring around the British Isles. Additionally, testing five mass stranding events against the extended matriline hypothesis. Mitochondrial DNA sequences were extracted from strandings that occurred in Scotland, Ireland and the Netherlands during 1995-2015 (n=112). The use of a longer haplotype sequence (539bp), revealed six new haplotypes, found predominately in northwest Scotland. There was no significant difference within the diversity of the type of stranding or stranding event however, one of the five mass stranding events contradicted the extended matriline hypothesis. On the east coast of Scotland in 2012, two unique haplotypes were involved in a mass stranding. As two different maternal pods were involved this indicates that social bonds can develop between unrelated individuals. From the increased diversity observed in this study, future investigations should focus on the origins of northwest Scotland haplotype diversity and the influence of drift from the North Atlantic. Additionally, kinship analysis of mass stranding events should be investigated to determine family relationships, inferring the influence of social bonds and implications on rescue efforts.

Characterising fat tissue structure and function in grey seals, an animal model of extreme fat deposition and mobilisation, using novel in vivo and in vitro approaches

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Grey Atlantic seals go through dramatic seasonal changes in body mass and composition because of the spatial and temporal separation of foraging, reproduction and moulting. The regulation of fat mobilisation during these processes is therefore a key factor for their survival. In humans, the excess accumulation of body fat is accompanied by adipose tissue hypoxia, oxidative stress and inflammation that are underlying factors of its various associated health problems. Therefore, the quick change in body mass and metabolic profile suggest that seals could be a good study model for obesity and its comorbidities. This study aims to assess the structure of the blubber, inflammation state, hypoxia and oxidative stress at different blubber depths and life stages: moulting adults, females and pups in early and late lactation and weaning pups. Two blubber biopsies from each animal were taken, one snap frozen and one placed in formalin. Adipocyte number and size, fat content, vascularisation and macrophage infiltration will be analysed through histology and immunohistochemistry. The oxidative stress steady state and pathways will be tested both in vivo and in vitro. In order to elucidate how seals cope with these conditions, physiological hypoxia state and hypoxia signalling pathways will be assessed using probes in wild animals and through in vitro experiments, respectively. We hypothesise that although typical oxygen reactive species would be present and hypoxia pathways stimulated, a compensatory machinery different from humans' will be stimulated to counterbalance their detrimental effects.

Climate Change and Culture in Bottlenose Dolphins: the Emergence of Innovations to cope with Extreme Weather Events

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Extreme weather events associated with global climate change are expected to occur with increased frequency. In February 2011, sea temperatures on the west coast of Australia were three degrees higher than the long-term average for this time of year. A massive influx of warm water into Shark Bay led to a catastrophic die-off in seagrass, followed by increased fish and invertebrate community mortality rates. We investigated the effects of the heat event on abundance and behaviour of Shark Bay bottlenose dolphins (*Tursiops aduncus*). For the western gulf of Shark Bay, we conducted Robust Design Capture-Recapture analyses on photo-identification data collected between 2007 and 2016, detecting no significant differences in our estimates of population size before and after the heat wave (Poisson GLM; $z=0.395$; $p=0.693$; effect size=1.56%; 95% C.I.=[-2.59%, 5.92%]). However, we detected notable differences in particular foraging behaviours after the heat wave. In the western gulf, dolphins engaged in 'shelling' - a foraging tactic that involves manipulation of large, empty trumpet and bailer shells to extract fish hiding inside - with increased frequency (Poisson GLM; $z=-2.151$; $p=0.0315$; effect size=0.271). In the eastern gulf, dolphins began feeding on prawns, a behaviour not previously recorded in this gulf. Both the increase in the number of shelling events and the emergence of prawn feeding after the heat wave suggest a rapid behavioural adaptation to environmental changes. This apparent ability to switch to novel food sources and foraging behaviours may reflect a 'cultural capacity' to endure extreme weather events and, in the longer term, persist in habitats that are subject to a changing climate, but otherwise favourable for meso-predators.

Sexual segregation in Antarctic Fur Seal Pups, *Arctocephalus gazelle*

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Sexual segregation is widespread in the animal kingdom, in which males and females can segregate in space, time and diet. Sexual segregation is apparent in many pinniped species in adult life, with the sexes segregating in foraging distributions, diving depths and diets. Common explanations for this segregation include the larger body size and higher energetic demands of males, as well as the constraints of parental care on females. However, sexual segregation is poorly understood in pinnipeds in early life. This study investigates sexual segregation in Antarctic fur seal pups. As part of a long-term monitoring programme, 300 randomly selected Antarctic fur seal pups were sexed within the beach and tussock grass areas at two sites on South Georgia, annually between 1989 and 2016. To investigate behavioural differences at an individual level, 19 male and 16 female pup were deployed with igot-U GPS data loggers at Bird Island, South Georgia. Their movements were tracked during the lactation period between December 2012 and April 2013. Image classification was conducted on an aerial image of Bird Island to determine habitat use by the pups. Results suggest sexual segregation in habitat use is apparent; males had a higher preference for the beach whereas females favoured the tussock grass. We postulate that this difference is due to contrasting drivers of pup behaviour. Male pups may prefer the more social area of the beach to play fight and gain social skills to ultimately compete for mates in later life, despite the increased dangers of injury and death from scavenging seabirds and larger seals on the beach. Females may prefer the relative safety of the surrounding tussock grass to minimize risk and increase their chances of survival. Exploring sexual segregation in additional pinniped species in early life could help underpin underlying drivers of sexual segregation in pinnipeds.

Investigation of blue whale (*Balaenoptera musculus intermedia*) diving behaviour in a patchy krill (*Euphausia superba*) landscape

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Antarctic blue whales (*Balaenoptera musculus intermedia*) are classed as critically endangered as a result of commercial whaling in the 20th century. Researching predator-prey interactions expands our understanding of blue whale ecology, enabling better conservation of this species. This study investigated the diving behaviour of blue whales in relation to the density (relative biomass) of their prey, Antarctic krill (*Euphausia superba*). Blue whale behaviour was recorded using focal follows, while active acoustic krill surveys (using an echosounder) were carried out to calculate krill density. Eight hours of focal follows (as part of eight tracks) of single individuals or closely associated pairs of animals were analysed with the acoustic data using geographical information systems (ArcGIS) and R. The duration of dives was found to be affected by the density of krill within 400m radii of the start location of the dives. However, some increased dive duration with increased prey density, whereas others had shorter dive durations when prey were denser. It is thought that a number of other factors, including the depth where the krill were situated, and the energetic costs of lunge feeding (the feeding technique used by baleen whales), have significant roles in determining the duration of dives. There was no significant relationship between the distances that whales travelled after finishing dives and the krill densities surrounding the dive locations, possibly because the small sample size prevented significant results to be drawn. Comparisons between the densities of krill surrounding dive locations, and the densities surrounding random points in the survey areas indicated that whales were not necessarily targeting dense patches of krill. It is possible that temporal 'mismatches' occurred between times that whales arrived at patches, and when prey data were collected, meaning that the prey field may have been surveyed after the prey had been depleted by foraging whales.

The role of kinship in the sociality of herring-eating killer whales (*Orcinus orca*) in Iceland

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Among killer whales, kin mediated sociality appears universal and in general basic social units are matrilineal, composed of mothers and their descendants both male and female. In specialist 'resident' and 'transient' populations in the Northeast Pacific, philopatry is thought to promote stable foraging traditions by knowledge transfer within matrilineal units. Icelandic killer whales feed upon herring, a schooling prey that undergoes frequent changes in distribution and school size. Recent studies have shown that unlike specialised populations described elsewhere, in Iceland there appears to be variation in movement patterns and isotopic niche among killer whales that feed upon herring opportunistically, or specialise on it either seasonally or year-round. We combined photo-identification with genetic data to understand the sociality and the role of kinship in this population. Individuals sighted in at least 5 different days (n=198) were considered associated if photographed within 20s of each other. Photo-identified individuals were genotyped (n=61) for 22 microsatellites and mitochondrial DNA control region (611 bp). The population showed non-random associations and fission-fusion dynamics at the individual level. Some sets of individuals displayed seasonal preferential associations. Social clusters were highly diverse and while kinship was correlated with association it was not a prerequisite for social membership. Indeed, some cluster members had different mitochondrial haplotypes, representing different matrilineages. Individuals with different movement patterns were genetically distinct, but associated with each other. No sex-biased dispersal or inbreeding was detected. This study reveals that the Icelandic population has a society where kinship drives social structure less strongly than in 'resident' fish-eating populations. We hypothesize that effective foraging on herring promotes the formation of flexible social groupings, which might include non-kin. The contemporary herring distribution promotes geographic overlap and social mixing of individuals with diverse movement patterns but the philopatry of both sexes maintains genetic structure despite probable constant gene flow.

Determining the Ecology and Physics of Tidal-Stream Habitats (DEPTH): Understanding the link between the physical attributes and animal distribution in tidal-stream habitats and how to best monitor their interactions with marine renewable developments

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Tidal-stream environments occur where water flow is constrained (e.g. through straits), and can be characterized by a wide range of physical features such as fast horizontal currents, intense turbulence and mixing and physical structures (e.g. jets, eddies, boils). Some marine predators such as marine mammals exploit these characteristics to capture prey. For example, fast horizontal currents and high turbulence could potentially disorientate and disaggregate shoals of fish, whereas upward vertical currents can drive them to surface waters, both increasing their overall availability. Tidal streams are also targeted for marine renewable energy (MRE) extraction due to the predictable, high energy resource for power generation. However, there is a lack of knowledge about how and why marine fauna use these habitats and consequently the ecological implications of the presence of tidal turbines. Knowing that the spatial and temporal distribution of species is generally linked with the environment, one of the main goals of this project is to understand the link between the physical properties of tidal-streams environments and animal distribution (including marine mammals). To address this, we plan to:

1) characterise the physical oceanography of a tidal-stream environment (Fall of Warness, Orkney) using data collected over the last 14 years;
2) use statistical models to identify environmental variables that appear to influence species behaviour and distribution;
3) explore our model's predictive power using the initial model inferences and new environmental data.

The results will be validated using behavioural data collected in situ. The results from this study will allow us to assess the importance of tidal-stream habitats for marine mammals (and other groups of species) and underlying key physical features. Moreover, we hope that the knowledge resulting from this study will be used to design an effective monitoring plan that can successfully determine the impact of MRE devices on species behaviour using validated models and selected environmental variables collected in situ.

Social interactions in island-associated bottlenose dolphin populations

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The focus of this dissertation is on social interactions of three island-associated populations of bottlenose dolphins: two in Hawaii (database one) and one in the Bahamas (database two). The databases consist of individual encounters per day in an area based on photo-id and involve long term studies of about 15 years. The analysis will therefore be based on the 'gambit-of-the-group' principle. Furthermore, a suitable association index needs to be determined. Examples include the half-weight index and generalised affiliation index. The choice of index will largely determine the input for the results (proportions) and methods. Expected methods include sociograms, model selection and time series analysis. Furthermore, Hal Whitehead has developed a script in SOCPROG that could be used in relation to this project. The focus of this method is on identifying types of relationships based on defined levels from the index results. Besides from the internal social organisation of the populations I would like to compare the populations amongst each other. Perhaps there are distinct differences or similarities between them. Finally, I could also compare my results to current literature on (bottlenose) dolphin social organisations to see if my results are in line with previous findings. Perhaps island-associated social organisation is different from other populations.

Population structure of long-finned pilot whales in Ireland

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Long-finned pilot whales (*Globicephala melas*) provide an interesting example of a cetacean with a recent complex evolutionary history in a pelagic environment. They have wide ranges but are largely parapatric and their genetic diversity have been under-studied, until recently. Levels of genetic diversity and determining the population structure in cetacea, such as the long-finned pilot whale, is essential to their conservation and management. This study began by analysing an 800 base pair unit of the mitochondrial DNA control region loci from 15 individuals stranded around West Scotland in a 20-year period. In conjunction with long-finned pilot whales, killer whales (*Orcinus Orca*) and sperm whales (*Physeter microcephalus*) exhibit low worldwide mtDNA diversity compared to other widespread cetaceans, interestingly these cetacea express similar social and behavioural dynamics. The pods have a matrilineal structure (natal pod philopatry) and the gene flow is mainly male-mediated between pods. As mitochondrial DNA is matrilineal this study comprises of female-mediated gene flow, assuming that one pod consists of related females, three multiple matrilines have been assessed in West Scotland from single stranding events. One of the individual sequences did not match previously described haplotypes (327 base pairs), increasing the global database of haplotypes. High genetic diversity has been shown in long-finned pilot whales in West Scotland, which contrasts with previous studies. The oceanic habitats and conservation zones are diverse with extremely deep waters, seamounts and submarine canyons that are suitable for long-finned pilot whales and their prey. The area and the abundance of rich habitat has promoted multiple pods of this this species in this area. The West Scotland samples were analysed and compared to previously published and unpublished sequences from a variety of sources (n = 20) taken from single and mass stranding events in the northern and southern hemispheres. In this study there is strong genetic differentiation between hemispheres, this contrasts previous research as haplotypes are not hemisphere exclusive. Overall, long-finned pilot whale phylogeography can be best explained by a recent worldwide demographic expansion. Further analysis using microsatellites needs to be completed to investigate the population structure of long-finned pilot whales in West Scotland.

Predicting prey capture attempts from movement signals

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Knowledge of foraging behaviour is key to understanding food-web topology and ultimately ecosystem structure and functioning. Yet identifying prey capture attempts remains challenging, particularly for marine top predators. Terminal acoustic buzzes are a commonly used proxy for potential prey capture events of the little known beaked whale family. We used acoustic buzzes to ground-truth magnetometer and accelerometer-based methods of detecting potential beaked whale prey capture attempts. Fifteen DTags were deployed on northern bottlenose whales in Jan Mayen. Tag position periods (i.e. time intervals in which tags were in the same stable position on an animal) were analysed separately (n=34). Receiver operator characteristic (ROC) analysis determined which signals (and peak thresholds) most efficiently predicted buzzes. Accelerometer, magnetometer and specific acceleration signals were calculated as the mean square and RMS jerk across each axis and as a triaxial combination. ROC statistics, 'sensitivity' (true positive rate) and 'specificity' (true negative rate), indicated that jerk of accelerometer or specific acceleration equivalently provided the best predictor of buzzes. Lateral axis accelerometer jerk had the highest mean sum of sensitivity and specificity (1.67±SE.02). Optimal thresholds (i.e. thresholds maximising the sum of sensitivity and specificity) on the lateral accelerometer jerk gave a 60-100% probability (mean±SE = 88.21±.02%) of a correct miss (i.e. no jerk peak identified when no buzz occurred) and a 45-100% probability (mean±SE = 82.14±.02%) of a correct hit (i.e. jerk peak identified when a buzz occurred). This study revealed that analyses of signals from low-power accelerometers can predict buzzes with high sensitivity and specificity, and are therefore promising methods to estimate potential beaked whale prey capture attempts in longer duration tags. Sudden accelerations along the lateral axis may be an important component of the prey capture movements of this data deficient species.

The relationship between prey availability and consumption by harbour porpoises (Phocoena phocoena) in the southern North Sea

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The harbour porpoise (*Phocoena phocoena*) is the most abundant cetacean in the North Sea; its diet is varied and includes commercial fish species. The recent distributional shift of harbour porpoises within the North Sea is thought to be linked to food availability. However, information on the relationship between porpoises and their prey is largely lacking, emphasising the need for research on porpoise feeding ecology. A functional response provides insight into prey 'preference' and predation pressure. This study modelled a Multi-Species Functional Response (MSFR) to describe the relationship between prey availability and consumption by harbour porpoises within the southern North Sea. Stomach contents from stranded porpoises along the Dutch coastline were used to estimate consumption and select 'main' prey species. The area where porpoises may have foraged prior to stranding was estimated by linking the likely time frame of the most recent feeding to predicted swimming speeds from Danish telemetry data. Fish survey data were used to generate distribution models to estimate prey availability. Bayesian methodology was employed to estimate MSFR parameters and to incorporate uncertainties in diet and prey availability estimates. Two models were compared: the shape of the functional response was either hyperbolic (Type II) or sigmoidal (Type III). The diet of harbour porpoises is diverse and switching behaviour between prey species was confirmed by the favoured Type III functional response model. Therefore, some prey species might be vulnerable to 'predator pit' effects. In this area porpoises seemed to have a strong 'preference' for sandeels, and the availability of sandeels might therefore have a particularly marked effect on porpoise consumption of other prey. Further work is needed to increase the reliability of the predictions by examining how resilient the results are to different assumptions about the area associated with porpoise foraging prior to stranding.

From brick to bullet: using Computational Fluid Dynamics to design bio-logging tags with minimal drag

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Bio-logging devices are used across taxa in movement and behavioural ecology to record data from organisms without the need for direct observation. Bio-logging technology has become more sophisticated in recent years, but less progress has been made in assessing and reducing the impact of attaching these devices to animals, despite concerns about the ecological usefulness of the data collected, and implications for animal welfare. Existing guidelines typically focus on tag weight (e.g. the '3% rule'), yet ignores the impact of aero/hydrodynamic 'drag' that is likely to be more important for aerial and aquatic organisms. Designing tags for animals moving in fluid environments is, however, not trivial, because tagged animals are subject to forces in turbulent flow and the impact of drag is a function of the position of the tag on the animal and its form and dimensions. These problems are further compounded by the fact that the position of the tag on the animal determines the quantity and quality of data that are attainable. To efficiently tackle this complex optimisation problem, we take an interdisciplinary approach and use Computational Fluid Dynamics (CFD) to design tags with minimal impact. We use the grey seal (*Halichoerus grypus*) as a model species to investigate the effects of several principal factors in telemetry design, including form, dimensions and tag position on the animal. We demonstrate that optimising a combination of these factors can substantially reduce drag, and highlight the counter-intuitive result that smaller tags are not always better. We conclude that CFD can be successfully used for optimising tag design and outline a recently developed optimisation algorithm.

Reconstructing behaviour: using posture to resolve modes of foraging in diving harbour seals

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Behaviour of aquatic animals is often inferred from dive shape using long-lasting time-depth tags. However, dive shape may be misleading for shallow-water species that rest, travel and forage on various prey at similar depths. Here we explore whether parallel sensors can help resolve modes of behaviour. 40 days of data (DTAG-4) were collected from 3 harbour seals in the shallow North Sea in 2016. These record 3-axis acceleration (200 Hz sampling rate) and sound (64kHz) in addition to magnetometer, depth (50 Hz), and GPS positions (every surfacing). During 8-day foraging trips, tagged seals showed both straight line and highly tortuous surface movements. Diving was almost continuous with about 250 dives/day, approximately 80% of which were flat-bottomed, likely to the sea floor, with duration 2-4 minutes. Long sequences of highly stereotyped dives suggested continual foraging. However, mean posture at the bottom of these dives was less monotypic. In 10% of flat-bottomed dives, animals rolled onto one side, or rolled continuously from side to side. These contained no transient accelerations (jerks) and so were presumably not foraging. The remaining flat-bottomed dives usually contained at least one jerk, which sometimes coincided with a vertical nose-down posture, presumably indicating seafloor prey capture. Nose-down encounters near the end of dives were associated with impact sounds, followed at the surface by sounds consistent with prey handling. This suggests that seals can acquire multiple prey per dive, switching opportunistically between small prey consumed underwater and larger prey brought to the surface. Diurnal behavioural cycles were not evident from depth records, but were clear from dive posture, with steeper mean pitch angles at night possibly indicating increased reliance on tactile sensing at the seabed. Simultaneous analysis of posture and jerk from acceleration data thus provides rich material to help interpret the sensory and ecological constraints on foraging.

Stereotypic flipper-sucking behaviour of a California sea lion (*Zalophus californianus*) increases after feeding

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Oral stereotypic behaviours in pinnipeds have been subject to little investigation. Accordingly, this study analysed the flipper-sucking (FS) behaviour of a California sea lion to determine whether FS expression differed under the following circumstances; before and after feeding, according to location (four enclosures tested) and social groupings (the subject was monitored when alone, when sequentially paired with three other sea lions and when all four sea lions were together). The importance of this study was further stressed in light of the severely self-injurious nature of this FS behaviour, which caused numerous welfare concerns. Moreover, since oral stereotypes are typically characteristic of ungulate species, this report may have broader applications by acknowledging stereotypic similarities between two very diverse mammalian groups. Overall, 102 observations were carried out and continuous sampling was used to obtain the proportion of time spent FS and the total number of flipper-sucks per 20-minute session (i.e. total FS intensity). Additionally, total FS intensity was sub-divided into individual counts of three distinct FS types. Other measures regarding the subject were noted such as proportion of time spent swimming, other repetitive behaviours and interactions with other sea lions. The results revealed that total FS intensity and duration increased significantly after feeding ($p < 0.001$). After meals, each FS type also increased in intensity and the subject nipped her side with her teeth substantially more ($p < 0.001$). The outside and inside locations were associated with significantly high total FS durations and intensities ($p < 0.001$), compared to the back and pen areas where stereotypic movements were recorded. Social grouping had no effect on FS expression, nor did whether observations were obtained in the morning or afternoon ($p > 0.05$). The results are comparable to post-feed peaks in walrus oral behaviours, suggesting that FS may be due to stimulated foraging motivations.