# 2nd World Seabird Conference

# Seabirds: Global Ocean Sentinels

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# WSC2 Abstract Book

## Tuesday October 27 2015

### PS1 The Influence of Sex and Wind

**PS1.1 Sex-specific, seasonal foraging by a monomorphic diving seabird (Common Murre)**

Chantelle Burke[1], William Montevecchi[1]
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We combine geolocators and stable isotopes to compare seasonal foraging behavior of Common Murres Uria aalge over successive stages of the annual cycle including chick-rearing, post-breeding (when male parents care for their chick at sea) and winter. During chick rearing, δ15N values overlapped with no observed sex differences in the timing of foraging, diving tactics (dive depth, duration) or daily foraging effort (total minutes/day > 3m). During post-breeding, δ15N values of both sexes decreased from chick-rearing in a similar manner and core foraging areas overlapped (50% kernels). After colony departure, males attending a chick exhibited a significantly higher daily rate of diving (104.2 ± 60.1) than females (56.7 ± 30.0), with nearly double the time spent foraging per day (169.9 ± 99.2) relative to females (93.4 ± 49.5). This increased activity by males occurred over a mean period of 63.5 ± 3.5 days after which males and females exhibited similar patterns in daily foraging effort, which we suggest represents the termination of chick nutritional dependence. In winter, daily foraging effort of the sexes were the equal and similar to the chick-rearing period, despite a significant decrease in available daylight hours. Both sexes dove intensively during daylight hours and bottom durations were significantly longer than during all other periods. We demonstrate that male-only care at sea during post-breeding represents a significant investment, for male parents lasting ~ 2 months and further that similar, intensive foraging patterns by male and female murres during winter reflect high energetic demands for a low-lipid-loading, diving seabird during harsh North Atlantic winters.

**PS1.2 Contrasting responses of male and female foraging effort to year-round wind conditions in the European shag Phalacrocorax aristotelis**

Sue Lewis[1]
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There is growing interest in the effects of wind on wild animals, given evidence that wind speeds are increasing and becoming more variable in some regions. Wind may alter foraging efficiency, with consequences for energy budgets, in particular among mobile taxa such as seabirds. Furthermore, these impacts are expected in the aquatic as well as the atmospheric environment, because of the profound effects of wind on wave patterns, potentially affecting diving species. Quantifying variation in individual responses to wind is central to understanding population-level effects. These effects will vary among individuals due to intrinsic factors such as sex, age or feeding proficiency. Crucially, this variation is predicted to become more marked as wind conditions deteriorate. The interaction between wind and intrinsic effects has not been tested, yet may have profound consequences for population dynamics as the climate changes. In many seabird species, in particular those showing sexual size dimorphism, males and females vary in foraging performance. Here, we undertook year-

round deployments of data loggers to test for interactions between sex and wind speed and direction on foraging effort in adult European shags Phalacrocorax aristotelis, a species in which males are ca. 18% heavier. The results supported our prediction that foraging effort of females would be progressively longer than that of males as wind conditions deteriorate. Since foraging effort is linked to demographic rates in this species, our results are likely to have important consequences for population dynamics by amplifying observed sex-specific differences in survival rates.

**PS1.3 Effects of extreme events on foraging movements of seabirds! A comparative study between juveniles and adults frigatebirds and boobies.**

Aurélien Prudor[1], Henri Weimerskirch[1]
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In addition to an increase in temperatures, decrease in productivity, and change in wind regimes, future climate changes are expected to be associated with an increase in extreme climatic events. Impacts of these changes on the foraging abilities of marine vertebrate are still poorly known. Here we examine the impact of extreme wind conditions on Great frigatebird (Fregata minor) and red-footed boobies (Sula sula), species highly sensitive to wind conditions for their flight. During the course of a long-term study (2011-2015) on the effects of climate variability on the foraging abilities of tropical seabirds, adults and juveniles were equipped with Argos and GPS devices to compare the response of the two species and two age classes to varying wind conditions. We predicted a contrasted response between species, and between adults and juveniles's birds which are in learning phase and supposed to be less efficient flyers. We determine for both age classes a maximum wind level at which the birds no longer control their trajectory. In addition, we focused on extreme climatic event such as cyclones. We show that extreme wind conditions associated with cyclones affect the two species and two age classes very differently; on the breeding grounds by affecting foraging decisions and at sea by affecting theirs trajectories; adults birds trying to avoid the center of the low pressure systems, and consequently moving in unfamiliar habitats. We discuss the potential consequences of an increase in stormy conditions on seabird populations.

**PS1.4 Flying fast or slow, high or low? Flight responses to winds during foraging trips by common murres and lesser black-backed gulls**

Tom Evans[1], Anders Hedenström[1], Willem Bouten[2], Susanne Åkesson[1]
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Wind is a major determinant of the energetic costs and travel speeds for foraging seabirds. Thus we should expect seabirds to modulate their flight behaviour to make optimal use of wind conditions. To investigate this, we deployed high-resolution GPS devices, measuring both position and altitude on two species with contrasting flight styles; lesser black-backed gulls (Larus fuscus) and common murres (Uria aalge); species breeding sympatrically at an island colony in the Baltic Sea. We compare different types of flights during central-place foraging trips by breeding birds, investigating flight behaviour with respect to wind conditions experienced using data from regional weather models. During flights returning to the island colony, lesser black-backed gulls were found to adjust both their altitude (ca. 50% variation explained) and airspeed (their speed with respect to the air, ca. 30% variation explained) depending on wind conditions. Gulls make use of the vertical wind-speed profile, with low wind speeds close to the sea surface owing to wind shear, and higher wind speeds

at higher altitudes; birds increase altitude when flying with tail-winds, and reduce altitude when flying with head-winds. Flight theory suggests that birds should fly at different airspeeds depending on their primary optimisation criteria (energy or time minimisation); further these optimal speeds are influenced by wind, with birds expected to increase speeds when faced with head-winds and reduce speed with tail-winds, predictions supported by our data. We discuss these results further comparing between species and types of flight (e.g. commuting versus searching).

**PS1.5 Wind, wing loading and flight dynamics in Cape gannets**

Danielle van den Heever[1], Andrea Thiebault[1], Pierre Pistorius[1], Yann Tremblay[2]
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The evolution of foraging specializations in seabirds has led to a range body size and wing shapes resulting in various flying abilities and therefore differing proportions of flapping and gliding phases. Within a species these proportions may vary with the wing loading of individuals as well as with the local wind and wave conditions. The extent to which the various strategies are used to lower energetic costs are largely species or taxa specific, allowing them to exploit the marine resources in different ways. Within a species, wing loading as well as local environmental conditions is also important determinants of time allocation towards the different modes of flight. We here study the influences of both wing loading and wind conditions on flying strategies used by Cape gannets (Morus capensis). Data were collected on Bird Island (Algoa Bay, South Africa) during the breeding season 2010-2011. 35 individuals were equipped with video cameras and GPS devices. The percentage time spent flapping vs. gliding, as well as the frequency of wing flapping within a portion of flight were determined from the video footage analysis, while the flight speed and direction were measured from the GPS data. In addition, measurements (including wing cord length, wing surface area and mass) were taken from the deployed birds so that their wing loading was assessed. Concurrently, data on the wind characteristics (direction and speed) were collected from a weather station located on Bird Island, and an index of sea-state was derived from the video data. We show how the wind affects the flight dynamics of individuals with different wing loadings, and the consequences in terms of foraging effort for Cape gannets. In the context of climate change and anticipated changes in wind regimes, this study provides insights into the capacities of these seabirds to deal with varying environmental conditions and their potential resilience to climate change.

**PS1.6 Different strokes for different folks: variation in flight within and between kittiwakes**

Philip Collins[1], Lewis Halsey[1], Jonathan Green[2], John Arnould[3], Peter Shaw[1], Stephen Dodd[4]
*[1]University of Roehampton, [2]University of Liverpool, [3]Deakin University, [4]Royal Society for the Protection of Birds*

Flying over the ocean to find patches of food is energetically expensive for seabirds, as such they must fly efficiently to ensure that energy expended does not overwhelm energy gained while foraging. With such a sensitive energy budget, fine details about where, when and how a seabird expends its energy in the pursuit of food could determine its fate; whether it reproduces, indeed whether it survives. With GPS trackers we can determine where seabirds forage, yet the finer details regarding their flight behaviours across foraging trips are unknown. Now, however, accelerometers are sufficiently miniaturised that we can study in-situ flight behaviour at a sub-second level of detail.

In particular we can investigate how variations in flight parameters are related to breeding success. We can also investigate whether such behavioural variations are associated with morphological differences. We collected accelerometry data from 22 breeding kittiwakes on Puffin Island, UK over the 2013 and 2014 breeding seasons. From these data we calculated flight parameters including: wingbeat frequency and amplitude, flight duration, flap: glide ratios, and frequency of foraging attempts. We also took a range of morphological measurements from each bird, which we used to calculate body condition indices. The breeding behaviour of the birds was monitored via direct observation and time-lapse camera recordings. With consideration being given to wind strength and direction, we compared these variables to identify the links between flight behaviour, morphology and breeding. Preliminary analysis has revealed a degree of variation in fine-scale flight characteristics both within and between individuals over foraging trips. How these characteristics are linked to morphology and breeding will be further examined and presented.

**PS1.7 Linking wind, foraging behaviour and body mass growth during incubation to assess incubation success of wandering albatross (Diomedea exulans) under different wind scenarios.**

Tina Cornioley[1], Arpat Ozgul[1], Luca Börger[2], Henri Weimerskirch[3]
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Wind affects locomotion of flying animals by defining their energy landscape. The ecological responses to wind however have not received much attention despite changes in wind patterns. We investigated the relationship between the wind and the foraging success of the wandering albatross during incubation. To do so, we built a foraging model describing the links between wind, foraging movements, mass gained by the foraging partner and mass lost by the incubating partner. We found that wind speed increased bird ground speed which increased maximum distance from the colony and that the latter two variables affected trip duration. Trip duration, which is the same as fasting duration for the incubating partner reduced mass loss of the incubating partner. Body mass at departure from the nest, which reduced mass gain, was the only determinant of mass gain. We then used the foraging model to assess the effect of different wind speed scenarios on the body mass growth of simulated incubating pairs and incubation success. Incubation failure is usually due to nest abandonment triggered by important mass loss. We tracked the number of times critical mass leading to nest abandonment was reached to assess incubation success. The simulations predicted that body mass generally increased, no nest abandonment occurred and that wind speed had no overall effect on body mass growth during incubation as it was buffered by foraging behaviour.

**PS1.8 Influence of ocean winds on migratory paths, stop-overs and the choice of wintering areas in a trans-equatorial procellariiform migrant**

Gaia Dell'Ariccia[1], Maria Dias[2], Paulo Catry[2], José Granadeiro[3], Joël Sudre[4], Simon Benhamou[5], Francesco Bonadonna[5]
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Trans-equatorial migrations of procellariiform seabirds are facilitated by the exploitation of favourable oceanic winds, which reduce the energy expenditure and shape the migratory pathways across hemispheres. Cory's shearwater (Calonectris borealis) is a long-distance trans-equatorial migrant, which exhibits an exceptional migratory flexibility. Contrary to the majority of other

shearwaters, which have a unique wintering ground, this species winters in several different areas of the Atlantic Ocean, ranging from the South to the North Atlantic, from the western to the eastern South Atlantic and even venturing into the Indian Ocean. In addition, while some individuals show high fidelity to the same wintering region year after year, others shift among wintering areas several thousands of kilometres apart in consecutive migrations, or even during the same wintering season. This peculiar behaviour has not been explained so far and offers the possibility to better understand how wind dynamics affect the spatiotemporal migratory behaviour of petrels, influencing stop-overs and the choice of the wintering area. With this aim, we analysed a dataset composed by 183 migratory GLS tracks of Cory's shearwater (recorded during five consecutive migrations, from 2006 to 2011, and belonging to 108 different individuals) in relation to concurrent wind data. Our results show how the variation in tail wind assistance influences the migratory pattern at the individual level, determining departures (from the colony, the stop-over sites and the wintering areas), the existence and timing of stop-overs during the journey and, more importantly, the choice of different wintering areas. Our findings are also relevant in the present scenario of climate change because shifts in the global wind patterns might entail deep modifications in the behaviour and spatiotemporal distribution of petrels across the oceans.

## PS2 Food and Foraging Areas

### PS2.1 Exceptionally long provisioning trips by Manx Shearwaters (Puffinus puffinus) breeding on the edge of Europe

Saskia Wischnewski[1], Mark Jessopp[1], Ashley Bennison[1], Barry O'Mahoney[1], John Quinn[1]
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Optimal foraging theory predicts that animals will only travel as far as necessary to meet their energy needs, yet marine prey resources are patchily distributed, often requiring central place foraging seabirds to travel large distances in search of food. During chick rearing ,when adult birds have to balance long chick guarding periods and high provisioning rates to ensure their chick's survival, travelling time is most critical and some known high quality sites, such as the mid-Atlantic ridge, are often considered out of reach. GPS tracking of Manx Shearwaters (Puffinus puffinus) off the west coast of Ireland reveals a maximum travelled distance of foraging trips up to four times greater than previously suggested for this species during chick rearing (max.3322km return, 8 days; mean 436km, return, 1.5 days, N=28). Kernel density estimation and areas of restricted search (ARS) show that key foraging sites are located in three distinct, independent locations: Galway Bay (short, <200km, N=26), the Outer Hebrides in Scotland (medium, <1000km, N=2) and Reykjanes Ridge in the mid-Atlantic (long,>1000 km,N=2). Although greater foraging ranges have been recorded in Procellariiform species during incubation, this is the furthest record for a northern hemisphere seabird during chick provisioning. Parameters such as wave height, wind direction, date of departure, gender or body condition were not able to predict trip length (Kruskal-Wallis, all P>0.05). When compared with foraging ranges previously observed in Manx shearwaters and other Procellariiformes, our results suggest that differences in the geographic location of colonies can significantly alter foraging ranges if it provides access to different sized ocean basins. They further add to an increasing body of evidence emphasizing the importance of the mid-Atlantic ridge area for coastal breeding seabirds in general, and the Reykjanes Ridges as a recently proposed MPA in particular.

**PS2.2 Food availability for tropical Procellariiformes: oceanography that drives critical resources**

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Great Barrier Reef wedge-tailed shearwaters obtain food for their chicks on short-trips near the breeding colony. Adult shearwaters were tracked with state-of-the-art GPS equipment in three breeding seasons to identify foraging ground locations then overlaid with oceanographic parameters to determine the characteristics that drive prey availability in these places. Most trips were single day (70-85%) and all were within 300km of the colony. Foraging was generally adjacent to the Capricorn shelf, where the largest oceanographic mechanism in the region, the meso-scale Capricorn Eddy, 'spins up'. The eddy interacts with bottom topography (reefs and slopes), creating upwellings and fronts. Five topographically and bathymetrically distinct zones were consistently revisited at varying levels of usage. The least used zone was most distant from the colony and exhibited characteristics more analogous to locations used by shearwaters on long foraging trips (deep, sea level anomalies and currents). Strong sea-surface temperature (SST) fronts were the dominant influence on foraging in 2013 indicating the dominance of the Capricorn Eddy over foraging activity. This was less important in 2014 when the dominant factors varied among zones and were usually anomalous or absolute values of SST and chlorophyll a, suggesting a weakened effect of the eddy and elevated importance of fine-scale phenomena such as localised upwellings. By contrast, a different mechanism influenced the highly used zone nearest the colony. Foraging here was more strongly influenced by terrestrial input, demonstrated through foraging associations between birds and freshwater plumes as well as higher than average chlorophyll a levels. Consequently, two different, independent trophic mechanisms (the Capricorn Eddy & terrestrial input), that are dominated by regional and seasonal climatic variation, are significant drivers of advantageous foraging associations for wedge-tailed shearwaters in the southern GBR.

**PS2.3 Comparing indices of forage fish availability to diets of sympatric kittiwake species in the Bering Sea and Aleutian Islands**

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The red-legged kittiwake (Rissa brevirostris) and black-legged kittiwake (R. tridactyla) are sympatric species breeding in the Bering Sea and Aleutian Islands, where they have been studied in the Pribilofs and at Buldir Island for nearly four decades. These species occur together on the breeding grounds but in the Bering Sea have been shown to have disparate wintering ranges and foraging behavior, with red-legged kittiwakes relying heavily on lanternfish (Myctophidae)from the Bering Sea shelf break, while black-legged kittiwake prey on a more diverse suite of species from the shelf itself, including a larger percentage of invertebrates. We explored the potential for the two sympatric kittiwake species to provide information about forage fish abundance in two regions, the Eastern Bering Sea and the western Aleutian Islands, which differ not only in their physical and biological habitats but also the amount of scientific information available. The "data rich" Eastern Bering Sea has multiple extensive and annual surveys of the fish community, in contrast to the "data poor" western Aleutian Islands. While neither region has long-term survey dedicated to measuring forage fish abundance, we hypothesized that the principal component of a suite of imperfect samplers of forage fish would be a useful descriptor of abundance. We compared abundance in

kittiwake diets of five fish species (pollock, sandlance, capelin, myctophid spp, and Atka mackerel) to local forage fish indices obtained from groundfish stomach samples, bottom trawls, midwater trawls, acoustic estimates and marine mammal scat samples. We propose that indices derived from multiple data sources with known biases such as differential prey preference and survey catchability can still provide accurate, if not precise, estimates of forage fish abundance trends. Furthermore, results from data-rich environments can inform estimates from data-poor regions.

**PS2.4 Stress incurred by chicks link changes in forage fish availability to the reproductive performance of rhinoceros auklets across the North Pacific.**

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Reproductive success of seabirds may serve as an indicator of foraging conditions during the breeding season. In the North Pacific the breeding success of rhinoceros auklets has been considered to be an informative indicator of the availability of forage fish in coastal systems. To date, however, efforts to link their reproductive output to changes in local forage fish communities has produced mixed results. Here we examine the foraging behavior of parents and the physiology of chicks to test the relationship between changes in prey composition and the condition of offspring produced on Teuri Is. in Japan, Middleton Is. in the northern Gulf of Alaska, and St. Lazaria Is. in Southeast Alaska; three colonies that encompass this species' breeding range in the North Pacific. In 2012 and 2013 we assessed the energy content and type of prey delivered to chicks, and used bird-borne temperature depth recorders to examine adult foraging behavior to determine what parameters best explained inter and intra-annual variation in concentrations of corticosterone in fledgling feather tissues, a reliable indicator of nutritional stress in the focal species. This approach allowed us to identify the colony-specific diet compositions, and seasonal and inter-annual dynamics of prey species associated with the best nutritional conditions for growing chicks. Our results suggest that feather corticosterone in rhinoceros auklet fledglings is an informative metric of tracking local environmental conditions and might be used for range-wide monitoring of short and long-term climate effects on coastal marine ecosystems in the North Pacific.

**PS2.5 Cyclic marine habitat preferences of benthivorous sea ducks as revealed by satellite telemetry**

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Sea ducks spend a major part of their life in the marine environment. However, they utilize different habitats during distinct periods of the annual cycle. The physical characteristics of the utilized habitats and available prey vary depending on species phenology and distribution ranges. The aim of this study was to characterize macro habitat preferences of different sea duck species during the non-breeding period and relate the habitat choices to species ecology. We used Argos-based satellite telemetry to track three species of sea ducks: Common Eider, Long-tailed Duck and Velvet

Scoter. Spatial distribution modelling was implemented by fitting generalized additive models. We found that each of the study species had distinct and highly consistent habitat preferences during the wintering period. Small variations in some physical parameters were distinguished, which are likely induced by prey availability. A range of diverse habitats were utilized by the sea ducks at resting and refuelling stopovers during the migration periods. The post-breeding moulting phase represents another distinct period with a highly specialized habitat choice that could be explained by needs of high energy intake and safety during the period of flightlessness. This study described clear habitat partitioning among different sea duck species and demonstrated high plasticity of these birds when utilizing distinct environments during different stages of the annual cycle. Tracking relatively few individuals proved being sufficient for characterizing typical species habitats and making predictions of habitat suitability over large scale.

**PS2.6 GIS-based assessment of the potential for predicting seabird distribution in shallow and intertidal habitats**

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Anticipating the presence and distribution of seabirds is a major issue in marine environmental impact and risk assessments. The coastal areas of Northern Norway are important for large breeding populations of seabirds and waders. Due to the influence of the Gulf Stream, combined with large tidal ranges and shallow waters, these areas are also important for wintering and migrating birds. While the locations of the breeding colonies are well known, the locations of preferred feeding areas in shallow waters and on the shore are less well defined being predominantly based on observations within limited spatial and temporal scales. Improved estimates/predictions of birds in shallow waters and the intertidal zone is an important issue for improving impact and risk assessments. With this in mind, a pilot study was initiated, where GIS techniques were applied to analyse the correlations between seabird observations in the coastal zone and assumed preference based on feeding mode, food availability and water depth. Data on water depth, fish spawning and nursing areas, kelp forests and intertidal zones were mapped on a 1x1 km grid and observation data for three species of seabirds superimposed on these. This paper presents the results of this pilot study.

**PS2.7 Leapfrog migration and habitat preferences of a small oceanic seabird, Bulwer's petrel (Bulweria bulwerii)**

Raül Ramos[1], Víctor Sanz[1], Teresa Militão[1], Joël Bried[2], Verónica Neves[2], Manuel Biscoito[3], Richard Phillips[4], Francis Zino[5], Jacob González-Solís[1]
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Our current understanding of migratory strategies and the reasons for their high variability along the phylogenetic tree remains relatively poor. Most of the hypotheses relating to migration have been formulated for terrestrial taxa; classically, oceanic migrations were considered as merely dispersive due to the scarcity of observations in the open ocean. We aimed to define the migration strategy of a small and previously untracked seabird, and provide new insights into the ecology and evolution of long-distance marine migrations. Using cutting-edge geolocators, we examined the year- round distribution and at-sea activity patterns of Bulwer's petrel sampled at 5 localities throughout its breeding range in the Atlantic. We assessed the migratory connectivity of the species and its habitat

use at population and meta-population scales. Our results provide the first evidence of an oriented leapfrog migration in oceanic seabirds. Ecological niche models based on breeding-season data effectively predicted that subtropical waters of the South Atlantic would be the preferred habitat for the northern populations during the non-breeding season. Habitat modelling also highlighted similarities in distributions between the breeding and non-breeding periods for the southern populations. Data on activity patterns suggested that birds from the northern and southern populations behave differently during the breeding season, as well as in their northern and southern non-breeding ranges during the wintering period. These results indicate that specific habitat preferences, presumably related to prey availability is the main factor explaining the observed distributions and the leapfrog migration described for Bulwer's petrel. The integration of diverse tracking data from multiple populations across international boundaries and its posterior habitat modelling have to be seen as powerful information to identify important areas common to many marine species in the vast oceanic environment.

**PS2.8 Foraging ecology of Gentoo penguins revealed through tracking and Animal-Borne Camera loggers**

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The Falkland Islands now globally hold the largest population of Gentoo penguins, Pygoscelis papua. Understanding the mechanisms driving their foraging ecology at this archipelago is therefore largely relevant to the species as a whole, and is important for effective conservation management. We use the first combination of TDR, GPS and animal borne camera loggers for a penguin species, coupled with data from stomach content analysis, at multiple sites across the Falklands, to gain insight into Gentoo penguin foraging ecology. The study was conducted during the breeding period, in the austral summer of 2012 and 2013. A total of 90 birds were fitted with both TDR and GPS units, of which 41 also carried cameras. Ninety sevent diet samples were collected, with 26 of these from birds carrying all three instruments. Birds were sampled from three colonies across the archipelago, Steeple Jason in the Northwest, Cow Bay in the Northeast and Bull Roads in the South. GPS data were filtered using a continuous-time correlated random walk model. During all sampling periods, the mean maximum distance from colony, total trip distance and trip duration were greatest at Cow Bay. Similarly, key dive characteristics showed birds to be diving deepest and for greatest duration at Cow Bay. Using filtered location data based on dive position we identified key foraging areas, and determined the most important marine habitat features using Generalized Additive Models. Camera footage, coupled with stomach content analysis, revealed that at Bull Roads where crustaceans dominated the diet, there was a high prevalence of crustaceans in the footage. This was in contrast to Cow Bay, where fish dominated the diet, and minimal crustaceans were seen in the footage. These data increase our knowledge of Gentoo penguin foraging ecology. Notably too, it sheds new light on the use of animal-borne camera loggers as potential indicators of prey availability.

## PS3 Monitoring Diet

**PS3.1 How to do a crap task efficiently: field protocols for DNA dietary scat collection.**

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Dietary studies are fundamental to assess seabird resource requirements, foraging overlaps with fisheries and identify any shifts in prey availability due to ocean warming. Dietary studies also allow seabirds to be used as indicators of change in the marine system. Seabird diet is typically determined by stomach content analysis of prey remains, or stable isotope analysis of blood or feathers. DNA-based dietary analysis is proving to be a highly effective, non-invasive alternative dietary analysis approach for many seabird species, by identifying prey DNA sequences in predator scat samples. To achieve the best results with this approach, it is0important to understand how different variables affect the quality of samples. We conducted field experiments to understand how certain environmental and physiological variables may affect the quantity and quality of diet data. Shy albatross (Thalassarche cauta) scats were collected from Albatross Island off Tasmania, Australia during the austral summer 2014/15. We investigated the longevity of DNA within the exposed scat samples, how substrate type affected the DNA obtained and how fasting during incubation changed prey and parasite prevalence in the scat. These field protocols will enable us to maximise the quantity of data collected and identify any limitations the technique may have in relation to sample acquisition. The use of this dietary technique is ideal for threatened species where minimising disturbance is critical. Understanding seabird dietary needs will further define ecosystem linkages, permitting the institution of improved management and conservation programs.

**PS3.2 Up the shit creek: new sampling method reveals trophic interactions of a specialised seabird**

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Because of difficulties to sample the diet of adult seabirds, only few studies have simultaneously examined the diets of adults and chicks. For some species, such as most terns, it is0often assumed that chicks and adults feed on the same forage species, although central-place foraging theory predicts that single-prey loaders should bring more energy rich prey to their chicks than they feed on themselves. Here we report on a new and easy sampling technique we used to assess the diet composition of adult Sandwich Terns Sterna sandvicensis by collecting faecal samples each week throughout the breeding season. The study shows that the adult diet varies through the breeding period. In the first weeks after egg-laying, adults primarily fed on sandeel, clupeids and Nereid worms (the latter being absent in the chick diet) although most energy was obtained from sandeel. Clupeids became increasingly important, sometimes already early during the egg-period, but in terms of energetic composition herring only became important when the first chicks hatched or shortly thereafter. Surprisingly, the composition of the chicks' diet closely followed that of the adults, suggesting that adults did not select different prey species for their chicks. However, the length of the prey items (especially of clupeids) found in the adult diet was much smaller than that fed to the chicks. Adults thus seemed to adapt prey size (and not prey species) to the energy demands of their growing chicks, but fed on a constant small fish size themselves. These results are in line with the optimal sharing theory depicting that parents should ingest all small prey, and fly off to the colony only with large prey, with the threshold being determined by their relative needs.

**PS3.3 A non-invasive method for studying the diet of a seabird breeding in an intensely exploited marine environment**

Davide Gaglio[1], Timothée Cook[2], Richard Sherley[3], Peter Ryan[1]
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Localised purse-seine fishing effort, in combination with environmental forcing, is considered to be the main cause for decreases in several endemic seabird species in the Benguela ecosystem. South African populations of African Penguin Spheniscus demersus, Cape Gannet Morus capensis and Cape Cormorant Phalacrocorax capensis, which rely on small pelagic fish (southern African Sardine Sardinops sagax and Cape Anchovy Engraulis encrasicolus), have all decreased over the last few decades and are listed as threatened. In contrast the population of Swift Terns Thalasseus bergii has increased over the same period. The different responses of the four seabird species to an altered distribution of prey are likely to be related to their life-history traits and foraging ecology, but the influencing factors remain poorly understood. Since 2013 we have investigated the foraging strategies of Swift Terns in the Western Cape, South Africa. Diet of Swift Terns was assessed using a novel non-invasive methodology that uses digital photography. More than 12,000 prey items were identified over two breeding seasons, and the technique was compared to more traditional prey sampling based on chick regurgitations. Standard lengths of fish were estimated relative to tern bill size and fish mass estimated using length-weight regressions. Results show that the main source of food is Anchovy (70%) which averaged 80-100 mm long. However, a wide range of other prey was also captured including cephalopods and arthropods. Spatio-temporal variation of Swift Tern diet was assessed and compared to data previously collected in the Western Cape in 1977-1986. Understanding how Swift Terns cope with local reductions in pelagic fish availability is vital for assessing the impact of commercial fisheries on seabird populations and fish stocks.

**PS3.4 Intra-annual variation in the foraging ecology of a threatened endemic tropical gadfly petrel: insights from a multi-faceted approach.**

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Population modelling for one of Reunion Island's endemic gadfly petrels, the Barau's Petrel (Pterodroma baraui), indicates that it is threatened with extinction. As an island endemic, it has adapted to specific environmental conditions, which implies a lack of plasticity and, therefore, vulnerability to abrupt environmental alterations such as those bought about by global climate change. The effective conservation of the species demands information on its biology and ecology during the different stages of its life cycle. Many aspects of the Barau's Petrels' terrestrial ecology have now been studied, but at-sea information is scarce and the material that exists is somewhat contradictory. For that reason, we combined stomach content, stable isotope, and qualitative fatty acid analyses to provide new accurate information on its at-sea feeding ecology. This allowed us to identify potential threats at sea and to investigate this bird's role in marine ecosystems of the Indian Ocean. Stomach contents consisted mostly of cephalopods whereas fishes, molluscs, arthropods, and crustaceans were infrequently encountered. The total fatty acid composition of blood differed considerably among individuals, but the low incidences of long-chain monounsaturated and n-3 lipids further discounted fish as important dietary constituents. Variations in δ15N indicated dietary

opportunism and highlighted a reliance on capital reserves during breeding. Finally, although baseline signatures are scarce, δ13C analysis confirmed the patterns of foraging behaviour as recently described using telemetry. These results imply some degree of resilience against shifts in prey availability, but confirm that successful reproduction is dependent on distant foraging areas. This implies vulnerability as over-investing in a single breeding episode may jeopardize survival and future fecundity.

**PS3.5 Partitioning of food and habitat by three coastal breeding terns and gulls in West-Africa**

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From 1998 onwards seabird breeding and feeding was monitored in colonies between Guinea and Mauritania. The most detailed data and longest time-series were obtained from Royal Terns Thalasseus maximus, Caspians Terns Hydroprogne caspia and Slender-billed Gulls Chroicocephalus genei breeding in the Saloum Delta National Park (PNDS) in Senegal. In all countries agents from National Park Services were trained in basic monitoring techniques. Parameters studied included number of breeding pairs, clutch and egg size and chick condition. Food was studied by analysis of fish otoliths in faeces and regurgitated pellets and feeding ranges were established since 2014 by the use of solar-powered data loggers (UvA-BiTS). Royal Terns had the largest feeding range, extending to the shelf break. Diet was rather divers, including deep sea species likely obtained while feeding on by-catch from trawlers. A significant correlation was obtained between the number of breeding pairs and the percentage of Carangidae (predominantly Trachurus sp.) in the diet. Caspian Terns had coastal feeding ranges mainly in waters less than 20 m of depth. Number of breeding pairs correlated best with the proportion of Mugilidae in diet. Annual chick condition did not significantly deviate from the long-year mean but younger chicks had a significantly lower condition index than older chicks. Slender-billed Gulls had the most coastal feeding range, generally in waters less than 5 m of depth and often including inland creeks. Number of breeding pairs correlated best with the proportion of Cichlidae in diet.

**PS3.6 Change in between- and within-individual variation in resource utilisation in gulls over the last 4 decades**

Ruedi Nager[1], Nina O'Hanlon[1], James Grecian[1]
*[1]University of Glasgow*

Many populations have shown changes in population size over the past decade, but the drivers of these changes are often poorly understood. Resource availability, during the breeding or non-breeding season, is one of the most important factors determining changes in animal populations. Thus identifying patterns of resource utilization are critical to understanding animal ecology. As a top-predator, seabirds are effective samplers of prey populations and their diet provides information on lower trophic levels in their foraging habitat. We explore the temporal variation in resource utilization of gulls in UK coastal waters during the breeding and non-breeding season. In the UK gulls showed large population declines in some regions but not in others. The challenge, however, is gathering information on resource utilization in the past. Foraging birds will incorporate a signature of what resources they used into feathers and thus museum skins carry a record of resource use in

the past that can be revealed using stable isotope analyses. Using feathers grown at different times of the year we can also study within-individual variation. at the data are complemented with a survey of published records of diet composition from the literature. As the state of marine coastal waters in the UK has changed dramatically in recent decades, we expect strong temporal changes in composition, breadth and diversity of the foraging niche and individual resource specialization. In particular we expect that as the ecosystem health of coastal waters declines, Herring Gulls increasingly diversify their foraging niche by including alternative resources into their diet, reflected in increased within-individual variability between breeding and non-breeding season as well as larger variability between individuals. Resource utilization may also differ between populations with different population trajectories and such knowledge may help to identifying potential drivers of population changes.

**PS3.7 Decadal change in the diet of Cape gannets reflects demographic and distributional shifts in commercially important prey species**

David Green[1], Norbert Klages[2], Robert Crawford[3], Janet Coetzee[4], Bruce Dyer[3], Gavin Rishworth[1], Pierre Pistorius[1]

*[1]Nelson Mandela Metropolitan University, [2]Private Consultant, [3]Oceans and Coasts, Department of Environmental Affairs, [4]Fisheries Branch, Department of Agriculture, Forestry and Fisheries*

As upper trophic level predators seabirds are often highly sensitive to changes in the availability of their prey. It follows that fluctuations in oceanographic conditions, which alter prey assemblages, may be reflected by shifts in seabird diet. Consequently, long-term studies of seabird diet can provide valuable insight into the nature of environmental shifts within the systems in which they forage. In recent decades, the Agulhas region in South Africa has undergone significant oceanographic change related to warming and intensification of the Agulhas current. Concurrent with this change, the population of Cape gannets Morus capensis at Bird Island, Algoa Bay, has grown rapidly, probably as a result of an increased availability of its dominant prey items, sardine Sardinops sagax and anchovy Engraulis encrasicolus. Using one of the longest and most complete time-series available on diet of a seabird (spanning 34 years), we tested for changes in composition and the abundance of dominant prey species of this population. These observed changes were also compared with acoustic survey estimates of their biomass, and annual catch data. Since 1979, the dietary contribution of sardine and anchovy fluctuated inversely to each other, being reflective of demographic and distributional shifts in these prey species. Conversely, a third species, saury Scomberesox saurus, dominant in the non-breeding diet of the 1980s, decreased significantly in dietary abundance over the following two decades. It is likely that dietary shifts of Cape gannets at Bird Island were ultimately related to climate-mediated oceanographic change.

**PS3.8 Trophic structure of seabirds in the Canary Current using stable isotopes**

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Studying the trophic structure of seabird communities is basic to understand their role in food webs and to achieve goals for their conservation. Although trophic ecology of breeding animals has been broadly studied, barely nothing is known about wintering ones due to their inaccessibility in this period, where they migrate to high productive areas such as upwelling systems. The Canary Current Large Marine Ecosystem (CCLME) in one of four major eastern boundary upwelling systems in the

planet, supporting complex communities of seabirds all year round, although its composition shifts from mainly oceanic species in the breeding season to mainly neritic ones in winter. Moreover, the CCLME also supports large but poorly regulated fisheries but little is known about the dependence of seabirds on fishery discards, a key issue in political management. In this study, we aim to understand the trophic structure of both breeding/oceanic and wintering/neritic seabird communities across the CCLME. We collated stable isotope data from fish, cephalopod and crustacean species. Regarding seabirds, we collated stable isotope data of relevant feathers from a total of thirteen seabird species. In the case of the wintering species, birds were previously tracked with GLS to ensure they spent the winter in the CCLME. Functional groups of prey segregated in the isotopic space, with demersal fishes showing more enriched δ15N values than pelagic ones. Both, seabirds and prey from the neritic environment showed more enriched δ13C and δ15N values than those of the oceanic environment. Within each environment, all seabird species were placed in a relatively small isotopic space, presumably feeding on naturally caught preys and excluding a clear dependence on discards. This is the first study that combines GLS data and isotopes from seabirds and their prey to understand their trophic and spatial community structure and provide useful information for their management.

## PS4 Fishery Bycatch 1 - Assessment

### PS4.1 Global patterns of sex and age-specific variation in seabird bycatch: a review

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Fisheries bycatch is a major threat to seabird populations worldwide, with mortality rates leading to steep population declines of several species. However bycatch can vary greatly within species. Understanding such sex and age-biased variation in bycatch rates is important for to develop an accurate assessment of the population-level impacts of this mortality. Here we reviewed the literature reporting sex and age composition of seabird bycatch in global fisheries and investigated how region, fishery type and foraging behaviour interact with such intraspecific variation. We found 35 studies reporting sex and age composition of seabird bycatch. The sampling unit for bycatch data, here called "report", was a single taxon from a single study - reported by gear type. Thus, most of the studies contain many reports. When possible, bycatch rates were separated by region and season. The data comprise 87 reports of sex and 75 of age proportions of seabird caught in four main types of fisheries (bottom and pelagic longline, gillnet and trawl), and include 36 seabird taxa. 40 % of the reports of sex ratios showed not bias; 40 % were male-biased and 20 % were female-biased. Biased sex-ratios also varied by location. We found a significantly higher frequency of male-biased bycatch in sub-Antarctic, whereas there was a significantly higher female biased mortality in subtropical waters. For studies reporting age-composition, 53 % were adult-biased, 36 % were immature-biased and 11 % were not biased. Differential at-sea distribution of sexes and age classes appears to be the better explanation for the sex and age-biased seabird bycatch observed in global fisheries. Modelling impacts of fisheries on seabirds population should taking into account this age and sex-specific differences in survival.

### PS4.2 Bycatch distribution of seabird bycatch in longline fisheries in all southern hemisphere

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In the pelagic, seabird especially Procellariiformes gather around the longline vessel to get the bait and occasionally are caught by accident, which is called bycatch. Bycatch seems one of cause of the some albatross population decline. Thus, several measures to mitigate seabird bycatch were developed. Recently, new mitigation measure was introduced in particular area of southern hemisphere. To improve the relationship between seabirds and human activity sustainably, it is0crucial to examine that the mitigation measure apply enough/appropriate area. However, the bycatch distribution of each species in southern hemisphere has been rarely reported so far. Our study aim to show the bycatch rate of albatrosses in each species in the southern hemisphere to help the assessment of the effect of newly introduced bycatch mitigation measure. We used Japanese scientific observer data to show the bycatch distribution. Species and sex of the bycaught albatross were defined by molecular biological technique and age of them were defined from feather and bill color from photo by experts. The number of bycatch in pelagic longline fisheries was the highest in the grey-headed albatross (Thalassarche chrysostoma), and after that, was observed in the yellow-nosed albatross group (T. chlororhynchos/carteri), the black-browed albatross group (T. melanophris/impavida), the wandering albatross group (Diomedea exulans/dabbenena/gibsoni/antipodensis), the white-chinned petrels (Procellaria aequinoctialis) in that order. As a whole, bycatch of albatross occurred in south of a latitude of 30 degrees south. Bycatch of grey-headed albatross was occurred in south of a latitude of 35 degree. Bycatch of some of wandering albatross group mainly occurred in south of a latitude of 35 degrees south, too. And bycatch of black-browed albatross group mainly occurred off South Africa and eastern Indian Ocean. We would discuss the distribution of bycatch albatrosses in each species.

**PS4.3 Climate change impacts on pelagic longline effort in the southern Indian Ocean: towards projecting climate-change induced changes in bycatch & population viability**

Pamela Michael[1], Chris Wilcox[2], Geoffery Tuck[2], Alistair Hobday[2], Peter Strutton[3], Christophe Barbraud[4]

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The Southern Ocean is a region of highly concentrated industrial longline fishing, with considerable fishing effort in the Indian Ocean south of 30˚S, which has been associated with albatross abundance declines. Climate change presents an additional challenge to understanding and managing this complex system. Specifically, tuna distributions are likely to shift, impacting fleet dynamics and distribution. Albatross distributions are also likely to shift, resulting in an unquantified overlap with future fishing effort and subsequent population impacts. To assess the impacts of climate change on the distribution of tuna, Japanese and Taiwanese industrial longline fleets, and albatross, a broad suite of information will be used. Here we report on fleet dynamics modeled at a monthly, 5 x 5 degree scale with fishing effort distribution influenced by the relative value of four tuna species, historic species-specific catch patterns, and the relative cost of fishing by time and area. An ensemble of climate change models provide the environmental variables used to project the distribution of each tuna species. Each fleet then allocates effort based on the relative value and cost of each fishing location. Historic demographic and distribution data from black-browed

albatross will be projected using environmental variables from the above ensemble. The potential bycatch from the projected overlap with fishing fleets will be quantified and used to infer the viability of the population. By incorporating climate change direct and indirect impacts on Indian Ocean black-browed albatross, novel insight into options to manage, mitigate, or compensate for future impacts will be generated.

**PS4.4 Interaction between wandering albatrosses and Atlantic pelagic longline fisheries: bycatch rates reflect bird-vessel overlap and estimated mortality risk**

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Wandering albatrosses (Diomedea exulans) at South Georgia are decreasing dramatically, mainly resulting from bycatch in longline fisheries. Until at least the early 1990s, the survival rate of adult females was lower than that of males, consistent with a sex-bias in bycatch reported for fisheries in the Brazil-Falklands Confluence (BFC) region. Here we use extensive tracking data (1990-2012) from breeding wandering albatrosses to examine their overlap with fishing effort reported to the Atlantic tuna commission (ICCAT). Analyses of data from multiple years indicated that breeding females have been at consistently higher risk than males from all the main pelagic longline fleets in the southwest Atlantic. The overlap index, based on the distribution of fishing effort and tracked birds, correlated positively with the number of ringed birds reported dead on longliners, and was therefore a good proxy for bycatch risk. The index also reflected substantial seasonal variation in interaction risk; overlap with pelagic longline effort was moderate during incubation, high during the post-brood chick-rearing period and negligible during brooding. The greatest overlap for both sexes was with the Taiwanese fleet, followed by vessels flagged to Brazil, Uruguay, Spain, Japan and Portugal. Females were consistently at greatest risk in the BFC region, whereas males showed lower and more variable levels of overlap with fisheries in latitudes from 35° to 45°S. By analyzing detailed bycatch data from great albatrosses (Diomedea spp.) collected by observers on board the Uruguayan fleet (2004-2011) and on Japanese vessels operating in Uruguay under an experimental fishing license (2009-2011), we confirmed the areas and seasons of greater risk as well as the presumed sex-biased mortality. We also determined a range of vessel operational practices and habitat variables affecting bycatch rates. Together, these results have major implications for the management of ICCAT longline fisheries.

**PS4.5 Exporting seabird by-catch: concentration of seabird foraging activity and fisheries interactions around closure areas**

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Fisheries are one of the main threats affecting the survival of seabirds around the globe. Fisheries management (e.g. fishing quotas, closures) may impact on a range of seabirds' traits such as foraging behavior. There is an extensive fishing closure in the Patagonian Shelf (120,000 km2) where trawling is banned. The concentration of fishing effort in the boundary of this area and the strong overlapping with the distribution of seabirds triggered the question of a potential exacerbated

negative effect of bycatch in such border area. Hence, this study was conducted having as main objectives: (1) the analysis of the effect of fishing closures on the flight patterns of Black-browed Albatrosses and Southern Giant Petrels, and (2) the analysis in space and time of seabird-fisheries interactions (i.e. contacts with the fishing gear as a proxy of risk of mortality) in relation to the fishing closure. For this, 55 satellite transmitters were deployed on the birds between 1999 and 2013. Discrete behavioral mode (foraging vs. transiting) was inferred from satellite transmitters using state-space models. Seabird bycatch data were obtained from on-board observers. The spatial density for each behavioral mode and the bycatch was determined by performing a Kernel analysis. Foraging in both species was mainly concentrated on the border of the fishing closure. However, the fishing closure did not influence transiting behavior. Seabird-fishery interactions were concentrated in the external boundary of the fishing closure (50% of the interactions in 70.000 km2) in relation with other areas distant to the closure. The study highlights that, although seabird bycatch inside closure areas is null, the "exporting effect" due to the concentration of fishing effort and seabird foraging in border areas may increase seabird by-catch in the neighboring waters. Hence, the design of management measures for seabird by-catch should contemplate regulations to address these negative side effects.

**PS4.6 Phoebastria, proxies and probabilities: estimating albatross bycatch in U.S. West Coast groundfish fisheries**

Thomas Good[1], Jason Jannot[1], Eric Ward[1]
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In 2011, a short-tailed albatross (Phoebastria albatrus) was reported caught and killed in the limited-entry sablefish longline fishery approximately 65 kilometers off the Oregon coast, U.S.A. While mortality caused by fisheries is a key threat affecting the species' recovery, bycatch of short-tailed albatross in U.S. Pacific Coast groundfish fisheries is so rare that estimating bycatch for various groundfish fleets and for the combined U.S. Pacific Coast groundfish fisheries is difficult. In cases when endangered species are too rare for quantifying the effects of an activity, federal agencies often rely on a proxy or surrogate species in the estimation process. In the case of the short-tailed albatross, patterns of North Pacific distribution, habitat use, and feeding behavior all support using black-footed albatross (Phoebastria nigripes) as a proxy species. Moreover, both species have been documented as bycatch in Pacific Coast and Alaskan groundfish fisheries, and the incidental takes of both species have occurred in similar habitats and areas. The bycatch estimation by proxy method, reported in a 2012 U.S. Fish and Wildlife Service Biological Opinion on the continued operation of the Pacific Coast Groundfish Fishery, estimated an annual take of one short-tailed albatross in U.S. Pacific Coast groundfish fisheries. These efforts have: led to biennial reporting of short-tailed albatross bycatch estimates from these fisheries, elevated the importance of accurate estimation of black-footed albatross bycatch, and helped lead to the establishment of a seabird bycatch avoidance program in the U.S. Pacific Coast longline sablefish fishery. We will present bycatch estimates for short-tailed albatross and black-footed albatross in U.S. Pacific Coast groundfish fisheries, compare the proxy method to short-tailed albatross bycatch data for comparable North Pacific fisheries, and explore bycatch estimation for extremely rare events using probabilistic modeling.

**PS4.7 A review of seabird bycatch in three South African fisheries and the impact of monitoring and legislation for management**

Bokamoso Lebepe[1], Ross Wanless[1]
*[1]BirdLife South Africa*

Accidental mortality during fishing activities in longline and trawl fisheries was a major threat to many seabird species in South African waters. In 2006 BirdLife International established the Albatross Task Force (ATF), initially in South Africa and now active in eight countries. Prior to the introduction of bycatch mitigation measures, seabird mortalities were up to 0.44 birds/1000 hooks on pelagic longlines, 0.033 birds/1000 hooks on demersal longline, and 0.56 birds/hour, on demersal trawl vessels. The ATF has worked onboard to assess the scale of seabird bycatch, trial mitigation measures, and work with fisheries and government to adopt regulations. Once in place, the ATF has undertaken monitoring to assess the level of compliance with regulations, and to refine and adjust measures where possible, to ensure that fishers can contribute actively towards improving seabird bycatch reductions. The success of this approach is evident by significant reductions in seabird bycatch pelagic longline (0.062 birds/1000 hooks, 86%), demersal longline (0.0017 birds/1000 hooks, 95%), and demersal trawl (0.15 birds/ hour, 75%). These successes demonstrate several things. First, reducing catastrophic bycatch is entirely possible without significant cost/implications. Second, collaborative approaches coupled with regulations are very effective. Third, ongoing monitoring and industry-independent verification is required to ensure paper regulations are adhered to and non-compliance to legislated seabird regulations is reduced in order to address seabird bycatch in fisheries globally.

**PS4.8 Seabird bycatch and mitigation in the South-Central Chilean trawl fishery**

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Seabird mortality was evaluated through direct observation on demersal trawl vessels in the south-central Chilean industrial trawl fishery for hake Merluccius gayi gayi, between June 2011 and August 2013 including a total of 25 at-sea trips and 266 trawls, totalling 706.9 hours observation effort. A total of 201 individuals were recorded as injured and a further 84 individuals were recorded killed during the study period. During the post-breeding dispersal in the winter period (autumn-winter), there was a higher frequency of mortality events that were related to different components of the fishing gear such as warp, netsonde cables and net entanglement. The black-browed albatross Thalassarche melanophrys (45.2%), Peruvian pelican Pelecanus thagus (17.9%) and Salvin's albatross T. salvini (16.7%) were among the main species affected. Using fishery effort data provided by the Subsecretaria de Pesca, the first annual mortality estimate was produced suggesting 890 (438-1,418) birds are killed in this fishery per year through interactions with trawl cables and the third wire. The use of a bird-scaring line as a mitigation measure eliminated cable-related seabird mortality. KEY WORDS: Seabird bycatch, trawler, Chilean hake, Merluccius gayi gayi, bird-scaring lines, warp cable, netsonde cable.

## S1 Individual Variation in Movement Strategies I

**S1.1 Cognitive mechanisms of seabird navigation**

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Perrins[1]
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Both in foraging and in migration the directed long-distance movements of pelagic seabirds are amongst the most remarkable on earth, yet our understanding of how birds navigate oceanic journeys lags far behind what we know about terrestrial navigation. As it has recently with terrestrial bird navigation, the analysis of individual route variability and fidelity offers a new window onto the cognitive mechanisms of seabird navigation, which I will explore using both theoretical perspectives and tracking data from our own research on several species of European breeding shearwater and auk.

**S1.2 Seabirds mated for life migrate separately to the same places: behavioral coordination or shared proximate causes?**

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Long-term pair bonds occur in most seabirds, but little is known about whether members of a breeding pair migrate together. This gap in knowledge is primarily due to past methodological difficulties in tracking long-term, large-scale movements of individuals. However, the development of new animal-borne geolocation devices has enabled researchers to track movements of individuals for a year or more. We tracked the annual migrations of breeding pairs of Scopoli's shearwaters and found striking individual consistency and sex differences in migration strategies. We also found that partners did not migrate together, but they did spend a similar number of days travelling to and from similar terminal wintering areas. Though migration destinations were alike, they were not identical. That partners did not appear to travel or spend time together in the non-breeding season suggests that similarities were not due to behavioural coordination. We performed additional analyses to uncover alternative, potential proximate mechanisms. First, we found that body mass of breeding adults during the chick-rearing period correlated positively with the decision to migrate farther south, so conceivably pair members might migrate to similar areas because of shared reproductive costs; however, partners were not of similar body mass. Distances between wintering areas among individuals from more closely neighbouring nests were smaller than among individuals with more distant nests. As neighbours tend to be more closely related due to high natal philopatry, this suggests that pair similarity in migration behaviour may reflect the influence of shared genes on migration strategy.

**S1.3 Inter-individual differences in the wintering strategies of Northern gannets (Morus bassanus)**

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Inter-individual variation in migratory behaviour is likely to have important ecological, evolutionary and conservation implications. Gannets tracked over multiple seasons from breeding colonies in the Northeast Atlantic displayed high levels of winter-site fidelity and dietary consistency. Analysis of feather stable isotopes revealed individuals exhibited one of three foraging strategies differing in trophic (δ15N) and habitat (δ13C) specialization. Individual variation in foraging behaviour within strategy was a consequence of pre-winter condition. Furthermore, pre-winter condition limited

migration strategy, which impacted diet and breeding onset. Interactions between foraging behaviour and migration strategies will have consequences for our understanding of carry-over effects.

**S1.4 Carry-over effects of stress incurred during reproduction on migration and telomere dynamics of Pacific black-legged kittiwakes**

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Both the intrinsic state of animals and environmental conditions interact to influence how animals move across landscapes. Here, we investigate carry-over effects of nutritional stress incurred during reproduction on the wintering movements, activity budgets, and telomere dynamics of black-legged kittiwakes breeding on two major colonies in the Bering Sea during 2008-2011. We found that individuals varied in their levels of stress incurred during reproduction and wintering areas possibly reflecting trade-offs between reproduction and longevity. We discuss inter-population differences in carry-over effects between "slow-living" Pacific kittiwakes with their "fast-living" Atlantic con-specifics.

**S1.5 Causes and consequences of within individual foraging strategies in albatrosses**

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Consistent individual foraging strategies are widely reported and demonstrate population level specialisation. However, while within individual specialisation is apparent from diet studies, little is known about causes and consequences of within individual plasticity and variability in behaviour. Here we examine the intrinsic drivers of such variation, testing for sex, personality and genetic correlates. We report how asymmetrical selective pressures among groups may drive differences in plasticity and variability, and demonstrate the importance of interactions between intrinsic traits and the environment on determining the fitness of individuals.

## S2 Seabirds and Indicators of Ocean Health I

**S2.1 What can Canadian Arctic seabirds tell us about changing emission patterns of contaminants?**

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Environmental contaminants are a global problem, and their presence in the Arctic reflects the way in which the Arctic interacts with the rest of the world. By examining contaminant levels in wildlife such as seabirds, we can look for the arrival of new contaminants in the Arctic, as well as determine whether existing chemical contaminants of concern are increasing or decreasing. Eggs of thick-billed murres (Uria lomvia), northern fulmars (Fulmarus glacialis) and black-legged kittiwakes (Rissa tridactyla) breeding on Prince Leopold Island (74°N, 90°W) in Lancaster Sound in the Canadian Arctic have been monitored for environmental contaminants since 1975. Concentrations of most legacy organochlorines such as the polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT) in arctic seabird eggs have declined significantly over the past several decades. Brominated flame retardants, such as the polybrominated diphenyl ethers (PBDEs), have increased in eggs of

thick-billed murres and northern fulmars between 1975 and 2005-2006 after which time levels declined, likely reflecting the phase-out of certain technical products. Concentrations of poly- and perfluorinated organic compounds such perfluorooctane sulfonate (PFOS) and the perfluorinated carboxylates (PFCAs) in the murre and fulmar eggs remained unchanged for several decades but have recently started to decline, which may reflect recent initiatives to reduce emissions of these compounds. In contrast, concentrations of Hg have been increasing in seabird eggs from the Canadian high Arctic. We examine the temporal trends of several contaminant groups in arctic seabird eggs in the context of emission patterns and initiatives to reduce those emissions, illustrating how seabirds make good indicators of the changing levels of contaminants in the marine environment.

**S2.2 Do long-term variations of Hg levels in Arctic seabirds reflect changes of the global environmental contamination or a modification of Arctic marine food web functioning?**

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Studying long-term trends of mercury (Hg) in arctic marine food-webs has been declared as a priority to better understand impacts of global change on the exposure of arctic species. However, detailed at-sea investigations in the Arctic are extremely challenging. Hence, most of the long-term monitoring programs have focused on large top-predators while Hg contamination studies of lower trophic levels are particularly limited. In this context, seabirds have been proved to be efficient indicators of the short-term environmental contamination, reflecting the contamination of lower trophic levels. Nonetheless, their use as bio-indicators in long-term studies is still limited by the difficulty to understand the drivers of measured trends: do long-term changes in seabirds reflect a general change of the food-web contamination or do they rather reflect a modification of their trophic ecology? Discriminate and evaluate the role of these drivers is therefore essential. In the present study, we aimed to determine if little auks can be used as bio-indicators of long-term changes of the environmental contamination. To this end, we measured long-term (2007-2013) changes in the Hg levels and isotopic niche of breeding little auks (Alle alle) from East Greenland. Concurrently, Hg levels were measured for the same period and at the same site in major zooplankton species consumed by these birds. Obtained results show an increased Hg contamination in breeding little auks over the study period (+65%). This trend was not related to a change of little auk trophic status (δ15N) or feeding habitat (δ13C). However, we found that Hg concentrations have also increased over the last years in three of their main prey: Calanus sp., Themisto libellula and fish larvae. These results confirm the growing contamination threat faced by East Greenland marine ecosystems, and validate the use of little auks as bio-indicators of long-term Arctic marine food-web Hg contamination.

**S2.3 Influence of non-breeding areas on heavy metal concentrations in Cory's Shearwaters**

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Environmental pollution is one of the major anthropogenic threats that seabirds face at sea. Due to their life history traits and trophic position, seabird are particularly vulnerable to contaminants that bioaccumulate with time and biomagnify through the food chain, such as Hg. Moreover, seabirds

can be exposed to contaminants from different areas over their migration cycle, but the influence in choosing a specific non-breeding area on heavy metals levels is poorly understood. Cory's shearwaters (Calonectris borealis) show a wide intra-population variability in the use of non-breeding areas within the Atlantic (the two main areas for this population are the Benguela and Canary current systems), thus making them an excellent candidate to study the influence of non-breeding areas on metal concentrations. To do so, we used information from geolocation and stable isotope analyses to infer the non-breeding areas of shearwaters breeding on Gran Canaria (Canary Islands). We then measured Hg, Cd and Cu in whole-blood samples of shearwaters that just returned to this breeding site after migration, and re-sampled them every 10 days (whenever possible), totalling up to 6 samples per bird. Birds arriving from wintering grounds surrounding the Benguela current showed significantly greater levels of Hg, Cd and Cu than those that remained in the Canary Current. Hg and Cd concentrations possibly resulted from differences in diet at the two non-breeding areas rather than differences in baseline levels of these elements between the two currents, whereas the reverse seemed to be true for Cu levels. Over the first two months in their breeding site Hg levels in blood progressively increased suggesting birds excrete this element in feathers during the winter moult. This study shows that the dynamics of heavy metals in blood can be influenced by the different exposure of birds over their migration cycle as well as by the timing of moulting.

**S2.4 From Antarctica to the subtropics: latitudinal differences in trace element and organic pollutant contamination in Southern Ocean skuas (Catharacta spp.)**

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Seabirds integrate bioaccumulative contaminants via food intake and have revealed geographical trends of contamination in a variety of ecosystems. Pre-fledging seabird chicks are particularly interesting as bioindicators of chemical contamination, because their food and their parents' foraging ecology during the chick-rearing period are relatively well-known. Thus, concentrations in chick tissues are easily related to dietary sources and represent the local environment. Here we measured mercury (Hg) and 13 other trace elements, and persistent organic pollutants (POPs, including organochlorine pesticides and polychlorinated biphenyls) in blood of skua chicks from 4 breeding locations that encompass a wide latitudinal range in the southern Indian Ocean: from Antarctica (Terre Adélie, Catharacta maccormicki), through subantarctic areas (Crozet and Kerguelen Islands, C. lonnbergi), to the subtropics (Amsterdam Island, C. lonnbergi). Levels of the highly-toxic Hg increased from chicks in Antarctica to chicks in the subantarctic and subtropical islands, with a factor of 8 between the populations with the lowest and highest burdens (0.5 ± 0.1 vs. 4.0 ± 0.8 µg/g dry weight, mean ± SD, at Terre Adélie and Amsterdam Island, respectively). Interestingly, selenium (Se) showed similar between-site differences to Hg, suggesting its protective role against Hg toxicity. Blood Hg and Se levels of Amsterdam Island skuas were among the highest ever reported in seabird chicks worldwide. The POPs pattern was largely dominated by pesticides, mainly DDT derivatives, the fungicide hexachlorobenzene and the insecticide mirex. This testifies to the current use of organochlorine pesticides in the Southern Hemisphere. Skua chicks from subantarctic islands presented higher POPs levels than the subtropical and Antarctic populations. Latitudinal differences in contamination are discussed in the light of skua feeding ecology, and of previous knowledge on contaminant transfer in the Southern Ocean.

**S2.5 Chemical markers of tracked shearwaters as indicators of marine environment**

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Warming trend, fisheries, and pollution may impact offshore ecosystems. Monitoring these ecosystems, however, is logistically challenging. To use seabirds as the monitors (Ramos, Gonzales-Solis 2012), our group 1) tracked the year-round movements of two species of migrant (streaked-shearwaters, SKSH; short-tailed shearwaters, STSH) by geolocators and 2) measured the mercury (Hg) in the breast-feathers, that were inferred to replace during breeding, and the outermost primary (P10) or tail-feathers (R6), that were inferred to replace during non-breeding. SKSH used the western North Pacific during breeding and the sea off southeastern Asia during non-breeding, while STSH used the Antarctic Sea during breeding and the northern North Pacific during non-breeding; with large individual variation in the wintering ground. Breast feather [Hg] was high (6ppm) in SKSH, while low (1 ppm) in STSH. Hg in P10 of STSH and R6 of SKSH showed large individual variation across the non-breeding ground: high in birds spent non-breeding in South China Sea (2.5 ppm) and Okhotsk-northern Japan Sea (2.5 ppm). There were regional and individual variation in the nitrogen (δ15N) and carbon stable isotope ratio, while effects of δ15N, a proxy of trophic level, on mercury contents was not obvious. With more knowledge of molting pattern, turnover rate and metabolism of chemical markers, and bio-magnification factor and base-line marine iso-scape, the chemical markers in the bird tissues conjunction with tracking data can make seabirds as more useful sentinel of marine ecosystems in ecologically and biologically significant areas.

## S3 Evolutionary Physiology

**S3.1 Micro- and macroevolutionary perspectives on the physiology-life history nexus in seabirds**

Craig White[1]
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Seabirds generally have slow life histories and exhibit long lifespans, small clutches, and extended periods of parental care. The repeated evolution of these slow life histories provides a natural experiment within which to examine the role played by life history in the evolution of physiological diversity. In this presentation, I will provide an overview of the tools of evolutionary physiology, focusing on the multivariate relationships among physiological and life history traits (the "physiology-life history nexus"). I will draw upon quantitative genetic and experimental evolution studies of model and non-model species to provide a background to the microevolutionary processes that shape the physiology-life history nexus, and compare the patterns observed at the microevolutionary scale with those observed at the macroevolutionary scale.

**S3.2 Preserved in salt: two charadriiform seabirds show few signs of ageing**

Kyle Elliott[1]
[1]*McGill University*

A substantial proportion of mortality in long-lived wild animals is believed to be associated with senescence. However, several studies have failed to detect physiological senescence in long-lived wild animals, especially seabirds. Most studies to date have examined only a single parameter or parameters associated with only a single physiological system. I assessed 29 physiological traits and

seven behavioural traits alongside five demographic parameters in two species of long-lived wild charadriiform seabirds (thick-billed murres Uria lomvia and black-legged kittiwakes Rissa tridactyla). For many of the parameters, I obtained values three years later from the same individual, demonstrating that patterns occurred longitudinally within individuals and were thus not attributable to the selective appearance or disappearance of individuals. Mortality increased with age, whereas reproductive success peaked at middle ages. There was no relationship between age and egg size, clutch size or either circulating or LHRH-induced levels of testosterone and estradiol, implying no senescence in reproductive systems. There was also no change in diet, foraging locations, chick provisioning/growth rate or time budgets with age, and consequently daily energy expenditure did not change with age. In contrast, several measures of resting metabolic rate or antioxidant capability changed with age in one or both species, suggesting increased oxidative stress as the animal ages. Cell-mediated immune function declined with age, whereas antibody-mediated immune function did not change with age, as individuals switched from innate to memory-based defenses. Cholesterol increased while hematocrit decreased with age. Although all individuals faced the same overall energy ceiling, birds from different age classes directed that energy towards different components (resting metabolism, antioxidants, immunity). In general, many of the biomarkers of mammalian ageing did not vary with age in seabirds.

**S3.3 The stress response of seabirds: mechanisms, sources of variation and an evolutionary perspective**

Olivier Chastel[1], Frederic Angelier[1], Aurelie Goutte[1], Sabrina Tartu[1]
*[1]CNRS*

vertebrates, stressors such as food shortage or predator attacks stimulate the rapid elevation of circulating glucocorticoid hormones (the so called "stress hormones" like corticosterone in birds). Indeed, the release of glucocorticoids during stressful perturbations is predicted to trigger physiological and behavioral adjustments that shift energy investment away from reproduction and redirects it towards survival. The acute hormonal response to stress is also known to be highly variable among individuals and between species but the source of such variation is often difficult to explain. In this talk, we will present correlative, experimental as well as comparative evidences in seabirds showing that individual features like age, breeding experience, quality, as well as species life-history traits can explain a significant part of the typical large variance observed in the acute stress response. These results will be discussed in an evolutionary framework and we will test if the observed within-individual and between species variance in the stress response support the hypothesis that individuals and species actively modulate their stress response with respect to the value of current reproduction ("the brood value hypothesis": i.e., the stress response should be attenuated when the brood/fitness value is the highest). We will then broaden the discussion on other potential sources of variation for the seabird stress response such as environmental contaminants (Persistent organic pollutants such as pesticides and PCBs).

**S3.4 Physiological mechanisms underlying fitness variation in an Arctic-breeding seabird**

Oliver Love[1], Holly Hennin[1], Pierre Legagneux[2], Constance O'Connor[1], Joël Bêty[2], Sebastien Descamps[3], Grant Gilchrist[4]
*[1]University of Windsor, [2]Université du Québec à Rimouski, [3]Norwegian Polar Institute, [4]Environment Canada*

Population and ecosystem health are driven by the capacity of individuals to maximize their fitness under continuously changing environmental conditions. Since physiological function directly mediates the relationship of the organism to its environment, physiological traits are useful to study as regulators of the life-history decisions and trade-offs that shape variation in fitness. Since 2003 we have been examining the pre-breeding physiological mechanisms at the heart of reproductive decisions, trade-offs and fitness in a population of Arctic-breeding common eiders at East bay, Nunavut, Canada. Targeting pre-breeding birds which have not yet committed to reproduction, we have focused on baseline levels of key energetic physiological traits (e.g., corticosterone, energetic metabolites, thyroid hormones) thought to mediate investment decisions in this mixed-strategy (capital-income) breeding seabird. We have been using both correlative data and field-/lab-based manipulations of these physiological measures to test state-based optimality models of reproductive investment. Recently we have combined manipulations of baseline corticosterone with the fine-scale tracking of spatial movement and foraging behaviour using GPS technology to further determine how individual variation in physiological management impacts behaviour and hence the evolution of optimal reproductive investment decisions. This type of mechanistic information is not only important for basic exploratory scientific studies, but it is increasingly needed in applied research to increase the predictive power of how we expect individuals and populations breeding in sensitive ecosystems like the Arctic to fair and respond as they face increasingly numbers of human-induced stressors.

**S3.5 Dive physiology of New Zealand breeding Procellariiformes: the interplay between physiological and ecological drivers.**

Brendon Dunphy[1], Graeme Taylor[2], Todd Landers[3], Rachael Sagar[1], Louise Chilvers[4], Louis Ranjard[1], Matt Rayner[5]

*[1]The University of Auckland, [2]Department of Conservation, [3]Auckland Council, [4]Massey University , [5]Auckland Museum*

Procellariiform seabirds are intriguing as they regularly attain depths not predicted by allometric models. How this is achieved is not known as even basic measures of physiological diving capacity are absent for this group. We combined time depth recorder (TDR) measurements of dive behaviour with haematology and oxygen store estimates for three procellariiform species of varying mass and predicted foraging behaviour: common diving petrels, Pelecanoides urinatrix urinatrix (147 g); grey-faced petrels, Pterodroma macroptera gouldi (503 g); and sooty shearwaters, Puffinus griseus (808 g), during their incubation phase. Among species, we found differences in dive depth, dive duration and dives h-1 with sooty shearwaters diving deeper and for longer than grey-faced petrels and common diving petrels. Conversely, common diving petrels dove much more frequently, albeit to shallow depths, whereas grey-faced petrels rarely dived whatsoever. Such differences in dive behaviour were reflected in haematological parameters with sooty shearwaters having higher red blood cell counts and haematocrit values compared to common diving and grey-faced petrels; whereas, common diving petrels had significantly lower Hct but possessed higher haemoglobin concentrations per cell (MCHC) and greater respiratory oxygen stores than both sooty shearwaters and grey-faced petrels. Such results provide the first insights into the physiological traits underpinning procellariiform dive behaviour, and confirm the trend for deep diving seabirds to have proportionally lower blood and respiratory oxygen stores than shallow divers. Furthermore, to gain insights into the evolutionary physiology of a species, the necessity for interpreting mechanistic

physiological measures within the light of ecological information is emphasised, this is particularly so for grey-faced petrels who possess the physiological capacity to dive to depth but rarely do so.

**S3.6 A physiologically informed model of seabird foraging ranges?**

Jonathan Green[1]
*[1]University of Liverpool (School of Environmental Sciences)*

Seabirds are a diverse group, with the key shared trait of obtaining their food from the oceans having evolved at least five times in the modern avifauna. This phylogenetic diversity is reflected in a diversity of locomotory and propulsive modes in both water and air; and a diversity of foraging strategies and niches from deep-diving to kleptoparasitism. Yet this group also shares many characteristics in terms of morphology (e.g. webbed feet), breeding biology (e.g. monogamy and biparental care), breeding ecology (e.g. coloniality, synchronous breeding) and their foraging ecology (e.g. as central-place foragers) so generalisations can be made about the way in which seabirds use the space around them. An understanding of the factors determining seabird foraging areas is currently under scrutiny as we seek to understand their size and extent, with the aim of protecting them. We know that colony size is a key factor and that there is inter-annual variation driven by variation in underlying environmental conditions which affect the distribution of prey. But we also know that foraging ranges are driven by the way in which birds move and feed. This in turn depends on their physiology, energetics, anatomy and morphology, yet the influences of these on foraging behaviour have not yet fully been considered in comparative analyses. In this study I combine what we know about the effects of colony size and environmental variation with an understanding of how movement relates to physiological traits such as body mass and wing loading. The aim is to generate a universal model of seabird foraging ranges which will improve upon current attempts to define foraging ranges from species-specific databases. I will present the findings from this analysis, based on a database of over 150 previous tracking studies from over 80 species, and key information on their physiological traits.

**S3.7 Investigations into the genomic basis for adaptation in seabirds**

Vicki Friesen[1], Anna Tigano[1]
*[1]Queen's University*

The genetic underpinnings of individual variation in physiological traits are largely unknown in seabirds. For example, are differences in cold tolerance between bridled and unbridled Common Murres (Uria aalge) due to phenotypic plasticity, genetic differences or both? If there is a genetic component, does it involve one locus or many? Answers to questions such as these have implications for both the need, and the potential, for species to adapt to environmental change. Thus, understanding the genetic basis of physiological traits is important both for understanding evolution and ecology, and for predicting the ability of seabirds to adapt to anthropogenic challenges such climate change. Next generation sequencing methods are providing exciting new avenues for investigating previously intractable questions. We are using traditional molecular methods as well as whole genome resequencing and candidate gene analysis to address a variety of questions. For example, we screened geographic variation in the Clock gene among Band-rumped (Oceanodroma castro) and Leach's Storm-petrels (O. leucorhoa) from throughout their ranges to test the role of Clock in regulating circadian rhythyms, and found latitudinal clines in allele length in both species. We also found geographic variation in genes associated with immune response in Black-

legged Kittiwakes (Rissa tridactyla), but not in Thick-billed Murres (Uria lomvia). Currently we are using restriction-site associated sequencing (RAD-seq) and whole genome resequencing to investigate the genetic basis of individual variation in cold adaptation in Thick-billed and Common Murres. We are also beginning to use molecular pedigree analyses to test the heritability of variation in physiological and life history traits, since heritability is a key determinant of the potential for a trait to evolve.

## S4 Seabirds as Prey: Top-Down Control of Seabirds

### S4.1 State-space modelling reveals multiple drivers of rapid population decline in macaroni penguins

Catharine Horswill[1], Norman Ratcliffe[2], Jonathan Green[3], Richard Phillips[2], Philip Trathan[1], Jason Matthiopoulos[4]
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It is widely recognised that both nutrient-driven processes acting from the "bottom-up" and predator-driven processes acting from the "top-down" are important drivers of population change. Despite this, fluctuations in the demographic rates of most seabird species are thought to result largely from bottom-up processes. Macaroni penguins (Eudyptes chrysolophus) at South Georgia declined at c. 6% per year between 1985 and 2000, stabilising thereafter. Using a state-space demographic model we separate the processes underlying this trajectory, and quantified the relative importance of each driver in a sensitivity analysis. A comparison of demographic rates provided clear evidence that the population decline was attributable to an imbalance between recruitment to the breeding population and adult mortality. The population trajectory was most sensitive to regulation of survival rates associated with predation pressure; however stabilisation of the population reflected the release of productivity from density-dependence constraints, as well as improved survival rates.

### S4.2 Penguin killers: predation effects of killer whales on penguins at sub-Antarctic Marion Island

Ryan Reisinger[1], Nico de Bruyn[1]
*[1]University of Pretoria*

Killer whales are large, versatile apex predators with substantial energy requirements. As such, they can have significant top-down effects on ecosystems. At Marion Island, Southern Ocean, killer whales regularly prey on king, macaroni and rockhopper penguins. Population sizes of macaroni and rockhopper penguins have declined over the last two decades, while king penguin populations have not. To assess the impact killer whales may have on these penguin populations, we used published information to calculate the energy requirements of the Marion Island killer whale population, and the energy content of penguins. We then calculated predation rates for different killer whale diet scenarios, informed by satellite tracking and stable isotope analysis. We predict that penguin populations at Marion Island are not especially sensitive to killer whale predation, given their large population sizes and low energy content (relative to seals). However, killer whale predation is a considerable source of mortality, which could exacerbate environmentally-driven population declines in penguins, especially if increasing seal populations allow a numerical response in killer whales, which would then cause higher predation rates on penguins. Killer whales likely also have

strong non-consumptive effects on penguins at Marion Island, such as fear effects and indirect interactions through prey resources.

**S4.3 When gulls eat terns: quantifying impacts of management decisions for a seabird colony**

Lauren Scopel[1], Antony Diamond[1]
*[1]University of New Brunswick*

In the Gulf of Maine (GOM) in the Northwest Atlantic Ocean, terns and auk colonies are susceptible to extirpation by a variety of predators. The most devastating at a regional scale are Herring (Larus argentatus) and Great Black-backed Gulls (L. marinus). The populations of these gulls expanded rapidly in the early 1900s, and in spite of recent declines in some parts of their range, they still exclude smaller seabird species in virtually all GOM colonies except those that are managed intensively. Managed colonies in the GOM routinely use a combination of nonlethal and lethal methods of control to reduce gull predation. On Machias Seal Island (MSI), New Brunswick, a change from a mix of nonlethal and lethal methods of gull deterrence to only nonlethal methods led to the complete reproductive failure of the region's largest tern colony for eight years (2006-2013). We documented subsequent changes in tern nesting distribution by habitat type, decreasing aggressiveness by terns, and behavioural changes in gulls. By comparing MSI to four other tern colonies in the GOM, we can attribute the collapse of MSI entirely to increased predation, and have determined a threshold of predation that terns will tolerate. Evidence from other colonies suggests that even when lethal control is used, gulls may still cause short-term reproductive failure if they are not deterred quickly enough, especially in inclement weather. Our findings indicate that top-down control by predators is a major determinant of seabird reproductive success, nullifying the potential of using seabird breeding success as an environmental indicator, and should be given equal consideration to bottom-up processes.

**S4.4 Top-down and bottom-up influences on large, sympatric colonies of Caspian Terns and Double-crested Cormorants**

Daniel Roby[1], Donald Lyons[1], Stefanie Collar[1]
*[1]Oregon State University*

We investigated the influence of bottom-up and top-down drivers on productivity of seabird breeding colonies at East Sand Island (ESI) in the Columbia River estuary on the Pacific Coast of North America; this island supports the largest-known breeding colonies of Caspian Terns (Hydroprogne caspia) and Double-crested Cormorants (Phalacrocorax auritus). The primary factor limiting reproductive success at these two colonies has been thought to be disturbance and depredation by Bald Eagles (Haliaeetus leucocephalus) the top predator in the system and associated nest depredation by sympatrically nesting gulls (Larus spp.). Interannual differences in reproductive success of terns and cormorants at ESI were, however, inversely related with average river discharge during the incubation and early chick-rearing periods. Abundance of marine forage fishes in the estuary was also inversely related to river discharge, apparently through effects on estuary salinities. For the tern colony, river discharge during incubation was positively associated with higher disturbance rates by eagles during early chick-rearing. Thus, river discharge apparently affected the reliance of eagles on seabird breeding colonies as a food source, through its effects on availability of alternative food sources for eagles. River discharge was also apparently inversely

related to reproductive investment by seabirds facing eagle disturbance. Our results support the hypothesis that reproductive success of Caspian Terns and Double-crested Cormorants at these two large estuarine colonies was driven by the interaction of bottom-up and top-down factors. Although appearances suggested that the top predator in this system was the sole cause of extensive seabird nesting failure, bottom-up factors affecting food availability for both seabirds and their predators also played a key role.

**S4.5 Native avian predators: top-down impacts on the common murre breeding population in Oregon, USA**

Cheryl Horton[1], Robert Suryan[1], Katie Dugger[1]
*[1]Oregon State University*

Over the past two decades, increased levels of avian predation were observed at Common Murre (Uria aalge) colonies in Oregon,where two thirds of the murre population on the west coast of North America breed. We investigated changes in the distribution and abundance of Common Murres over a period of Bald Eagle (Haliaeetus leucocephalus) recovery from endangered status (n=19 years), and quantified impacts of disturbance and predation at three focal breeding sites (n=1 -7 years) known to experience varying amounts of eagle predation. Changes in the number and size of murre colonies on the north and central coast were associated with regional eagle nest density and initial number of murres present at each site, rather than immediate proximity of eagle nests to murre colonies. Between 1998 and 2006, counts of murres declined by 50% on the north coast where eagle nest density was highest, while counts and number of occupied breeding sites increased on the central coast where eagle nest density was lower. At individual murre breeding sites, eagles caused the majority of disturbances (~55%), but secondary nest predators (gulls, corvids, and vultures) had a greater impact on murre reproductive loss, causing ~5X more egg/chick loss than eagles. We found higher rates of disturbance and colony disruption at sites with high or medium eagle density vs. the site with lowest eagle density within a season. In addition, we observed a negative association between mean murre reproductive success and mean eagle disturbance rate at a single site over 7 years (R2 = 0.6981, p=0.01). Finally, we documented failure of remaining murre chicks at central and south coast sites after disturbance by juvenile California Brown Pelicans (Pelecanus occidentalis) in 2012. Our observations provide some evidence for top-down regulation of murres in Oregon, mediated by native, avian predators delisted from the U.S. Endangered Species Act.

**S4.6 Climate-driven changes in terrestrial predator abundance mediates top-down cascade on a threatened seabird**

Sarah Thomsen[1], David Green[1]
*[1]Simon Fraser University*

Changes to predator-prey dynamics have been increasingly recognized for their potential role in contributing to declining seabird populations. Scripps's Murrelets (Synthliboramphus scrippsi) are a state-listed Threatened seabird that nests only on islands in Southern California and Northern Mexico. On Santa Barbara Island, their largest US breeding colony, these small nocturnal seabirds face threats from native predators including the Barn Owl (Tyto alba) as well as an endemic subspecies of deer mouse (Peromyscus maniculatus elusus) that consumes murrelet eggs. These deer mice undergo extreme variations in density and are also important prey for owls. Therefore, we investigated climate effects on the density of owls and deer mice and predator effects on murrelet

adults and their eggs. First, we confirm the links between an ENSO-driven rainfall pulse, terrestrial productivity, and the subsequent increase and then sharp decline in mouse and owl numbers on the island from 2010 to 2013. Next, we evaluated evidence for prey switching in Barn Owls. There were substantial differences in the number of murrelets killed by owls among years, which is consistent with the alternative prey hypothesis. Finally, we examined murrelet hatching success from 1993-2013 and found that it was best predicted by both terrestrial and marine influences. We discuss the implications of a climate-driven impact on a seabird mediated through terrestrial pathways, as well as the next steps for evaluating the overall impact of these native predators on murrelets.

## S5 Individual Variation in Movement Strategies II

### S5.1 Seabird individual foraging consistency depends on food availability in the Benguela upwelling

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Foraging strategies are keys to population dynamics and recent evidences of consistent individual differences in foraging could have consequences on fitness, hence potentially influencing foraging specialisation. Here we show that individual consistency in seabirds of the Benguela varies with environmental conditions. Between 2005 and 2013, we equipped > 60 gannets and penguins for which we obtained at least two consecutive trips within 24h to 3 days during years of contrasting food availability, as assessed from annual large-scale acoustic surveys. We compared foraging characteristics, bearings and foraging areas between consecutive trips. Behavioural individual consistency was higher during years of high food availability, and was also higher in penguins than in gannets. Individual differences may be accentuated in ecosystems with predictable resources, where individual memory and fidelity to foraging sites may be advantageous to ensure successful foraging with limited energy expenditure, thus favouring foraging specialisation. Further, higher foraging consistency in penguins might explain their limited capacity to cope with food scarcity, and their current population crash.

### S5.2 Multi-colony tracking reveals spatio-temporal variation in carry over effects in the black-legged kittiwake Rissa tridactyla

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Relationships between events in different phases of the annual cycle are key determinants of individual life histories and population dynamics. Carry over effects may persist throughout the annual cycle, whereby breeding effort drives the timing of autumn migration and winter destination which, in turn, affects the timing of colony return in the spring and subsequent breeding performance. In addition, these effects may vary among populations due to differences in local conditions or migration distances, which may lead to heterogeneity in population dynamics across a species range. Using miniature geolocators, we investigated year-round carry over effects in black-

legged kittiwakes Rissa tridactyla at 10 breeding colonies in the East Atlantic, in 2009-2010. In 2009, breeding adults at each colony were deployed with geolocators and their breeding success was recorded. In 2010, the birds were recaptured, the loggers retrieved and breeding success recorded again. Across the study colonies, both successful and failed breeders in 2009 wintered largely in the North-west Atlantic between Newfoundland and the Mid-Atlantic Ridge. Variation in carry over effects of breeding outcome on timing of autumn migration and winter destination were apparent among colonies. These differences, in turn, had impacts on the timing of spring migration and subsequent breeding success in 2010. Our study demonstrates that the spatio-temporal dynamics of carry over effects at a meta-population scale are complex, but we find general support for the prediction that migration strategies are linked to breeding outcome and local conditions.

**S5.3 A lifetime of risk? Individual consistency in albatross movement strategies and overlap with fisheries**

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In many long-lived species such as seabirds, the period from independence to recruitment is a critical life-history stage when mortality rates may be much higher and more variable than in adults. Despite this, little is known about how juveniles and immatures develop foraging skills and whether they specialize on particular habitats. Wandering albatrosses have amongst the widest non-breeding distributions of any seabird, yet there is high degree of among-individual variation in movement strategy. The South Georgia population has halved since the 1960s, with declines linked to mortality of juveniles in longline fisheries. Here, we use a longitudinal dataset of individual albatrosses tracked with geolocators from fledging to recruitment to investigate their early life distributions. We examine the ontogeny of migration strategies, individual consistency in foraging habitats and subsequent overlap with fisheries, to determine if certain strategies put some individuals at greater risk of bycatch. These results have important implications for the conservation of this and other long-lived migratory species.

**S5.4 Is phenotypic plasticity more important than environmental parameters in explaining the foraging strategies of a pan-tropical seabird?**

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The degree of individual foraging plasticity strongly influences the ability of species to responds to changes in prey availability. The foraging strategies of six different populations of a pan-tropical species, the Masked Booby (Sula dactylatra), were studied using GPS. Data were collected over the past ten decades at study sites located in the Southern Gulf of Mexico, East-Pacific, Southwest- and West-Pacific, and South-Atlantic. We analysed to what extent foraging bouts, determined through Hidden Markov Models, varied among populations and in relation to prevailing environmental conditions. Repeatability in foraging trip duration, total distance travelled and maximum distance from colony were analysed to assess wether within-individual consistency in these parameters

differed between populations. We found that foraging bout characteristics varied among populations according to environmental conditions. The degree of individual repeatability in trip duration, total trip length and maximum distance from colony were more pronounced in some populations than in others, possibly due to higher intra- and inter-specific competition for food. Our study highlights the importance of assessing phenotypic plasticity in foraging strategies and the need of multi-regional data sets to predict how populations may respond to environmental change.

**S5.5 Early life migration and habitat exploration: Individual movements from fledging to recruitment of a long-lived seabird from a high Arctic colony**

Børge Moe[1], Jorg Welcker[2], Elin Noreen[3], Jannik Schultner[1], Olivier Chastel[4], Jan Bustnes[1], Geir Gabrielsen[5], Richard Phillips[6], Claus Bech[3]
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Early life stages have been termed 'the lost years' because of limited ability to track movements of young seabirds. We provide the first analysis of individual kittiwake movements (N=15), revealed by geolocators, from fledging to recruitment (2-4 yrs old). We compare with adults from the same colony and demonstrate explorations over large geographic scales in the North Atlantic. In the first spring and adjecent summer, a substantial proportion of immatures explored Arctic waters, and potential breeding areas, located more than 3000 km away from the natal colony in the Barents Sea. Information on such early life movements and habitat exploration is important for understanding development of individual migration strategies, dispersal, recruitment and ultimately population dynamics.

**S5.6 Individual consistency in migratory behaviour: an interspecific comparison among Atlantic shearwaters and petrels**

Jacob Gonzalez-Solis[1], José Manuel Reyes-González[2], Teresa Militão[2], Fernanda De-Felipe[2], Zuzana Zajkova[2], Joël Bried[3], Veronica Neves[3], Ingvar Sigurdsson[4], Daniel Oro[5], Peter Ryan[6], Richard Cuthbert[7], Richard Phillips[8], Raül Ra
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Reasons for individual consistency in avian migration and its variability among avian taxa are poorly known. However, ascertaining its relationship with environmental variability and life-history traits is essential to understand the migratory plasticity of long-lived species and their potential to cope with marine habitat changes. We compared individual consistency in migratory strategies of 7 seabird species tracked from 3 to 6 consecutive years using geolocator devices: Manx, great, Boyd's, Cory's, Scopoli's and Cape Verde shearwaters and Bulwer's petrel. All birds were genetically sexed. Some species, such as the Cory's shearwater, showed strong individual consistency in migratory schedules whereas in other, such as Boyd's shearwater, there was virtually no individual consistency from year to year. Our results suggest that distinct strategies among species relate to differences in predictability and traceability of conditions across the year, possibly driven by differences in the geographic proximity between breeding and wintering areas. Site fidelity to non-breeding grounds (ortstreue), as indicated by distances to the wintering area, was high in Bulwer's petrels, and

relatively low in Boyd's shearwaters, while great and Calonectris shearwaters showed intermediate values, suggesting differences among species in the inter-annual stability of the marine habitat. Individual consistency in the size of the wintering areas also varied substantially among species, e.g. it was high in Bulwer's petrels but low in great shearwaters, suggesting differences among species in the inter-annual stability in the distribution and abundance of their prey. Our results provide the first interspecific comparison into individual consistency in migratory strategies among shearwaters and petrels, with clear implications at ecological, evolutionary and conservation levels.

## S6 Seabirds and Indicators of Ocean Health II

### S6.1 Mercury in wintering seabirds, an aggravating factor to winter wrecks?

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Every year, thousands of seabirds cast ashore and are found dead along the coasts of North America and Western Europe. These massive mortality events called 'winter wrecks' have generally been attributed to harsh climatic conditions and prolonged storms which affect bird energy balance and impact their body conditions. Nevertheless, additional stress factors, such as contaminant body burden, could cumulate to energy constraints and actively contribute to winter wrecks. However, the role played by these additional factors in seabird massive winter mortality has received little attention to date. In February/March 2014, an unprecedented seabird wreck occurred along the Atlantic French coasts during which >45.000 seabirds were found dead. By analyzing mercury (Hg) concentrations in various tissues collected on stranded birds, we tested the hypothesis that Hg played a significant role in this mortality. More specifically, we aimed to (1) describe Hg contamination in wintering seabirds found along the French coasts in 2014, and (2) determine if Hg concentrations measured in some vital organs such as kidney or brain reached toxicity thresholds that could have led to deleterious effects and to an enhanced mortality. We found some the highest Hg levels ever reported in atlantic puffins, common guillemots, razorbills and kittiwakes. Measured concentrations ranged from 0.8 to 3.6 µg.g-1 dw in brain, 1.3 to 7.2 µg.g-1 in muscle, 2.5 to 13.5 µg.g-1 in kidney, 2.9 to 18.6 µg.g-1 in blood and from 3.1 to 19.5 µg.g-1 in liver. However, these Hg concentrations were generally below estimated acute toxicity levels in liver, kidney or brain. This suggests that Hg was not directly responsible for the high observed mortality, but could have been a major aggravating stress factor for emaciated birds already on the edge. Importantly, this study also demonstrated that blood, which can be non-invasively collected in seabirds, can be used as a predictor of Hg contamination in other tissues

### S6.2 Patterns and causes of mercury concentrations in northern common eiders; all birds are not equal

Jennifer Provencher[1], Mark Forbes[1], Grant Gilchrist[2], Greg Mitchell[2], Mark Mallory[3]
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Contaminant concentrations have been found to vary among species, but less work has examined the variation of contaminants within species. We use the northern common eider duck (Somateria molissima) as an avian model to study the patterns and potential causes of differential patterns in mercury concentrations in a marine bird species. Our first objective was to examine and compare mercury concentrations in the resident sub-species of eider duck (S. m. sedentaria) and the

migratory eider sub-species (S. m. borealis) in northern Canada. No significant differences were found between the groups of eiders, suggesting that exposure to mercury does not greatly differ for eiders among the regions used by these groups. Importantly, contaminants have also been found to have a sex biased distribution, which may lead to the negative impacts affecting the two sexes differentially. Therefore our second objective was to investigate both sub-species for the presence of a sex bias in mercury concentrations. Resident eiders showed no sex bias in mercury concentrations, suggesting that for eiders the drivers of sex bias in mercury is related to differences in their foraging ecology or exposure versus inherent differences between the sexes (e.g. hormonal or immunological differences). Lastly, we used a path analysis to explore the possible causes of the sex bias patterns in the migratory eider ducks. Mercury concentrations in eiders did vary directly with sex, and indirectly with sex through body and liver mass. This suggests that the male sex bias in mercury is in part due to their size, but that other factors not considered here also cause males to have higher mercury burdens than females. Our work emphasizes the need to understand how contaminants may be differentially distributed within a species, and between closely related groups when interpreting results and making comparisons.

**S6.3 Global POPs monitoring using seabirds preen gland oil**

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As marine top predators, seabirds accumulate persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane and its metabolites (DDTs) and hexachlorocyclohexanes (HCHs), in their tissues through biomagnification. In a previous study, we demonstrated the usefulness of preen gland oil of seabirds as a nondestructive biomonitoring tool. In this study, we analyzed PCBs, DDTs and HCHs in preen gland oil from 122 live individuals including 107 adults (18 species) and 15 chicks (5 species) from 11 sampling locations over the world oceans during 2005-2013. PCBs, DDTs and HCHs concentrations of seabirds preen gland oil were higher in the northern hemisphere than the southern hemisphere. Especially, PCBs and DDTs were highly concentrated in European shags (Phalacrocorax aristotelis in U.K.) and HCHs were concentrated in black-tailed gulls (Larus crassirostris in Japan). These are probably due to their foraging areas proximity to the pollutant sources. PCB and DDT concentrations in preen gland oil from adult black-tailed gulls were 2-3 orders of magnitude higher than those from chicks, while HCH concentrations from the adults and the chicks were similar. In the chicks, lower chlorinated biphenyls (more metabolizable congeners) were more abundant than adults. These suggest that chicks' metabolic system against xenobiotics has not been established. PCBs, DDTs and HCHs concentrations in male European shags were not correlated with age (range : 3-16 years old). These results suggest that POPs concentrations in preen gland oils reflect recent exposure. The nondestructive biomonitoring of POPs in seabird's preen gland oil can be carried out simultaneously with ecological investigations, therefore provides us helpful information to understand the global distribution and transport of POPs and their effects on seabirds.

**S6.4 Fitness consequences of mercury and legacy POPs exposure in Southern Seabirds: lessons from the PolarTOP project**

Olivier Chastel[1], Aurélie Goutte[1], Christophe Barbraud[1], David Costantini[2], Sabrina Tartu[1], Yves Cherel[1], Paco Bustamante[3], Pierre Labadie[4], Hélène Budzinski[4]
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Seabirds are top predators of the marine environment that accumulate contaminants over a long life-span. Chronic exposure to pollutants is thought to compromise survival rate and long-term reproductive outputs in these long-lived organisms, thus inducing population decline. Although toxic effects of heavy metals and persistent organic pollutants (POPs) have been described under controlled laboratory conditions, their consequences on long-term fitness have been virtually neglected in free-living vertebrates because of the dearth of long-term data sets that would be required to address this topic. Further, to date very few data are available on the physiological mechanisms involved in the fitness consequences of contaminants exposure in free-living birds. In this talk we will present results from the PolarTOP project which took advantage of the long-term capture-mark-recaptures studies of several seabird species (albatrosses, petrels, penguins and skuas) from the French Southern Territories, to investigate the fitness consequences of contaminant exposure (mercury (Hg) and legacy POPs). Using studies on wandering albatrosses (Diomeda exulans) and south polar skuas (Catharacta maccormicki), we show that blood Hg and POPs negatively impacted long-term breeding probability, hatching and fledging probabilities. Using matrix population models, we projected population declines in response to an increase in Hg concentrations. At the proximate levels, results from the PolarTOP project suggest that the mechanisms underlying these deleterious fitness effects are multifaceted, through endocrine disruption, increased oxidative damages, behavioural impairments and interactions with reproductive costs.

**S6.5 Relationships between contaminants and stress hormones in Arctic Seabirds**

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Seabirds adopt different life-history strategies in order to cope with environmental stressors. At the endocrine levels, the release of stress hormones by the hypothalamo-pituitary-adrenal (HPA) axis triggers physiological and behavioral adjustments that help copying with the stressors. Stress hormones like corticosterone (CORT) are therefore considered as major mediators of reproductive decisions and have a strong connection with fitness. Seabirds are exposed to elevated levels of environmental pollutants (e.g. polychlorinated biphenyls, PCBs) which are notorious endocrine disruptors. However the CORT -PCB relationship has been poorly investigated. We explored the CORT-PCB relationships in Svalbard breeding black-legged kittiwakes Rissa tridactyla. We reported significant positive relationships between circulating CORT and blood PCBs. To understand how PCBs disrupt CORT secretion, we performed several experiments which suggest that in kittiwakes, PCBs may interfere with CORT secretion by increasing the number of ACTH receptors on the adrenals. Finally we explored whether the CORT-PCB relationship followed a general pattern in six other seabird species occupying different trophic positions, and hence covering a wide range of PCB exposure. Blood PCB concentrations were positively associated to CORT levels in three species and negatively associated to CORT levels in one species. This result suggests that the nature of the PCB-CORT relationships may also depend on the level of PCB exposure. The fitness consequences of PCB exposure for seabirds will be discussed in the context of the environmental challenges affecting Polar Regions.

## S7 Population Ecology of Penguins

### S7.1 Comparative population ecology of the Pygoscelis spp. penguins

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Along much of the Antarctic Peninsula and connected islands of the Scotia Arc, the three species of Pygoscelis penguins (Adélie [P. adeliae], chinstrap [P. antarctica], and gentoo [P. papua]) breed sympatrically; this area of overlap allows for direct examination of the similarities and differences in their life history traits, and provides insights into why some populations are increasing in response to climate change even as others suffer declines and even local extirpation. The basic elements of Pygoscelis life history in the Antarctic Peninsula region are remarkably consistent: all three species breed colonially, lay two eggs in nests built of stone (or vegetation, where available), eat various species of krill (Euphausia spp.) and fish in varying proportions, and have relatively high rates of site and mate fidelity. A number of studies have identified individual factors associated with the differential success of gentoo penguins, which are increasing in abundance and expanding their breeding range southwards, versus chinstrap and Adélie penguins, which are in general decline within the same region. However, differences in individual demographic rates are only part of the story. Emerging from these data is a more general divide based on behavioral plasticity. Across a suite of characteristics, gentoo penguins display more flexibility; they have a more variable diet, a more flexible breeding phenology, an ability to relay a clutch if the first is lost, are less strictly faithful to a nesting locations, and are better colonizers of new habitat than either chinstrap or Adélie penguins. This suite of life history characteristics appears to offer advantages under climate change scenarios. Thus, while the three Pygoscelis penguins face many of the same challenges in the Antarctic Peninsula region, subtle differences in life history traits appear advantageous to their ability to thrive under current changing conditions.

### S7.2 Comparative population ecology of penguins at islands of the South Atlantic Ocean

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We review penguin demography at locations in the South Atlantic that lie to the north of the Southern Antarctic Circumpolar Current Front. The region hosts globally important populations of king, gentoo, northern rockhopper, southern rockhopper and macaroni penguins (Magellanic penguins are described in another talk). Numbers of king penguins at the small Falkland (Malvinas) colony are increasing but trends are unknown for the huge South Georgia population. Gentoo penguin populations in the Falklands (Malvinas) declined sharply from 2000-2002 owing to a toxic algal bloom, but afterwards underwent a rapid recovery. Gentoo penguin numbers in South Georgia declined in the 1990s during a positive Southern Annular Mode event, but have since recovered. Breeding success of gentoo penguins in South Georgia is more variable than that in the Falklands (Malvinas), with periodic breeding failures that coincide with poor krill availability.The populations of all three species of Eudyptes penguins underwent catastrophic historic declines, although the quality of the early counts means that the timings and magnitudes of these are uncertain. Macaroni penguin numbers at South Georgia declined from 1985-1999 before stabilising. These patterns were

correlated with variability in sea temperatures and predation pressure. Since 2000, southern rockhopper penguins in the Falklands (Malvinas) have undergone a rapid increase associated with changes in sea temperatures. Their survival and productivity rates are substantially higher than those of macaroni penguins. Northern rockhopper penguins in Tristan have declined since 2011. This decline followed a shipwreck that resulted in substantial numbers of birds being oiled. These patterns highlight the complexity of penguin demography and the diversity of factors driving it. We argue that improved monitoring of demographic rates, particularly survival, are needed to allow more effective diagnosis of population trends in the future.

**S7.3 Comparative foraging and population ecology of penguins of the South Indian ocean**

Charles-André Bost[1], Christophe Barbraud[2], Karine Delord[3], Jean-Baptiste Thiebot[4], Annette Scheffer[5], Cécile Bon[1], Yves Cherel[1], Henri Weimerskirch[1], Yvon Le Maho[1], Céline Le Bohec[1], Mark Hindell[6], Newi Makhado[7], Pierre Pistorius[8], Robert Crawford[1]
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Penguins play a major role in the trophic food webs of the south Indian Ocean. The Sub-antarctic island groups of Crozet, Prince Edward, Amsterdam-Saint Paul, Kerguelen and Heard host more than 76%, 63%, 27%, 10% and 16% of the world populations of the king, macaroni, southern rockhopper, northern rockhopper and gentoo penguins, respectively. Long term monitoring studies indicate contrasting trends according to the species/locality during the last 20 years. While king penguins are still increasing at Kerguelen and Heard, some large colonies (Crozet) have stabilized or even recently decreased. Populations of macaroni and rockhopper penguins are stable at Kerguelen while they have drastically decreased at Prince Edwards.The northern rockhopper penguin has considerably decreased at Amsterdam.Tracking studies and food sampling/stable isotopes analyses have documented the at-sea distribution and trophic during the breeding, post-moult, winter and more recently their juvenile periods. King penguins rely on distant frontal zones during the incubation and chick rearing periods. Eudyptes penguins target fronts during incubation and extensively use the shelf area during chick rearing. During the winter season, dispersion occurs at a very large scale for oceanic species.The influence of the regional marine environment on the migration patterns was investigated in three species of the Eudyptes genus and their wintering habitat modelled. Overwintering conditions may influence the proportion of macaroni and rockhopper penguins that breed in the following summer and breeding success.At a long term scale, using next-generation sequencing, the reconstruction of the past demography of king penguins from Crozet strongly supported the hypothesis of a sudden population expansion scenario following the last glacial maximum. However the southward shift of the position of frontal zones during the 21th century might drastically affect penguins' colonies distribution and populations.

**S7.4 Comparative population ecology of New Zealand's Eudyptes and Megadyptes penguins**

Thomas Mattern[1], Ellenberg Ursula[2], Yolanda van Heezik[1], Philip Seddon[1]
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Of the world's 18 extant penguin species six species live and breed in New Zealand. Four of these are Eudyptes species, namely the Fiordland (E. pachyrhynchus), Snares (E. robustus), Erect-crested (E.

sclateri) and Southern Rockhopper penguins (E. chrysocome); the former three species and the Yellow-eyed penguin (Megadyptes antipodes) are all endemic to New Zealand. With exception of the Snares penguin, the populations of all these species are believed to have undergone significant declines in the past decades. In comparison with most other penguin species world-wide, New Zealand penguins - particularly those breeding on the remote sub-Antarctic islands - have received little scientific attention which hampered interpretation of determined and assumed population trends. However, in recent years a handful of studies have started to gather first information on the marine ecology of various species and provide us with some insights of potential factors driving population developments. For the Yellow-eyed penguin on the mainland a picture emerges which puts anthropogenic alterations of the marine habitat at the forefront of factors negatively affecting population developments in recent years. Rockhopper and Erect-crested penguins struggle with decreasing oceanic productivity in the sub-Antarctic region. This, however, seems to be of lesser concern for Snares and (presumably) Fiordland penguins that breed in subtropical water closer to the NZ mainland. In the light of increasing selective pressure as a result of anthropogenic influences in the marine environment (e.g. fisheries interactions, habitat alteration, climate change) behavioural flexibility and adaptability seem to be the key for success for penguins in New Zealand.

**S7.5 Status and trends of South American banded penguins**

Pablo Garcia Borboroglu[3], P. Dee Boersma[2], Pablo Garcia Borboroglu[3], Susana Cardenas[4], Alejandro Simeone[5]

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The three species of banded penguins that breed in South America range in IUCN's classification status from near threatened for the Magellanic penguin (Spheniscus magellanicus), to vulnerable for the Humboldt (Spheniscus humboldti), to endangered for the Galápagos penguin (Spheniscus mendiculus). The population size of each species influences the extent of its distribution. The smallest population (1,500-4,700 penguins) is found only in the Galápagos Islands. The Humboldt penguin numbers at least 60,000 birds and breeds along the coasts of Peru and Chile. This species is considered vulnerable because of interactions with fisheries, habitat destruction, and the extreme fluctuations and a decline in their population with ENSO events. Like the Galápagos penguin, Humboldt penguins never recovered from the 1972 and 1983-84 El Niños. The Magellanic penguin, the most abundant and widespread species, is found in both the Pacific and Atlantic Oceans and numbers more than a million individuals. Magellanic populations do not seem to fluctuate as strongly with ENSO events. Conversely, Galápagos and Humboldt penguins are clearly negatively impacted in the Pacific. In the Atlantic, where ENSO events are not as well developed, big storms can cause reproductive failure. The trends for these temperate penguin species are likely to be negative over the long term because of stressors associated with the increased frequency and severity of ENSO events and ineffectual management of commercial fisheries.

**S7.6 A spatial perspective to understand demographic changes in magellanic penguins**

Luciana Pozzi[1], Pablo García Borboroglu[2], Dee Boersma[3], Miguel Pascual[1]

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Seabirds are often studied at individual colonies but increasing evidence suggests that dispersal processes are important. The Magellanic penguin (Spheniscus magellanicus) is the most abundant seabird breeding in Argentina, with 66 colonies along 2000km of coastline. Colony size varies from several hundred pairs to over 200,000. The abundance and distribution of colonies has changed over the last decades: some colonies declined, others increased, and new colonies established in the northern limit of their breeding distribution. To understand what factors might drive these changes, we used information for eight colonies scattered along 600 km in Northern Patagonia (Rio Negro and Chubut provinces). We determined colony size, breeding productivity and foraging distance. We estimated population trends and evaluated connectivity by two methods: by direct search of banded penguins breeding in non natal colonies and by the comparison of observed population trends and expected rates in the absence of dispersal. All northern colonies increased steadily. In the southern sector, the biggest colonies declined but smaller populations remained stable. Northern colonies had higher breeding success but their increase could not be explained without immigration. Population trends suggest a density dependent growth. Both foraging distances and the condition of chicks at fledging depended on colony size. Density dependent processes, likely exacerbated by less favorable oceanographic conditions in the southern sector, may have promoted the recruitment of penguins in the northern area. Penguins banded as chicks at Punta Tombo were recaptured breeding in northern colonies. Metapopulation models suggest that density dependent emigration from the south may have contributed to the establishment and growth of northern colonies. Given the confounding effects of mortality and emigration processes, our results highlight the need of a spatial perspective for the study of population changes.

**S7.7 Comparative ecology of the temperate African Spheniscus demersus and little Eudyptula minor penguins**

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African Spheniscus demersus and little Eudyptula minor penguins inhabit temperate waters off southwest Africa and southern Australia/New Zealand, respectively. Whereas the African penguin (Endangered) collapsed in the early 21st century, the smaller little penguin (Least Concern) has a relatively stable overall population. The two species have similar maximum levels of adult survival and breeding success but little penguins start breeding at a younger age. Both species feed on mid-trophic level prey, including sardine (pilchard) Sardinops sagax and anchovy Engraulis spp. (both Clupeids) and, to a lesser extent, cephalopods. Both penguins are affected by parasitism, disease, degradation of breeding habitat and marine oil spills and have breeding distributions that are restricted by mammalian predation. Food scarcity was the primary driver of the recent decrease of African penguins and it has at various times reduced adult survival and breeding success of little penguins. In southern Africa, it resulted from environmental change and local overfishing that produced mismatches in the distributions of the breeding localities and the prey of penguins. In Australia/New Zealand, it followed widespread die-offs of sardine in the 1990s, caused by disease, and later was associated with rising sea surface temperatures off Western Australia that altered availability of sandy sprat Hyperlophus vittatus (another Clupeid). Although sardine and anchovy are

more abundant off southern Africa than in Australia/New Zealand, they are also fished more intensively off southern Africa. Trophic models will be used to compare food web characteristics and the role of harvesting on food availability in the two systems. The effects of climate change, particularly relating to sea-surface temperatures, appear to be negative at the northern limit of the little penguin's distribution but largely positive in the short to medium terms at more southerly latitudes.

## PS5 Carry Over Effects (and Colony Effects)

**PS5.1 Which phase(s) of the non-breeding period may affect subsequent reproductive timing in a migratory diving seabird?**

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Recent progress in animal tracking now allow surveying the at-sea ecology of seabirds on a year-round basis. To investigate the link between at-sea ecology of the birds during the non-breeding period and their following breeding timing and performance, we tracked Rhinoceros auklets during their non-breeding period over 4 successive years from Teuri Island (Japan Sea) using light-based geolocation loggers (n=48 datasets). We used a "broken-stick" model to segment staging versus migrating phases within the individual tracks at sea. We reveal that the longer the winter stopover and pre-laying periods' duration, the later the dates of breeding onset. On the contrary, later dates of post-breeding departure had no significant effect on the subsequent breeding timing, and the duration of migrating phases were little variable. Moreover, isotopic signature of whole blood collected in the early breeding season suggested that lower trophic levels during pre-laying phase correlated with later breeding onset dates. Finally, eggs were significantly smaller on average during years of later breeding. We conclude that foraging conditions at sea during these two phases (and only these) of the non-breeding period may generate cumulative carry-over effects to the subsequent reproductive period in this migratory seabird, both in terms of timing and performance.

**PS5.2 Extreme climate events and individual heterogeneity shape life history traits and population dynamics of the Southern Fulmar.**

Stephanie Jenouvrier[1], Clara Peron[2], Henri Weimerskirch[3]
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The Southern fulmar is an ice-dependent species, and individuals forage near the ice edge. During an extreme unfavorable year --- when sea ice area is reduced and the distance between the ice edge and the colony is high --- observed foraging trips were greater in distance and duration. As a result, adults brought less food to their chicks, which fledged in the poorest body condition. During such unfavorable years, breeding success was extremely low, hence the population growth rate was greatly reduced. The opposite pattern occurred during extreme favorable years. Previous breeding status had a strong influence on life history traits and population dynamics, as well as their responses to extreme conditions. Successful breeders had a higher chance of breeding and raising their chick successfully during the following breeding season as compared to other breeding stages, regardless of environmental conditions. Successful breeders coped better with extreme unfavorable sea ice conditions. For environments characterized by ``ordinary'' sea-ice conditions, these inter-individual differences in breeding success were more likely to carry over through the life of

individuals and randomness in individual pathways was less than that of other species for which such stochasticity was quantified. This pattern is consistent with individual heterogeneity in vital rates arising from innate or acquired phenotypic traits. In addition, unfavorable ESIC tend to exacerbate individual differences in intrinsic quality, expressed through differences in reproductive status. Finally, we find that changes in the frequency of extreme events may have a strong impact on the population persistence of the Southern fulmar.

**PS5.3 An experimental study of carry-over effects on migratory strategies in a pelagic seabird**

Annette Fayet[1], Akiko Shoji[1], Robin Freeman[2], Chris Perrins[1], Tim Guilford[1]
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Long-lived pelagic seabirds spread their reproductive investment over many years and are known to be subject to carry-over effects, the process by which investment in one breeding season may affect the reproductive outcomes in the next season. However, how carry-over effects also affect migration, the other main event in the annual cycle of many pelagic seabirds, is currently unclear. Here we focus on potential carry-over effects of breeding on phenology, migratory routes and at-sea behaviour during the overwintering period. We experimentally manipulate the reproductive cost of 60 pairs of UK breeding Manx shearwaters Puffinus puffinus by swapping chicks of different ages between nests to artificially lengthen or shorten the chick-rearing period by ~30% (3 weeks), and we record the subsequent trans-equatorial migration of the adults using geolocators. We investigate potential spatial differences in migratory routes between the manipulated and control birds, measuring route similarity with nearest neighbour analyses and comparing stopover and overwintering areas with density kernel analyses. Furthermore we use an ethoinformatics approach to compare activity levels (e.g. foraging, resting...) over winter between groups, applying Gaussian mixture models to salt-immersion data collected by the loggers to identify flying, resting and foraging behaviour at sea. In addition, we quantify parental investment with a combination of salt-immersion and RFID data (feeding frequency) and daily chick weights during the manipulated breeding season and the following one, which allows us to investigate the links between 3 consecutive events in the birds' life cycle (breeding-migration-breeding).

**PS5.4 Evidence for carryover effects on breeding and migratory behaviour in the Manx shearwater: Insights from multi-colony and multi-year tracking**

Holly Kirk[1], Robin Freeman[2], Akiko Shoji[1], Annette Fayet[1], Chris Perrins[1], Tim Guilford[1]
*[1]Oxford University, [2]Institute of Zoology*

Behavioural decisions (regarding timing, route and stopovers) made by individuals of long-distance migratory seabird species can have a critical impact on breeding success and individual condition. Analysis of large-scale multi-year behavioural datasets enables us to understand the interactions between the timing and outcome of different life-history events as the first step towards understanding decision making in these species. We analysed behavioural data from 126 individual Manx shearwaters (Puffinus puffinus) on five different breeding colonies over a seven year period. Using geolocation and saltwater immersion loggers, we compiled a comprehensive description of the annual behavioural cycles of these birds and applied machine-learning methods to identify the timing of key breeding and migratory events. With these data we investigated interactions between the timing of these events and migratory route and the degree to which behavioural strategies are

conserved between individuals. The timing of departure from the overwintering location had a strong carryover effect on other events. Departure date largely dictated the route taken to the breeding colony and the subsequent body condition on return to the colony. Birds on different breeding colonies also exhibited clear differences in incubation behaviour and breeding season departure dates. Variation in the timing of many of these events was consistent within birds, indicating the presence of individual behavioural strategies. This detailed behavioural information is crucial for our understanding of decision making in migratory seabirds as well as understanding how these populations will respond to environmental change.

**PS5.5 Overwinter migration strategy influences individual level survival during a mass mortality event**

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Climate warming is predicted to be associated with increased climate variability and hence frequency of extreme weather events. Such extreme events may have immediate and downstream effects on seabird productivity and survival, yet these impacts have rarely been studied in detail, particularly at the individual level. However, understanding individual level responses is crucial if we are to understand the consequences of increased climate variability on population processes. Here, we focus on understanding the impact of severe winter weather on a marked population of European shags (Phalacrocorax aristotelis), a partially migratory species that breeds on the Isle of May, Scotland. This study system presents a unique opportunity to combine individual-level data on overwinter behaviour across a broad spatial scale with downstream consequences on fitness parameters and social dynamics. We focus on a severe wreck of shags (>700 corpses recovered) that occurred across the north-east coast of the UK in winter 2012-13, associated with two prolonged periods of strong onshore winds and rain in December and March. We investigated whether winter migration strategy or intrinsic factors such as sex and age were linked to survival, and whether there were downstream effects on social structure and breeding success. We found that females, older age classes and winter residents had significantly lower survival over the wreck winter. Moreover, there was significant persistent social disruption in the returning breeding population after the wreck, with higher levels of divorce recorded than in previous years when overwintering survival was high. Our study clearly demonstrates links between intrinsic factors, including winter migration strategy, and survival, and highlights the implications of future increases in the frequency of extreme weather events on populations of mobile species.

**PS5.6 Year-round Time-Activity Budgets and associated drivers of variability in Cape gannets at Bird Island, Algoa Bay**

Pierre Pistorius[1], David Green[1], Yann Tremblay[2], Maelle Connan[1], Gavin Rishworth[1]
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Time-activity budgets provide insight into how animals deal with environmental constraints. Although these budgets are largely shaped by the environment, they are also influenced by the intrinsic state of an organism. We used new generation VHF technology to record Cape gannet, Morus capensis, time-activity budgets continuously for up to three years. Trip duration and nest attendance data from over 13,000 foraging trips (one third outside the breeding season) were used

to assess the influence of sex, body condition and offspring developmental stage on parental behavior while breeding. We also investigated time allocation between land and sea during the poorly studied pre- and post-breeding period. During the breeding season foraging trip duration and chick provisioning rate was sex-specific and associated with chick developmental stage. Females made fewer, longer foraging trips and spent less time at the nest during chick provisioning than males. These sex-specific differences became increasingly apparent with chick development. Outside of the breeding season adults returned regularly to their nests with a consistent seasonal pattern between years. Females continued to undertake longer trips, lasting up to three times longer than males, and spent significantly less time at their nests. Immediately after the breeding season, males and females largely visited their nests independently, making only brief visits. However, from mid-way through the inter-breeding interval (June), partners became increasingly synchronous and spent progressively longer periods at their nests. Nest attendance peaked in October prior to egg laying with relatively long nest attendance bouts by males possibly being associated with mate guarding. The onset of incubation was marked by short alternating incubation shifts. We consider possible evolutionary and mechanistic processes associated with these patterns.

**PS5.7 Inter-colony variation in winter distribution of Atlantic Puffins from Iceland**

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Until recently, limited information was available on the distribution of Atlantic Puffins Fratercula arctica from Iceland during the nonbreeding season, particularly that of adults. This study presents data from 23 adult Atlantic Puffins tracked with geolocators from colonies in south (10), west (6), north (4) and east Iceland (3) between 2007 and 2014. The overall wintering area for these Puffins was extensive; the mid- to north-western Atlantic Ocean, east, south, and west of southern Greenland, with some birds travelling as far south as 45°N, and northwards in the Davis Strait. Individuals from the colonies in west and north Iceland reach wintering grounds further north in the Davis Strait than birds from the south and east colonies, and those from south Iceland spend the winter the furthest south. In addition, a few birds wintered in the area around the Mid-Atlantic Ridge. Other temporal and spatial aspects of migration were similar among Puffins from all colonies, in particular the rapid movement of many birds from Iceland to Labrador in early August. Birds from the western and northern colonies thereafter moved gradually north within the Davis Strait, then south along the south-western coast of Greenland, whereas birds tracked from south and east Iceland migrated rapidly to the south and west in August and then gradually northward during the winter. All Puffins began the return migration to their colony in April. The remarkable similarities between successive nonbreeding seasons in the movement patterns of two Puffins tracked, respectively, for two and four years, suggest that the differences among colonies in migration strategies are stable, with implications for relative vulnerability to localised future effects by climatic and other potential drivers of environmental change.

**PS5.8 Site-specific foraging behaviour in Australasian gannets (Morus serrator)**

Melanie Wells[1], Lauren Angel[1], John Arnould[1]

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For many seabird species,information on feeding behaviour has been derived from only a few locations within their range such that the influence of environmental variability on foraging strategies is not known.Such information,however,is crucial for predicting how populations may respond to environmental change.The Australasian gannet breeds in numerous locations in Australia and New Zealand encompassing a range of oceanographic conditions and has been reported to forage primarily on small schooling prey.The present study used animal-borne cameras and GPS loggers to investigate the foraging strategies of individuals(n=52)from two colonies in south-eastern Australia experiencing contrasting oceanographic regimes: Point Danger(PD),a narrow deep water continental-shelf site with seasonally high marine primary productivity;and Pope's Eye(PE),in a shallow embayment(average depth <8m)with generally low primary productivity. Individuals from PD displayed typical pelagic area-restricted search patterns(range 150 km)and foraged almost exclusively(>90%)in association with conspecifics and other marine predators(dolphins,fur seals),diving repeatedly on large aggregations of small schooling prey(anchovies, pilchards, garfish).Some individuals from PE displayed similar behaviour when foraging outside of the embayment in the deeper waters of Bass Strait(80 m). In contrast,the majority(>75%)of PE individuals were observed to patrol along shallow sand banks in the embayment(range 30 km)in the absence of conspecifics,using both plunge and duck-diving techniques to capture single large prey(barracouta,jack mackerel,arrow squid), often on the benthos.While this strategy had a lower capture rate,the larger prey size and presumably lower energy expenditure(fewer dives)may confer advantages to birds using it. These results highlight the need to obtain information on the behaviour of predators in different regions to better understand their foraging plasticity.

## PS6 Foraging Strategies

### PS6.1 Sympatric North Pacific albatross species show contrasting responses to climate variability

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Climate-driven environmental change in the North Pacific has been well documented, with marked effects on the habitat and foraging behavior of seabirds. However, the mechanistic linkages connecting changes in behavior to seabird populations are not well understood. We evaluated effects of environmental variability on the foraging behavior and reproductive success of Laysan and Black-footed albatrosses breeding in the Northwest Hawaiian Islands. We assessed trip metrics and reproductive success using data collected from 2001-2012 and 1981-2012, respectively, and assessed relationships with variability in the location of the Transition Zone Chlorophyll Front (TZCF), Sea Surface Temperature (SST), Multivariate ENSO Index (MEI), and the North Pacific Gyre Oscillation index (NPGO). Environmental factors strongly influenced behavioral metrics for both species, but Laysan and Black-footed albatrosses employed different foraging strategies in response to poor foraging conditions. Black-footed albatrosses travelled farther and covered a larger geographic range in response to increased SST during incubation and brooding trips. Conversely, Laysan albatrosses travelled shorter distances and covered a smaller range during brooding when SST was higher, but showed no significant responses to SST during incubation. The effects of climate variability on reproductive success were more pronounced in Laysan than in Black-footed albatrosses, but

reproductive success for both species correlated negatively with SST, NPGO and distance to TZCF, and positively with MEI. We found strong negative spatial correlations (>95%) between habitat use and SST anomalies for Laysan but not for Black-footed albatrosses. Our results document different responses to environmental variability between sympatric species and link climate variability with both albatross behavior and reproductive success, information critical for predicting how albatross populations will respond to future climate change.

**PS6.2 Comparative foraging ecology of macaroni and southern rockhopper penguins at Marion Island**

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Gause's law of competitive exclusion predicts that when two ecologically similar species breed sympatrically and compete for the same resource, they must have evolved to partition that resource. At Marion Island, macaroni Eudyptes chrysolophus and southern rockhopper E. chrysocome penguins co-exist whilst having similar prey preferences and breeding cycles; the only major difference being a two week separation in the onset of breeding. Despite partial spatiotemporal segregation, interspecific competition may still be significant during the 70 day chick-rearing period if these species have not evolved to partition their marine environment. Additionally, populations of macaroni penguins have declined by 30 % and southern rockhopper penguins by 70 % over the last two decades, indicating species-specific responses to environmental pressures; which may be attributed to a competitive advantage over a shared resource or due to environmental changes associated with contrasting foraging strategies. Thus, in order to compare aspects of their foraging ecology, we used miniature GPS and TDR loggers to record movements and diving behaviour of both species over three consecutive chick-rearing periods (2011/12, 2012/13 and 2013/14). During the 2011/12 chick-rearing period, both species generally travelled towards the edge of the island shelf and foraged in waters > 3000 m deep. Mean maximum ranges were 53.1 km and 43.8 km for macaroni and southern rockhopper penguins, respectively. Trip duration and maximum range were related to chick age, with penguins foraging further away and conducting more overnight trips as chicks got older. Both species predominantly foraged at 30 to 70 m deep, however, macaroni penguins conducted more deeper dives and dived for longer than southern rockhopper penguins. Data from 2012/13 and 2013/14 will be analysed and inter-annual variation in foraging behaviour investigated. Spatial overlap of core foraging areas between species will also be assessed.

**PS6.4 Flexible foraging behaviour of a small zooplanktivorous seabird, the little auk Alle alle, in a changing Arctic**

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The little auk is a zooplanktivorous alcid breeding in the high Arctic. As the most numerous seabird in the Arctic it is an essential component of pelagic food webs in this region. Due to the high cost of foraging, little auks forage mainly on copepods associated with cold Arctic waters, larger and energetically more profitable than their counterparts associated with warmer Atlantic waters. Thus, the little auk is potentially highly susceptible to impact of climate change in the Arctic, currently observed and predicted in the future. We compared bathymetry, sea surface temperature and

chlorophyll a concentration among the foraging areas of the GPS-tracked individuals from three breeding areas in Svalbard differing in environmental conditions [Bjørnøya (B) at the rim of Arctic environment, Hornsund (H) influenced by Arctic water and Magdalenefjorden (M) influenced by warm Atlantic water but with productive marginal sea ice zone in fly range]. We took advantage of "space-for-time" substitution to forecast effects of expected climate changes. In general, foraging areas were characterized by enhanced productivity and zooplankton concentration. In areas with high contribution of cold Arctic water masses, little auks foraged in cold water shelf zone and at the shelf break zone, close to the colony (H, Me=43 km). In areas with low contribution of cold water masses around the colony, little auks searched for close patches of enhanced productivity (B, Me=44 km) or performed mainly long-distant flights to the marginal sea ice zone (M, Me=126 km). Results show that little auks adopted a flexible foraging strategy, allowing them to respond to a wide range of environmental conditions and prey availability through the plasticity of their foraging behaviour. To date, changes in the Arctic marine environment have not posed a threat to the ability of little auks to feed their chicks with energy-rich zooplankton.

**PS6.5 Sharing the ocean: seasonal variability in segregation between age classes in the wandering albatross**

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Wandering albatrosses are long-lived seabirds that use vast oceanic areas in the southern hemisphere, from subtropical to Antarctic waters. Juveniles, immatures, breeding and non-breeding adults are known to adopt different strategies that lead them to forage in partially distinct areas. However, depending on the season, overlap between age-classes may occur more or less strongly. Here we examine the monthly distribution of wandering albatrosses according to their age, sex and breeding status. We used a dataset of 508 satellite and geolocation tracks (455 adults with different breeding status, 21 immatures and 32 juveniles) to calculate area and utilization density kernel overlaps. We found that segregation occurs at several levels between age classes and sexes but also that some classes overlap more than other during certain periods. Oceanic features like fronts have a significant influence on the structuration of the spatial distribution of the different groups. As sexual and age-segregation in foraging grounds are thought to have evolve to reduce intraspecific competition, we suggest that variation in the seasonal spatial distribution and overlaps between groups may be linked to variability in foraging strategy and individual life history traits.

**PS6.6 Foraging by experienced and inexperienced Cory's shearwater along a 5-year period of ameliorating environmental conditions**

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Experience is believed to be an important factor determining the foraging success of animals, but there is limited knowledge on how foraging tactics differ among individuals, and on how individuals develop efficient foraging strategies. Pelagic seabirds are some of the longest living organisms and in several species breeding is deferred far beyond their physical maturity. The complex foraging skills needed to successfully rear a young is considered the most likely explanation for this life trait, making seabirds particularly interesting for the investigation of how foraging skills differ and develop through their life-span. In our study, the spatial distribution and foraging tactics of experienced and

inexperienced Cory's shearwaters (Calonectris borealis) were compared along five consecutive pre-laying and chick provisioning periods with a general trend of ameliorating environmental conditions (from 2010 towards 2014). Kernel overlaps of foraging areas and habitat modelling demonstrated that while experienced males showed high fidelity to shallow feeding grounds, inexperienced birds were more explorative and relied more on less productive pelagic areas. Our results seem to support the prediction that differences between experienced and inexperienced individuals are enhanced by food scarcity. In fact, there was a higher spatial, trophic and behavioural segregation between both groups when environmental conditions were poor, which progressively diminished with improving environmental conditions. Still, we cannot rule out the fact that inexperienced birds might be gaining experience with each breeding season and thus honing their foraging skills toward those of experienced individuals.

**PS6.7 Trophic ecology of a seabird species with reversed sexual size-dimorphism, the brown booby, using stable isotope analysis**

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Reversed sexual size dimorphism (RSD) is relatively rare in birds, but occurs in skuas, boobies and some shorebirds. Most studies attempting to explain its evolution assume that size-related differences in foraging strategy are of prime importance. In the present study, we examine the trophic ecology of brown boobies, Sula leucogaster, to determine seasonal variation in diet and the degree of dietary segregation between males and females. We used stable isotope analysis (SIA) of blood and feathers of paired adults as well as of their prey. At our study site on the Pacific coast of Mexico, female brown boobies were heavier and larger than males in all standard morphometrics. Comparison of the payloads brought by parents returning from foraging trips suggested that females provide larger meals to the chicks. Analysis of regurgitates of adults indicated that all prey are epipelagic fish, mostly flying fish species. The three main species of fish in the diet differed significantly in δ13C and δ15N. There was significant variation among nests, and between partnered brown boobies, in δ13C, and among nests, but not between partners, in δ15N in blood. Post-hoc paired comparisons showed that the blood of males was significantly depleted in 13C. There was also a significant effect of sex on δ13C but not on δ15N in feathers P1 and P9. Overall, comparison of the range of SI ratios in blood, P1 and P9, together with prey, indicated seasonality in the degree of diet variability among individuals, and that dietary segregation between male and female brown boobies is higher during breeding and the early non-breeding period, than for the remainder of the year. This study therefore shows clearly that foraging strategies, including both diet and contribution to chick provisioning differ between the sexes, and are potentially related to RSD in this species.

**PS6.8 Sexual foraging segregation and the association with prey availability in the world's largest gannetry**

Jonathan Botha[1], David Green[1], Andréa Thiebault[1], Pierre Pistorius[1]

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The occurrence of sex-specific foraging has been documented in a range of seabird species, but the underlying mechanisms remain poorly understood, particularly in monomorphic species. We assess whether sex-specific foraging behaviour occurs in Cape gannets, Morus capensis, at Bird Island, Algoa Bay (South Africa). The foraging distributions of a total of 108 chick-rearing birds were tracked using GPS loggers over three consecutive breeding seasons, for which the availability of prey was known. Sex-specific foraging strategies were evident during the 2012/13 breeding season, when prey biomass was relatively low close to the breeding colony. During this season, the foraging range of females extended well beyond that of males. Prey was more abundant throughout the distributional range during the other two breeding seasons, resulting in no apparent sex-linked segregation in foraging distribution or time activity budgets. The observed segregation during the 2012/13 breeding season thus seems to be a response to food limitation. During such periods of low prey availability in the area close to the breeding colony, high levels of intraspecific competition may have forced one sex to utilize feeding grounds at greater distances from the colony as a means of resource partitioning. The extension in the foraging range of females during periods of low prey availability may also result from differential nutritional requirements between the sexes, but warrants further investigation during different stages of the breeding cycle.

## PS7 Tracking Methods

### PS7.1 Actave.net - a novel approach to the analysis of seabird activity data recorded with GLS immersion loggers

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Studying the behaviour of seabirds outside the breeding season has long been very difficult. But the emergence of miniaturised data loggers in recent years made it possible to track and record behavioural patterns of even the smallest seabird species over extended periods of time. Light sensors provide the means for determination of geographical position (via geolocation) while immersion sensors record activity. Immersion data can provide profound insights into the activity of the focal species. It reveals seasonal variability of activity, and in combination with GLS data provides information on the spatial distribution of principal behaviour types like flying, resting and foraging. However, immersion data - generally called 'activity data' - tend to be rather extensive and the analysis complex so it often falls on the wayside in favour of the much quicker to process GLS data recorded be the devices. To alleviate this problem we developed Actave.net, a web-based software that autonomously processes raw activity data files, produces downloadable decomposed time-series data, and provides a suite of interpretative graphs of the processed data that greatly facilitate visual inspection of long-term activity patterns. To explain the biological relevance of the parameters calculated by Actave.net, we provide case study using a data set from deployments of GLS immersion loggers on thin-billed prions Pachyptila belcheri from New Island, Falkland Islands/Islas Malvinas covering the late 2009/10 breeding season, the entire non-breeding period as well as the onset of the first two months of the 2010/11 breeding cycle. We discuss spatial parameters (e.g. home distance, travel speeds), relevance of flight bouts and various activity types, and provide details about the relationship of environmental parameters (e.g. day length, lunar cycle) on the birds' activity patterns.

### PS7.2 The statistical prediction of foraging can be used to explore impact of fisheries interactions on seabird ecology.

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The miniaturisation and reduction in cost of GPS loggers has led to a proliferation of studies on seabird foraging ecology. However, Time Depth Recorders (TDR) are still comparatively expensive, so in the majority of studies foraging events are based on GPS track metrics such as Area Restricted Search (ARS) and first passage time. We used concurrent deployments of GPS and TDRs (n=9) to train a model to reliably predict seabird foraging events (plunge dives) based on GPS tracks alone, in northern gannets (Morus bassanus). The model predicted that foraging events in a trip could be predicted by GPS tracks when applied to a dataset of gannets not equipped with TDR devices (n=7), we predicted approximately 600 new foraging events. Diet of instrumented birds was investigated using Stable Isotope Analysis, with 9 birds classified as low users and 7 birds classed as high users of fisheries discards. Track data and predicted foraging events from the two groups was analysed in relation to fisheries data using the Vessel Monitoring System. The overall rate of plunge diving was slower in areas of high fisheries activity for all birds. However, high users of fisheries discards had a higher rate of diving than birds of lower discard use which supports a 'junk food hypothesis.' The combination of multiple fine scale data formats provides a fully detailed insight to seabird ecology. Prediction and projection techniques as utilised in this study have the power to greatly enhance long distance ecological studies of seabirds. If used in more studies, this may provide a solid basis for extending the efficiency and quality of research.

**PS7.3 Combining GPS tracking and Stable Isotope Analysis in a synanthropic seabird: the Lesser Black-backed Gull Larus fuscus**

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The Lesser Black-backed Gull (Larus fuscus) has colonized and quickly proliferated along the Belgian coast during the second half of the 20th Century. The Belgian L. fuscus breeding population exploits human-conditioned nesting space and human-generated sources of food: fishery discards, industrial food waste, soil invertebrates in agricultural lands and urban garbage. This synanthropic behaviour, extensive to a large proportion of its populations along the North-eastern Atlantic coasts, has expanded the species' breeding range through the exploitation of anthropogenic resources. However, ecological trap conditions emerge as natural nesting grounds give way to urban development and food availability is affected by swift changes in human activities. In particular, the onset of a European ban on discarding by fisheries may result in a sharp and permanent decline in their key food source. Stable isotope analyses on chick feathers have revealed an overall importance of fishery discards in the food provided by local breeding parents to their chicks. However, the relative amount of fish in chick diet showed a significant degree of individual variation, which was as well observed in foraging patterns given by GPS tracking data during the chick rearing period. This variation points toward the possibility that gulls develop individual foraging strategies, which would in turn have consequences in the capacity to respond to changes in local food availability. Through cost-benefit analyses on the different observed foraging strategies of this generalist feeder, and an evaluation of the local availability and distribution of the exploited food sources, we aim at evaluating the future viability of the local L. fuscus breeding population, as well as potential changes in foraging distributions.

**PS7.4 Foraging movements of northern fulmars during the pre-laying exodus: insights from state-space modelling of geolocator data**

Ewan Edwards[1], Lucy Quinn[2], Paul Thompson[1]
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Linking breeding colonies and foraging areas at sea is critical to management and conservation of marine predators. Tracking has recently expanded our knowledge of where seabirds forage at sea, both during breeding and migration. Whilst post-breeding tracking using GLS has revealed broad-scale patterns in distribution, often over remarkable distances (Egevang et al., 2010; Hedd et al., 2012), its usefulness at finer scales, especially during the breeding season when foraging range is constrained, is unclear. Meanwhile, tracking using high-accuracy GPS/PTT devices has focused on the chick-rearing period when loggers are easier to deploy/recover on nesting birds (Guilford et al., 2008; Thiers et al., 2014). GLS loggers deployed in previous years, could provide valuable information during the early breeding season. We used incubation tracking data from double-tagged (GPS/GLS) fulmars tagged in Scotland, within a state-space modelling framework (SSM; Winship et al., 2012) to estimate error around GLS locations. We then fitted the SSM to GLS-only data from the pre-laying exodus, using the mean of these error estimates, for 39 birds with loggers deployed in previous years. We compared the spatial distribution of males and females during this critical period (Mallory, 2008). Trip durations were estimated from the GLS data. During the pre-laying exodus, Scottish fulmars forage across a range of biogeographic regions. Birds were tracked to a maximum of 2900 km from the colony, and excursions lasted a maximum of 32 days. Males (18 days) spent less time away from the colony than females (25 days), and most (60 %) males remained within the North Sea. Most (68 %) females flew north, foraging within the Norwegian/Barents Sea where birds could experience 24h daylight. Whilst allowing access to productive foraging regions, this wide-ranging behaviour exposes fulmars to threats in foreign waters, such as bycatch, and poses questions related to seabird management in European waters

**PS7.5 Mining tracking data with behavioural modelling: examples of two threatened New Zealand Procellaria, the Westland and the Black Petrel**

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Understanding the at-sea behaviour of marine birds is critical for identifying important foraging and migratory habitats to prioritise management operations and species-specific conservation plans. Despite the proliferation of at-sea movement data owing to the ongoing development and availability of several key tracking technologies, comparatively few attempts have been made to model patterns of behaviour within individual seabird's tracks. Here, we present two examples of how inferential movement models can extract behavioural information relevant to both applied and basic research objectives. We describe two case studies of tracking datasets with threatened species of Procellaria petrels in New Zealand. First, we employ a switching Hidden Markov model to characterise changes in states of behaviour within high-resolution GPS tracks collected during foraging trips of Black petrels (P. parkinsoni). We then illustrate how these outputs can help identify areas of possible conflict with commercial fisheries. Second, we show how for even very-low-

resolution tracking data, such as those obtained by popular light-based geolocation methods, a simple multivariate statistical technique (k-means cluster analysis) can reliably classify behavioural modes. Specifically, we provide an example of the annual movement trajectories of migratory Westland petrels (P. westlandica), identifying how behaviour varied during the major phases of the year: breeding, nonbreeding and migration. The major aim of our presentation is to demonstrate that, through application of a variety of inferential models, valuable information about the at-sea behavioural patterns of seabirds can be readily derived from their movement trajectories. We hope our findings encourage others to consider employing such methods for their own research endeavours, particularly for birds of conservation interest.

**PS7.6 Stable isotope analyses as a tool to identify non-breeding areas of Atlantic shearwaters**

Teresa Militao[1], Daniel Oro[2], Peter Ryan[3], Yann Kolbeinsson[4], Jacob Gonzalez-Solis[1]
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Geolocators are revealing many new aspects of the migratory dynamics of seabirds but are relatively expensive to use in large numbers, birds need to be recaptured and studies are usually limited to breeders. In these circumstances, intrinsic markers, such as the analysis of stable isotope ratios in feathers, can be a useful alternative or complementary technique to trace areas used during the non-breeding period. Here, we used geolocation to determine non-breeding areas from five shearwaters species and present for the first time an interspecific comparison of the δ15N and δ13C values of their feathers moulted in the main productive areas of Atlantic Ocean (upwelling, continental shelf and currents confluence). Moreover, to understand whether isotopic differences among areas would result from geographic variations in diet or in isotopic baselines, we compiled the isotopic values of the main prey of shearwaters (small epipelagic fish and cephalopods) from the principal non-breeding areas. Great (Puffinus gravis), Manx (P. puffinus), Cory's (Calonectris borealis), Scopoli's (C. diomedea) and Cape Verde shearwaters (C. edwardsii) breed in different archipelagos throughout the Atlantic or the Mediterranean Sea and share several feeding grounds in the Atlantic in different periods of their annual cycle. The estimation of variance components of δ15N and δ13C values of feathers showed that the factor non-breeding area was always more important than the factors species, individual or year. However, there were some isotopic differences between seabird species that shared the same non-breeding areas, suggesting small diet differences among species. Moreover, in general, seabirds and prey species showed a similar isotopic variation among areas. Our results indicate that isotopic variation in seabirds were mainly caused by geographic variation at baseline, suggesting stable isotope analysis of feathers as a powerful tool to identify the non-breeding areas of untracked seabirds.

**PS7.7 Creating spatial models without the spatial data: How long term ecological data can help identify important oceanographic regions for top predators**

Grant Humphries[1]
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Advances in GPS tracking technologies have allowed for rapid assessment of important oceanographic regions for seabirds. This allows us to understand seabird distributions, and the characteristics which determine the success of populations. It many cases, quality GPS tracking data

may not be available however, long term population monitoring data may exist. In this study, a method to infer important oceanographic regions for seabirds will be presented using breeding sooty shearwaters as a case study. Chick size and harvest index data derived from a long term dataset of Maori 'muttonbirder' diaries were obtained and used as response variables in a gridded spatial model. It was found that areas of the sub-Antarctic water region best capture the variation in the chick size data. Oceanographic features including wind speed and charnock (a derived variable representing ocean surface roughness) came out as top predictor variables in these models. Previously collected GPS data demonstrates that these regions are used as "flyways" by sooty shearwaters during the breeding season. It is therefore likely that wind speeds in these flyways affect the ability of sooty shearwaters to provision for their chicks due to changes in flight dynamics. These methods can be applied to any long-term time series to identify regions of importance for seabirds

**PS7.8 Unravelling the migration and wintering grounds of Red-necked Phalaropes Phalaropus lobatus nesting across the Western Palearctic**

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The Red-necked Phalarope Phalaropus lobatus is a circumpolar species nesting in Arctic and subarctic areas. Outside the relatively short breeding season this species is almost entirely pelagic with the three distinct wintering areas in tropical waters of the Indian and Pacific Oceans. Due to its small size and pelagic nature, very little is known about its non-breeding movements. Past ringing recoveries show that at least part of the continental Scandinavian population migrates south-east, likely into the Arabian Sea. Even less was known about the movements of birds nesting on islands in the northeastern North Atlantic. A recent study from Scotland revealed a unique migration pattern of a bird migrating south along the western side of the North Atlantic, across the Gulf of Mexico to wintering grounds off Ecuador and Peru in the Pacific Ocean (Smith et al. 2014. Ibis 156(4)). We hypothesize that other populations from the northeastern North Atlantic follow a similar route to the Pacific, whereas continental populations migrate to the Arabian Sea, effectively representing two geographically distinct populations nesting within the Western Palearctic. In order to study that, a total of 134 birds were equipped with geolocators in Greenland (4), Iceland (39), Scotland (20), Swedish Lapland (30), Northern Finland (11), Northern Norway (20) and Russia (10) in 2012-2014. Sixteen birds were recovered in 2013-2015 from all countries. The results confirm the existence of two geographically distinct populations using separate migration flyways. These results may help interpreting the decline of some populations during past decades and are therefore important for the conservation of the species.

## PS8 Fishery Bycatch 2 – Mitigation

**PS8.1 Efficacy of the Smart Tuna Hook in reducing bycatch of seabirds in the South African Pelagic Longline Fishery**

Barry Baker[1], Steve Candy[2], Dominic Rollinson[3]

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While considerable progress has been made in mitigating bycatch in demersal longline fisheries proven and accepted seabird avoidance measures in pelagic fisheries require substantial improvement. We report on an at-sea experiment to test the efficacy of a mitigation method known as the Smart Tuna Hook. This method uses a modified tuna longline hook which accepts a specially designed shield that disarms the hook once baited, making it impossible for any seabird to be hooked. The shield is released within 15 minutes after the hook has been immersed in salt water, allowing fish to be caught after the baited hook has passed beyond the normal diving depths of most seabirds. After release from the hook the shield sinks to the seafloor where it corrodes within 12 months, leaving no pollution or toxic residue. The byproduct is iron oxide and carbon. Our experimental work was conducted on pelagic longline vessels targeting tuna and swordfish out of Cape Town, South Africa during the Austral spring of 2014. Seabird bycatch was high and a total of 13 birds were caught across the three trips. Eleven of these birds were caught on the control treatments and 2 birds on the STH treatments. The use of the Smart Tuna Hook led to a reduction in the bycatch of seabirds of between 81.8% - 91.4% in one of the highest-risk fisheries to seabirds in the world. Importantly, there was no detectable difference between setting methods in the catch rates of commercially valuable species, indicating no detectable detrimental effect on fish catch for any species. In a fishery where the bycatch rate of seabirds exceeded 1 bird/1000 hooks and where the capture of more than 25 birds by a vessel each season leads to a suspension of fishing activity for that vessel, the Smart Tuna Hook clearly provided a significant deterrent to seabirds attacking baits, and offers a feasible option for pelagic fishers to significantly reduce the level of interactions with seabirds.

**PS8.2 Korea's Southern Bluefin Tuna fishery experiments with line weighting options for seabird bycatch reduction**

Yuna Kim[1], Zang Geun Kim[2], Sang Chul Yoon[2], Hee Won Park[2], Gi Chul Choi[2], Jae Gu Jung[2], Ross Wanless[4], Sung Il Lee[2]

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Seabird bycatch is a major threat to albatrosses and petrels. Many mitigation measures have been developed and tuna RFMOs adopted some as mandatory. From July 2014, the Indian Ocean Tuna Commission requires vessels operating south of 25간 to use at least two out of the following three measures: setting lines only at night, deploying a bird-scaring streamer line, and adding weights to branchlines. Adding weights is complex and concerns for catch rate and safety of crews remain high. Previously, trials of weighing configurations were conducted on-board Korean pelagic longline vessels during production fishing. Those trials indicated that 45 g weights at the hook were best suited to Korean operations, and we adopted this regime for our trials. In 2014, 45g weights were on a vessel totalling 73 000 weighted branchlines and 73 000 unweighted branchlines. Preliminary results from 2014 trials show that 45g weights can be incorporated into fishing operation safely without operational problems. Catch rate of target species was 19% lower on weighted branchlines compared to controls, but the difference was not significant (?2=-1361935, P=0.29). Although no bird was caught on weighted lines, we cannot draw a firm conclusion about their effectiveness in reducing seabird bycatch because only one bird was caught on the control lines, and seabird abundance was relatively low. Further work is required, preferably during times of high seabird

abundance, to achieve robust sample sizes for assessing impacts of weights on target and non-target catch rates.

**PS8.3 Diving behaviour of Procellaria petrels and its relevance for mitigating longline bycatch**

Dominic Rollinson[1], Ben Dilley[1], Peter Ryan[1]
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This study investigates the diving behaviour of two Procellaria petrels: White-chinned P. aequinoctialis and Grey P. cinarea. The White-chinned Petrel is the seabird species most commonly killed by Southern Hemisphere longline fisheries, while Grey Petrel populations have been adversely affected by seabird bycatch by longline fisheries, particularly off New Zealand and Australia. Procellaria petrels also facilitate albatross mortality, by bringing baited hooks that have sunk beyond the dive depth of albatrosses back to the surface. Despite the importance of understanding diving ability for mitigating longline bycatch, little is known of either species' diving behaviour. We obtained data from temperature-depth recorders (TDRs) from nine White-chinned Petrels breeding on Marion Island, south-western Indian Ocean, during the late incubation and chick-rearing period, and seven Grey Petrels from Gough Island, South Atlantic Ocean, during the pre-breeding period. White-chinned Petrel maximum dive depth varied considerably among individuals (range 2-16 m). Males dived deeper than females, and birds feeding chicks dived deeper than incubating birds, but dive rate did not differ between the sexes. Time of day had no significant effect on White-chinned Petrel dive depth or rate. Grey Petrel maximum dive depth was deeper (22 m), with similar individual variation (2-22 m). Our findings will help to improve the design and performance of mitigation measures to reduce seabird bycatch in longline fisheries, particularly minimum line sink rates and optimum aerial coverage of bird-scaring lines.

**PS8.4 Bird Barriers: A silver lining for seabirds in South Africa's demersal trawl fishery**

Mmatjie Mashao[1], Edward Rice[2], Lisa Mansfield[1], Bronwyn Maree[1], Ross Wanless[1]
*[1]BirdLife South Africa, [2]University of Cape Town*

Thousands of seabirds are accidentally killed in demersal trawl fisheries globally through cable strikes and net entanglements. In the South African demersal hake trawl fishery, bird-scaring lines (BSLs) can reduce seabird bycatch by up to 90% when used correctly. However BSLs can be ineffective in rough weather and leave the cable exposed during hauling and parts of the setting process. Furthermore, the reduction in total bycatch rates is driven by massive reductions in albatross interactions, whereas some smaller species are at increased risk with BSLs as they are no longer outcompeted by the albatross, so additional measures are warranted. Birds aggregate at scuppers where discards enter the water, and foraging birds were distracted by food, frequently ignored BSLs and drifted sternwards (as the boat steams ahead) and into the area where warp contacts are likely (the danger zone). We tested a new device that creates a physical barrier between the scupper and the danger zone: Bird Barriers (BBs). We investigated the effect BBs had on birds entering the danger zone and recorded warp collisions for 112 trawls. BBs significantly reduced numbers of individuals entering the danger zone: albatrosses Thalassarche spp. (67%), White-chinned Petrels Procellaria aequinoctialis (62%) and Cape Gannets Morus capensis (47%). Warp collision rates were significantly reduced for Pintado Petrels Daption capense, White-chinned Petrels and Great Shearwaters Puffinus gravis. Therefore BBs were more effective at discouraging

smaller birds from moving into the danger zone than BSLs. Season and the presence of Cape Fur Seals Arctocephalus pusillus had significant effects on bird interactions. BBs were less effective for plunge diver species (Cape Gannets) suggesting feeding behaviour influences the efficacy of BBs. Further BB testing is required and different designs and positions are recommended for future testing.

**PS8.5 Collaborating with fishermen to reduce seabird bycatch in U.S. West Coast sablefish longline fisheries**

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Bird scaring lines (BSLs) are an essential part of best practices to protect longline fishing gear from seabird attacks, save bait and reduce incidental seabird mortality. Regulations and performance standards for BSLs in the U.S. were designed for demersal longline fisheries in Alaska and will soon be required in the U.S. west coast demersal longline fishery (for vessels >55 ft). We initiated research and outreach to assess whether the Alaska BSL performance standards were sufficient for the U.S. west coast longline fishery for sablefish. We collaborated with fishermen to characterize vessels and gear, quantify gear sink profiles, and seabird attacks on baited hooks while increasing awareness of the need for seabird conservation. Unlike Alaska, some vessels in the west coast fleet use a combination of floats and weights along the groundline to keep the keep the hooks off the seafloor where macro invertebrates degrade bait and target catch. Longlines with floats sank beyond the reach of albatrosses (2 m depth) 2.25 times further astern than Alaskan style gear without floats. Attack rates for most vessels without floats remained low within the mean aerial extent (AE) of BSLs (34.4 m astern ± 1.6 SE) and within the distance astern at which gear sank to 2 m (66.3 m ± 7.3 SE). Therefore, most west coast vessels without floats can be protected from bird interactions using existing Alaska BLS specifications. However, the delayed sink rate of longlines with floats extended the seabird attack zone (149.7 m astern ± 19.7 SE) well beyond the BSL aerial extent and exacerbated the risk of BSL entanglements with fishing gear. Attack rates increased with distance astern for longlines with floats even with the use of paired BSLs, suggesting that existing performance standards are inadequate for this gear type and further refinement of safe, practical and effective seabird mitigation strategies is needed.

**PS8.6 99% there: Seabird bycatch success story in a South African trawl fishery**

Bronwyn Maree[1], Ross Wanless[1], Tracey Fairweather[2], Benedict Sullivan[3], Oliver Yates[4]
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Globally, many thousands of seabirds are killed accidentally in demersal trawl fisheries through cable interactions and net entanglements. However, multi-year datasets for estimating seabird-trawl interactions robustly are scarce. In 2004/2005, an estimated 15 500 (7000-26 000) seabirds were killed annually through cable strikes in the South African deep-water hake trawl fishery; the majority were albatrosses. We reanalysed those data using fishing effort from vessel logbooks (previously unavailable). The new estimates are ¡¬40% lower across all taxa: ¡¬9300 birds in 2004, of which ¡¬7200 were albatrosses. We compare these figures to data from 2006 to 2010, when vessels used a single measure (bird-scaring lines) to reduce seabird mortality. From 64 trips and 690 hours of observation, 41 seabirds were confirmed killed due to cable strikes, of which 22% were albatrosses.

Fatal cable interactions occurred overwhelmingly when vessels discarded offal, with the highest rates (birds killed per hour of observation) in winter and during setting. Comparing rates shows that bird-scaring lines alone resulted in 73-95% lower mortality in the winter/discard strata (all seabirds: 0.56 birds per hour before, 0.15 birds per hour after, $P < 0.001$; albatrosses: 0.44 birds per hour before, 0.02 birds per hour after, $P < 0.001$). Estimated total mortality [mean and 95% confidence intervals (CIs)] in this fishery in 2010 was 990 (556-1633) seabirds, including 83 (38-166) albatrosses, a reduction in mean albatross deaths of > 95%, reflecting both bird-scaring line effectiveness (accounting for > 90%) and annual fishing effort reduced by 50% from 2004-2005 to 2010. Bird-scaring lines cost < US$200 each in South Africa, a trivial expense per vessel for a measure that reduces fatal interactions with threatened seabirds so effectively. Our results provide a strong case for the mandatory adoption of bird-scaring lines in trawl fisheries with high densities of scavenging seabirds.

**PS8.7 Halting global seabird bycatch: The Albatross Task Force**

Oliver Yates[1], Ben Sullivan[1], Kondja Amutenya[2], Luis Cabezas[3], Leandro Chavez[4], Rory Crawford[5], Andres Domingo[6], Rodrigo Forsellado[6], Esteban Frere[4], Juan Gonzalez[3], Sebastian Jiménez[6], Bokamoso Lebepe[7], Christine Madden[7], Bronwyn Maree[7], Mbali Mbonambi[7],
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The overlap between fisheries and vulnerable species has impacts on a range of non-target taxa. One of the worst affected families is the Diomedeidae, with 15 of 22 species of albatross at risk of extinction. Estimates suggest that globally, 300,000 seabirds per year are killed when scavenging baited hooks from longline vessels, through fatal collisions with trawl cables or entanglement in trawl nets. To combat declining albatross populations, BirdLife International and the RSPB launched the Albatross Task Force; a grass roots conservation project in South America and southern Africa. The main objective of the ATF is to demonstrate simple, affordable measures that mitigate seabird bycatch under commercial fishing conditions. ATF research has shown that without exception in targeted industrial fisheries, the use of a combination of mitigation measures can reduce seabird bycatch by >90%, with no negative impact on fish catch. However, the implementation of the measures across fishing fleets remains a logistical and political challenge. The ATF approach of working in collaboration with industry and government from the outset, through a team of locally employed experts has proven extremely effective with sustained reductions in three South African target fisheries. New fishery regulations stipulating mandatory use of mitigation measures are either in place or under development in the other six industrial fishing fleets where the ATF is active. In each scenario, regulations have been built on the back of collaborative experimental mitigation research that clearly demonstrates the efficiency, simplicity and practicality of measures, reinforced by positive national and international advocacy. This is supported in parallel by education and awareness campaigns for the fisheries sector. The grass roots approach of the ATF, taken at an international scale has set a new benchmark for direct conservation to reduce bycatch of non-target species in the world's fisheries.

**PS8.8 Addressing seabird bycatch concerns in Marine Stewardship Council standard review**

Stephanie Good[1], David Agnew[1]
*[1]Marine Stewardship Council*

In MSC assessments, bycatch of non-target species is taken into account in relation to the impact on a population when determining an outcome score. Prior to the most recent standard review, if impacts on populations were not significantly hindering recovery or otherwise significantly impacting them, there was no further requirement to reduce impacts. However, following a review of best practice including the FAO Guidelines on Bycatch Management and Reduction of Discards, the MSC standard has now been revised to require fisheries to review alternative measures for minimising mortality of unwanted catches (which would always include seabirds) and to implement these measures if they are more effective at minimising mortality than those currently employed and practical and cost effective to implement, even if populations are not being significantly impacted by the fishing activity. In addition, more robust information requirements include requiring data sources with high levels of verifiability and low levels of bias when a species/population is close to or below its biologically based limits or the status is known. The MSC has also added requirements to consider the cumulative impacts of MSC fisheries on a stock or population when certain criteria are met. For Endangered, Threatened and Protected (ETP) species identified in an assessment, where there are mortality limits established within a jurisdiction, the all the MSC certified fisheries within that jurisdiction need to ensure that their impact is cumulatively within those limits. To facilitate fisheries and certification bodies being able to quickly find alternative measures and their relative merits, the MSC in collaboration with New England Aquarium is working on a Bycatch Information Exchange.

# Wednesday October 28 2015

## PS9 Individual Specialisation

### PS9.1 Jack of all Trades or Master of Some? Individual specialists, population generalists and Gentoo penguin foraging ecology across the Scotia Arc during a time of rapid environmental change.

Rachael Herman[1], Michael Polito[1]
*[1]Louisiana State University*

Populations of Gentoo penguins (Pygoscelis papua), have increased in the Scotia arc in recent decades, while sister species such as Chinstrap (P. antarctics) and Adélie penguins (P. adeliae) have experienced substantial declines in numbers. Previous dietary analyses suggest Gentoo penguins have a generalist foraging niche, which may help buffer them from recent climate-driven declines in key prey species, such as Antarctic krill (Euphausia superba). Ecological theory indicates that generalist populations fall under two different categories: Type A generalist populations exhibit large variation within individuals, and little variation between individuals, where Type B generalist populations are comprised of individual specialists, with large variation between individuals. It is important to identify which type of generalist population Gentoo penguins fall under, as these strategies impart differing ecological and evolutionary ramifications under times of environmental change. We conducted stable isotope analysis using tail feathers from Gentoo penguins at multiple breeding sites across the Scotia arc, including the Falkland Islands, South Georgia, the South Shetland Islands, and the Western Antarctic Peninsula, to assess individual variation in winter diets

and determine the type of generalist strategies that Gentoo penguins utilize. Preliminary analysis indicates the presence of individual specialization within some colonies, suggesting that individual resilience to further shifts in food availability may vary within Gentoo penguin populations.

**PS9.2 Individual success: Linking foraging patterns with energetic physiology in an Arctic seabird**

Graham Sorenson[1], Sebastien Descamps[2], Grant Gilchrist[3], Michael Janssen[3], Travis White[4], Oliver Love[1]

*[1]University of Windsor, [2]Norwegian Polar Institute, [3]Environment Canada, [4]Carleton University*

Polar ecosystems (Arctic/Antarctic) are currently facing some of the most rapidly emerging environmental stressors worldwide. Because polar systems tend to exhibit extreme, but highly stable environments, polar species may not have the physiological or behavioral flexibility to respond to rapid environmental change. Unfortunately we know very little about the underlying mechanisms (e.g. physiology and behavior) that allow individuals to continue to respond optimally to this degree of change. Seabirds provide a great model to study the effects of large-scale anthropogenically-derived change due to their place as a top predator, their wide distribution and extensive foraging ranges, and their strong dependence on oceanic patterns for food resources. We are combining measurements of energetic physiology (baseline corticosterone and energetic metabolites) during the reproductive period with the tracking of foraging trips using light-weight GPS units in Arctic Thick-Billed Murres (Uria lomvia). We are taking an individual-level approach by examining relationships between within-individual changes in foraging behavior and energetic/stress physiology. Results will provide new insights on how individual flexibility in physiological and behavioural processes relate to the success of individuals and hence the populations they make up.

**PS9.3 Strong differences in individual specialisations in spatial use and dive behaviour over time in a benthic seabird, the Kerguelen shag, and their implications for foraging success**

Elodie Camprasse[1], Charles-André Bost[2], John Arnould[1]

*[1]Deakin University, [2]Centre National de la Recherche Scientifique*

Individual specialisation, which occurs when individuals use a small subset of the population's resource base, has received a growing attention in the past decade. However, quantitative measures of it are lacking for most species and its implications are poorly known. In the present study, Kerguelen shags (Phalacrocorax verrucosus) were used to investigate the relationships between foraging specialisations, foraging success and body condition. A total of 21 nesting pairs were fitted with GPS loggers, 6 of which were also instrumented with a dive behaviour data logger. The loggers recorded between 3-20 successive trips for each bird, with 10 individuals being instrumented in incubation and again a month later when rearing chicks. Adults and their chicks were weighed before and after deployment to estimate foraging success. Species in the blue-eyed shag complex have been suggested to display foraging area fidelity and fidelity to one or more specific depth ranges. Here we show that some individuals not only visited the same foraging grounds on consecutive trips but did so repeatedly over a one-month interval. Maximum range, trip duration and choice of foraging grounds varied greatly between individuals. A remarkable consistency in individual dive depth was exhibited in most individuals. As benthic foragers, Kerguelen shags appear to exhibit strong individual differences in specialisation. The implications for foraging success and

whether specialists pair with other specialists, as well as the effect of age on specialisation, were investigated.

**PS9.4 Interlocality and interannual variability in foraging behaviour of red-footed boobies: influence of environmental drivers.**

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While resource acquisition strategies of marine predators are well studied in polar and temperate environments, far less is known in tropical marine environments. Tropical waters are characterised by a low productivity, a low seasonality, and in some areas a high interannual variability due to climatic events such as El Niño and La Niña. Due to these conditions, tropical seabirds may use particular foraging strategies to minimize costs associated with more dispersed resources and low-quality foraging area. Here we study the influence of environmental variables on the foraging behaviour and habitat used by a pan-tropical species: the red-footed booby. Individuals from different tropical islands were fitted with GPS tags during the breeding season. Trip parameters such as duration, total distance covered, maximum range from the colony and proportion of time on the water were estimated for each track. Area-restricted search (ARS) behaviour were detected with the First-Passage Time method. Different environmental drivers were then extracted from these ARS : Sea Surface Temperature (SST), Chlorophyll A concentration and submesoscale filaments produced by the stirring and straining by mesoscale eddies. We show that foraging behaviour and habitats varied extensively i) between years for a given locality, due to the interannual variability of environmental conditions, ii) between sites that are located in different oceanographic conditions.

**PS9.5 Foraging site-fidelity in Australasian gannets**

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During the breeding season, seabird foraging range is greatly restricted by the need to frequently return to a central location and provision young. Seabirds may be able to increase their foraging success by remembering locations of high prey density and returning to these locations. Previous studies of colonial seabirds have found site-fidelity is adopted to optimise prey availability. In the present study the site-fidelity of Australasian gannets (Morus serrator) breeding at Pope's Eye was examined across two years (n= 12, 2012; n= 18, 2013). Pope's Eye is a small, man-made structure occurring in a shallow embayment of northern Bass Strait, Australia. Data for four consecutive foraging trips were collected using GPS data loggers to measure metrics of at-sea movement (i.e. trip duration and distance from colony) and tri-axial accelerometers to measure indices of foraging effort (i.e. overall dynamic body acceleration, proportion of time spent resting and diving). Results indicate strong inter-individual variation with some individuals making short trips, less than 15 km from colony, whereas others foraged up to 80 km from the colony, across all four trips. Additionally, birds conducting short trips often returned to the same area suggesting a higher degree of site fidelity to close proximity locations. Gannets showed a preference for foraging areas, either foraging inside the shallow embayment or in the deeper waters of Bass Strait. These findings suggest individual specialisation may occur in the Australasian gannet in regards to their foraging strategy and type of prey targeted, reflective of the environment in which they forage.

**PS9.6 Evidence for multi-scale foraging behavior of Masked Boobies (Sula dactylatra) in the Gulf of Mexico**

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Patterns in resource use may vary widely among individuals, leading to a wide array of foraging strategies that are challenging to describe at the population level. In marine environments, apex predators must efficiently process environmental cues derived from physical habitat features to locate prey, and variability and patchiness of the environment may be reflected in foraging behavior among individuals. We sought to examine foraging behavior and habitat use of 116 masked boobies (Sula dactylatra) tracked with GPS units during May and November 2013, and December 2014 at a regionally important breeding colony in the southern Gulf of Mexico. Birds exhibited individual variability in foraging behavior and searched for prey at nested hierarchical scales ranging from 60 m - 30 km. The oceanographic variables that were related to foraging behavior at small scales (at the prey patch level) varied widely between individuals, suggesting that individual masked boobies use different foraging strategies. Sea surface height and velocity of water corresponded to foraging most frequently (44% and 38% of birds respectively), a finding that is consistent with the characterization of the Gulf of Mexico as a highly dynamic system strongly influenced by currents and eddies. This study provides valuable information for creating models that explain population activity by integrating individual components and improving management plans by considering the range of behavior within a population. Furthermore, our data, when combined with other tracking efforts in the northern Gulf and Caribbean, provide valuable information for marine spatial planning efforts and serve as a baseline for anthropogenic based threats such as development, pollution, and commercial fisheries.

**PS9.7 Individual and population level foraging consistency in Campbell Albatross**

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Consistent individual differences in foraging behaviour are common among marine vertebrates. Such foraging specialisations have relevance for addressing a number of key ecological and applied questions, and are therefore the subject of an emerging field of research. However many studies do not differentiate between measures of individual consistency averaged at the population-level and those measured at the individual-level. We tested for spatial foraging consistency in the threatened Campbell Albatross (Thalassarche impavida) during the chick-brooding period at both the population and individual level using eight traits within and between two years. Terminal latitudes in 2012, terminal longitudes across all timeframes, total distance travelled across years, and angle of departure in 2011 were highly repeatable when measured at the population level. Individual level analyses revealed that males and females showed similar overall patterns of behaviour, with most individuals demonstrating consistent behaviour. However, individual metrics showed sex differences in the response to as yet unknown changes in the environment or foraging resources, that were masked by population-level estimates. Our results highlight inter-individual differences in foraging

behaviour of Campbell albatross, with males being more consistent than females. However these sex-specific differences were not apparent when estimating consistency at the population-level.

**PS9.8 A migrant with varied routes and destinations: causes and consequences of individual variability in Cory's shearwaters**

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Among migratory birds, populations may display patterns that vary from high connectivity and low individual variability, where all individuals of a population spend the non-breeding season in a single wintering area, to cases where connectivity is low and individual variability high, with each population linked to varied non-breeding quarters. Cory's shearwaters are, amongst seabirds, at an extreme of variability, with six widely spread major wintering areas used by individuals from the same nesting colony, spanning almost the entire Atlantic and entering into the SW Indian Ocean. Results from tracking since 2006 (> 200 migratory tracks obtained with geolocators) will be presented, depicting patterns of within and between-individual variation in migratory strategies and at-sea behaviour. Sex and carry-over effects from reproduction explain part of the between- and within-individual variability in migration. Males are more likely than females to remain close to the nesting colony and winter in the Canary current. Individuals experimentally freed from parental care duties are also less likely to migrate long distances, and our study is the first to experimentally shift migratory destinations in a long-distance migrant. Long-distance migratory individuals arrive later to the breeding site and are less likely to engage in reproduction. This and other consequences of different migratory strategies will be discussed, as well as the potential implications for adaptation in a context of global change.

**PS9.9 Changes in seabird foraging activity, forage fish, and plankton composition at a site in the Salish Sea, Washington, USA**

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Published and unpublished reports suggest that seabird numbers have decreased markedly in the Salish Sea over the past several decades. A number of recent studies indicate that changes in the availability of prey may be driving this trend. We tested the hypothesis that seabird feeding activity at a known foraging location decreased in 2010 and 2011 in comparison to the mid-1990s, and that this decrease was associated with a concomitant decrease in the abundance of small, pelagic fish, and changes in the plankton community. We found significant decreases in seabird foraging activity between decades, a decrease in area integrated backscatter (a measure of fish abundance), and a decrease in calanoid copepod abundance, while the abundance of Noctiluca increased. We suggest that a shift in plankton composition and abundance has had a bottom-up negative impact on seabirds in this ecosystem.

## PS10 Foraging Aggregations

**PS10.1 Adaptive significance of collective foraging strategies in seabirds.**

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After a major biological extinction about 65 million years ago, seabird species greatly diversified. The specific characteristics of the marine environment, as well as the resources it includes, constitute a strong driver for the evolution of seabirds, shaping their morphology and behaviours. We reviewed the foraging characteristics (foraging habitat, diet, feeding techniques, sensory use) of 362 species (Sphenisciformes, Procellariiformes, Phaethontiformes, Gaviiformes, Pelecaniformes, Suliformes, Charadriiformes), in conjunction with published studies on the social aspects of their foraging strategies. Correspondence analysis was used to find correlations between solitary/collective behaviours and foraging characteristics. The first level of differentiation relates to habitat: species foraging on benthic resources are mostly solitary, while species foraging on pelagic resources are mostly gregarious while feeding. The second level of differentiation relates to diet and associated feeding techniques, as well as sensory use, to distinguish among species feeding on pelagic resources. For example, scavengers are occasionally observed in groups over carrion. As they use olfaction to detect food, these species are most probably able to find prey solitarily but may aggregate, either through local enhancement or independently over large prey items. On the other hand, species foraging on schooling prey are always observed in groups. This suggests the use of a grouping strategy to capture prey in schools. For some species this behaviour may also result from the predominant use of conspecifics to locate prey, as suggested by their plumage that display the most contrasting colour patterns, making them highly visible. We conclude on the adaptive significance of collective foraging strategies to exploit pelagic resources.

**PS10.2 Using spatial and dietary analyses to understand facilitated foraging in a tropical seabird**

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Seabirds are well known to feed in association with other marine top predators. For tropical seabirds, inhabiting waters where resources are unreliably and patchily distributed, reliance on foraging in association with sub-surface predators is thought to be a highly important strategy for finding food. Known as facilitated foraging, the phenomenon occurs when sub-surface predators, such as tunas and cetaceans, drive forage fish to the surface of the water where seabirds can access them. This study is situated in the Tasman and Coral seas of East Australia, using the wide-ranging tropical procellariiform, the wedge-tailed shearwater Ardenna pacificus. To investigate facilitated foraging within the region, we compare dietary and spatial data from wedge-tailed shearwaters and sub-surface predators. Seabirds were sampled on Lord Howe Island (Tasman Sea) and Heron Island (Coral Sea) for telemetry data, stomach contents and blood and feather isotopes, which were compared with Australian Fisheries Management Association spatial Catch Per Unit Area data and CSIRO collated stomach content and isotope databases for sub-surface predators. By testing spatial and dietary overlap between wedge-tailed shearwaters and numerous sub-surface predator species we can ask: do they forage in the same areas? do they eat the same prey? and do they occupy the same trophic niche? This talk will demonstrate where wedge-tailed shearwaters forage for food with regard to oceanography and sub-surface predators off the East Australian coast. We will present specific facilitated foraging relationships between wedge-tailed shearwaters and several commercially valuable tuna and billfish species, based on spatial and dietary overlap. By understanding which sub-surface predator species tropical seabirds most rely on for facilitated foraging opportunities, we can identify which fisheries pose the greatest risk to tropical seabird foraging.

**PS10.3 Local Enhancement among Seabirds and Other Marine Predators and its Consequences for Conservation**

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There is increasing recognition of the importance "Positive Interactions" among species in structuring communities. For seabirds, an important kind of positive interaction is the use of birds of the same species, birds of other species, and other marine predators such as cetaceans, seals and fishes as cues to the presence of prey. The process by which a single bird uses, say, a feeding flock of birds as a cue to the presence of prey is called "Local Enhancement" or "Facilitation". There are subtly different uses of each of these terms, but the issue we address here is whether the feeding success, and therefore presumably the fitness, of individual seabirds, is increased due to the actions of other individuals of either the same or different species. If this contention is true, then it implies that conservation of any one species of seabird must take into consideration the status and possible conservation of those species that the focal species uses as a cue while foraging. For example, conservation of Great Shearwaters, which often feed over tuna schools, should take in to consideration conservation of tuna.

**PS10.4 Responses of seabird, tuna, and dolphin foraging aggregations to El Niño-Southern Oscillation oceanographic variation in the eastern Pacific Ocean**

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Tropical surface waters of the eastern Pacific Ocean constitute an important ecoregion for seabirds that feed in association with sub-surface predators such as tunas and dolphins, a foraging guild which includes at least 14 International Union for the Conservation of Nature Red List vulnerable species. Mean densities of feeding flocks in this water mass exceed mean densities in adjoining equatorial and subtropical surface waters by 3.23 and 4.57 times, respectively. Observing the responses of seabird-tuna-dolphin foraging aggregations to El Niño-Southern Oscillation (ENSO) perturbations in physical structure of surface waters provides a prescient natural experiment through which the oceanographic drivers that create this important habitat may be disentangled. To examine empirical changes in seabird, dolphin, and tuna foraging associations over a range of ENSO states, we combined 8 years of National Oceanographic and Atmospheric Association seabird feeding flock and marine mammal transect surveys with spatially explicit Inter-American Tropical Tuna Commission purse seine fishery data. Contrasting density surface models from positive and neutral ENSO states revealed a significant displacement of dolphin-associated flock foraging activity away from the core of the eastern Pacific warm pool during positive phase ENSO events. Purse-seine data further revealed a spatial overlap of dolphin-associated sets per unit of fishing time, which provides a proxy correlated to transect flock densities (adjusted-$R^2$ = 0.23), with mesoscale negative sea surface height anomaly features. Mean sea surface height anomalies in this tropical surface water mass generally follow the equatorial Niño 3.4 index at a positive lag of 1-5 months, and directly reflect surface mixed layer thickness and temperature. The interaction of local mixed layer depth and temperature may thus play an important role in mediating tuna behavior which in turn influences seabird flock foraging opportunities.

**PS10.5 Influence of seasonal food availability on the dynamics of seabird feeding flocks at a coastal upwelling area**

Cristobal Anguita[1], Alejandro Simeone[1]
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So as to obtain information on the quality of certain traits of the environment, seabirds usually rely on the presence and behaviour of other individuals, both from the same or different species. The formation of multi-species feeding flocks (MSFF) through local enhancement is considered a key strategy for obtaining food in seabirds and its functionality has most likely been associated with foraging efficiency. However, little is known on the temporal stability of the composition and abundance of MSFF as well as on the effect that seasonal food availability may have on their dynamics. Based on studies that suggest that flocking is most frequent when food is scarce and patchy, we hypothesized that seabird MSFF composition, abundance and frequency of occurrence will be modified according to the seasonal availability of food. We used an 8-year data base (2006-2014) of monthly at-sea-counts (linear transect with fixed width) within continental shelf at an upwelling area in the coast of Valparaiso, central Chile (33°S). Results indicate that despite contrasting seasonality in food availability (using chlorophyll-a MODIS data as proxy for productivity), no significant influence on MSFF attributes are evident (univariate and resampling multivariate negative binomial GLMs; P>0.05). Rather than seasonal food availability, MSFF dynamics are most likely driven by the phenology of migratory species with a strong influence of boreal and austral migrants that modulate flock dynamics consistently throughout the year in this highly variable and patchy environment. We highlight the importance of local enhancement as a mechanism by which migratory and resident birds interact (allowing them to reduce resource unpredictability), which finally has a major impact on structuring seabird MSFF dynamics. Financial support was provided by research grants from the Vicerrectoría de Investigacion y Doctorados, Universidad Andres Bello, to AS.

**PS10.6 Factors influencing neighbourly associations in foraging little penguins**

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Recent studies have documented that little penguins (Eudyptula minor) may associate at-sea for extended periods, displaying synchronised diving behaviour throughout a foraging trip. Such associations have been hypothesised to provide benefits when foraging on small pelagic schooling prey. Previous observations were conducted over single foraging trips with a small number of simultaneously monitored individuals. Consequently, it is0not known whether such behaviour is temporary or consistent over time. In the present study, 6-19 individuals were simultaneously instrumented with GPS and dive behaviour data loggers for 2-4 consecutive foraging trips during early and late chick-rearing periods. The study was conducted at two breeding colonies (London Bridge and Gabo Island, south-eastern Australia) of contrasting population size (100 and 35,000 respectively) where individuals have access to similar prey types. Tracked birds were sampled in areas of comparable nesting density and patch size at both colonies. At the small London Bridge colony, where individuals use a short (35 m) common pathway from their nest to the shoreline, 88% of individuals displayed extended associations during consecutive foraging trips. In contrast, at Gabo Island, where individuals use a longer (130 m) pathway with numerous tributaries to reach the shoreline, few of the instrumented birds (15%) displayed associations with nesting neighbours and

these were primarily for a short period during a single foraging trip. In the larger colony, competition for food could potentially explain the lack of association behaviour. However, data from animal-borne video cameras indicate individuals at this colony regularly display at-sea associations in large groups. These results suggest that the longer pathways these individuals traverse with large numbers of conspecifics may facilitate associations irrespective of their nesting proximity. Therefore, such interactions may be opportunistic in nature.

**PS10.7 Fine scale behavioural responses of wandering albatrosses to fishing vessels: long-distance attraction but no sex-specific differences despite sexual size dimorphism**

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Understanding behavioural responses of seabirds to fishing vessels is crucial in order to better understand these interactions, which can be central to both their foraging ecology and their conservation because of the risks of bycatch. Here we present fine temporal and spatial responses of wandering albatrosses (Diomedea exulans) to longline vessels operating in the French EEZ around the Crozet Islands. By overlapping the trajectories of GPS-tagged individuals with trajectories of fishing vessels (Vessel Monitoring System), we were able to show that wandering albatrosses were attracted to vessels from distances as far as 30km, which is far more than previously thought. Moreover, using this attraction distance estimate, we investigated whether the behavioural responses of albatrosses, that we decomposed into 3 behavioural steps: "probability of encounter", "probability of interacting after an encounter" and "time spent interacting before leaving", differed between individuals of varying age and sex, taking advantage of long term demographic information on the tracked individuals. Because wandering albatrosses present an important sexual size dimorphism, potentially leading males to exclude females where their foraging range overlap (such as in the EEZ around Crozet where these vessels were operating), we predicted different behavioural responses with sex (and potentially with age, which is known to affect foraging behaviour in this species). This was not the case, females interacted with vessels as much as males, and no difference was detected in any of the 3 behavioural steps described above. In general, our results depicted a rather opportunistic behaviour. The simple methods used here could be employed to analyze other seabird-fisheries systems worldwide in order to better understand the factors modulating the behavioural responses of seabirds to fisheries at the individual scale.

**PS10.8 Assessing potential conflicts between trawl fisheries and Magellanic penguins breeding at a marine protected area in Patagonia, Argentina**

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Fisheries often overlap with foraging seabird distributions, and may lead to competition for common resources, incidental mortality and the provision of supplementary food in the form of discards. We assessed the interactions between trawl fisheries and Magellanic penguins breeding at the Patagonia Austral Marine Park, Golfo San Jorge, Argentina. Magellanic Penguins instrumented with GPS during the chick stage (n = 32) overlapped with operating vessels (17.9-66.2%). Stomach

samples (n = 114) showed that penguins fed on at least 14 species, mostly Anchovy (Engraulis anchoita) (%M = 61.7%), followed by Squid (Illex argentinus) (21.6%) and Hake (Merluccius hubbsi) (9.5%). Stable isotope analysis (n = 120) confirmed that Anchovy was the dominant prey (70-80%) from incubation to chick fledging and molt. Trawlers targeted Hake and Argentine Red Shrimp (Pleoticus muelleri), and caught a mean of 79.5 species per year (n = 1430 hauls) of which only 19 showed FO% of over 5%. Hake was also the most frequent species in the bycatch (94%) and was dominant in over 95% of hauls. Anchovy was present in less than 14% of hauls and was rare (<5%) in over 88% of them. Analysis of Similarity showed significant differences between penguin diet and the fishery's catch. Prey types designated by SIMPER as contributing most to the observed differences were Anchovy and Hake. Discards appear to be unimportant to breeding penguins, given the relatively frequent but low number of birds associated to vessels (49%; <8.2 birds per haul, n = 129 hauls) and the relatively low contribution of Hake to their diet. Trawl fisheries currently appear to have no significant impact on penguin populations in the study area, although incidental mortality resulting from vessel attraction (0.001-0.31 birds per haul; n = 31686, obtained from 2003 to 2013 by the On-board Observer Program) and plans to develop an Anchovy trawl fishery in the study area raise concerns on the potential impact on penguin populations.

**PS10.9 Seabird-fishery interactions in southwest coast of India**

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Research on seabirds of India is very limited and most of the information is available on shore birds. Seabird fishery interaction study was conducted from September 2013 to October 2014 in southwest coast of India. There were about 23 species of seabirds belongs to 15 genera of 8 families observed in the area. Among seabirds present in the area, the Flesh-footed Shearwater, Persian Shearwater, Brown headed Gull, Black headed Gull, Little Cormorant, Wilson's storm Petrel and Terns fishery interactions were studied. The Flesh footed Shearwater Ardenna carneipes and Persian shearwater Puffinus persicus preferred to feed on Oil sardine than Thryssa and Anchovies. The foraging behaviour study showed that it ate only live fish and not at all eating dead fish. The Flesh-footed shearwaters distribution and abundance was directly correlated to the occurrence of oil sardine shoal in mud bank area. Flesh-footed shearwater abundance was more during upwelling period. When ship pass through the oil sardine shoal, one or two shearwater seen it and made high pitched squeal. Immediately all other shearwaters flock in that area came close to the ship and heavy completion was observed among them in scavenging fish. Most of the Terns preferred to feed on white shrimp Penaeus indicus and Metapenaeus dobsoni. The economic value of fishes exploited by the seabirds and their ecological significance are discussed in the paper in detail.

## PS11 Studying Rare Seabirds

**PS11.1 Is it the seas or the trees: modeling the at-sea distribution of the Marbled Murrelet in the Pacific Northwest, USA**

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The Marbled Murrelet, Brachyramphus marmoratus, is a federally listed alcid that forages in nearshore waters of the Pacific Northwest, and nests in adjacent older-forest conifers within 40-80 km of shore. To estimate abundance and distribution of murrelets, we conduct at-sea surveys from

May to July each year, starting in 2000 and continuing to present. We record numbers of individuals sighted by using distance-based transects and compute annual estimates of density after adjusting for detectability. At-sea transects are subdivided into 5-km segments, and we summarized mean and variance of density at each segment in Puget Sound and along the coast from the Canadian border South to San Francisco Bay. We used a boosted regression tree analysis to investigate the contributions of marine and terrestrial attributes on murrelet abundance in each segment. We observed that terrestrial attributes, especially the amount and pattern of suitable nesting habitat in proximity to each segment, made the strongest contribution, but that marine attributes also helped explain variation in murrelet abundance. Hotspots of murrelet abundance therefore reflect not only suitable marine foraging habitat but proximity of suitable inland nesting habitat.

**PS11.2 New insights into the at-sea ecology of a data-deficient seabird of unknown breeding provenance - White-vented Storm Petrel Oceanites gracilis galapagoensis**

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The Galápagos White-vented (Lowe's) Storm Petrel Oceanites gracilis galapagoensis (WVSP) is only known from Galápagos waters, and here by historical reports observed throughout the archipelago at sea. With a weight of down to 14.5 g it ranks with the smallest seabirds worldwide, yet morphometric data indicate it may be larger than O. gracilis subspecies seen in the coastal waters off Peru and Chile. The breeding grounds of this possible Galápagos endemic are to-date unknown. We here present the first results of our 2014 at-sea survey and mark-resighting study and give brood patch scoring and moult as an indication of breeding timing to lay a baseline of the bird's foraging distributions and at-sea ecology. To-date, we equipped 108 captured birds with complete colour-band IDs; 68 of 71 of our subsequent re-sightings of 35 different individuals at sea during June-January monitoring were made near the initial capture location (distances < 10 km). These re-sighting data of known individuals, in conjunction with kernel density analyses of abundance data obtained during our survey, indicate concentration on potentially distinct foraging areas, which may predominantly be utilized by different pools of individuals. These data, together with first estimates of population size and observations of WVSP behaviour and foraging provide new insights into the at-sea ecology of this data-deficient taxon.

**PS11.3 Fregetta in a haystack: a ten year research program to attract, find and study New Zealand storm petrel at an unknown breeding site.**

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The New Zealand storm petrel (NZSP) (Fregetta maoriana) was rediscovered in 2003 following 108 years of presumed extinction, yet remained of unknown breeding provenance. Here we overview the challenging research program to find the breeding site of this critically endangered seabird and

understand its biology. Development of a novel at-sea capture technique and use of radio telemetry was critical to the discovery of four NZSP breeding burrows in February 2013 on Te Hauturu o Toi (Little Barrier Island), only 50 km from the centre of Auckland, New Zealand's largest city. Telemetry data and field observations indicated strong moonlight avoidance behaviour over the breeding site and provided the first data on the species breeding biology including incubation shift length and timing of breeding season (Jan/Feb - to Jun/Jul), unlike numerous other Procellariiformes breeding in this globally significant seabird region. The use of acoustic attraction has been critical to ongoing efforts to study the species breeding biology. The first NZSP vocalisations were captured using automated recorders at known breeding sites in 2014 and we report on the results of a mark recapture program to indicate the species population size using both spotlighting and acoustic attraction. Moreover, we report on the attempts to establish an artificial study colony for the species using acoustic attraction and forced occupations of spotlight caught individuals in light of the fragility of the species natural breeding habitat its cryptic breeding behaviour. Our research presents novel avenues for breeding-ground searches and biological studies in one of the most threatened avian orders, and highlights the general need for locating breeding sites and understanding the breeding biology in data deficient birds.

**PS11.4 Conservation Status of Townsend´s Shearwater, Puffinus auricularis auricularis**

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Townsend´s Shearwater (Puffinus auricularis auricularis) is a critically endangered species endemic to the Revillagigedo Archipelago. We conducted field work from December 2010 to January 2014 to assess the current status of the species at historical breeding sites on Socorro, Clarion and San Benedicto islands, to gather information on the length of its breeding season the extent of breeding grounds, and to estimate an approximate number of breeding birds by means of direct observations and automated acoustic surveys. Searches for cat sign were also undertaken to learn about the potential impact of cat predation on the species. Our results confirm that the species is found primarily on Socorro Island in one area to the north of the island's summit where the dense vegetation provides protection from cat predation. Direct counts of aerial activity and acoustic activity and counts obtained from automated acoustic monitoring yielded maximum tallies of 479 and 192 vocalizations respectively. These findings suggest a low breeding population size and confirm the species precarious status. In collaboration with the Mexican Navy, we proceeded to the replacement of street lights on the Naval Base at Socorro Island in order to reduce the potential negative impact caused by light attraction.

**PS11.5 Confirmation of a wintering ground for Ross's Gulls (Rhodostethia rosea) in the northern Labrador Sea**

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The Ross's Gull (Rhodostethia rosea) is one of the least known seabirds in the world; less than one percent of the estimated global population can be accounted for at known breeding sites, and its

wintering range has never been determined. Anecdotal reports over the last two centuries have prompted extensive speculation as to possible wintering areas used by this species in the north Pacific/Bering Sea region, but none have ever been confirmed. Here, using satellite and geolocator telemetry, we show that some Ross's Gulls from a colony in the Canadian Arctic winter in a restricted area of the northern Labrador Sea. Our discovery of a wintering area in the northwest Atlantic indicates that Ross's Gulls breeding in the Nearctic may be part of a disjunct population, or that birds breeding in the Palearctic may winter off the east coast of North America.

**PS11.6 Ecology and population dynamics of Flesh-footed shearwaters in New Zealand**

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Flesh-footed shearwaters Puffinus carneipes are among the top three species for threats to population viability due to adverse effects of fishing mortality in New Zealand. We studied their populations at 3 sites, following their foraging movements using GPS tracking, and estimating population size and trend. We provided the first survival estimate for the species from 23-year and 13-year datasets at two sites, to show that adult breeder survival was high. However, population trends at sites varied, with one major breeding site having a negative trend, while the two others showed positive trends. The overlap with four main fishing methods: trawl, surface-longline, bottom longline and gillnet was examined. From these analyses we concluded that the species is most likely to have interactions in discrete areas within its foraging range, and these are highly concentrated during the early chick rearing period when foraging is restricted in area, and fishing activity occurs close to the breeding sites. Targetted observer monitoring and mitigation actions are possible based on the multi-facetted data produced from our study.

**PS11.7 The Status of Mediterranean Shag (Phalacrocorax aristotelis desmarestii) along the Turkish Black Sea Coast and the Update of the Marine IBA?s.**

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The Mediterranean Shag (Phalacrocorax aristotelis desmarestii) is the Mediterranean subspecies of the European Shag (Phalacrocorax aristotelis) which is endemic to the Mediterranean Basin and Black Sea. It occupies marine habitats but does not usually occur far from land. This species shows a strong preference for cliffs, sea-caves and rocky islets with adjacent deep, clear water. They forage over sandy and rocky sea beds. We have conducted colony counts along the coasts by boats between December 2012 and May 2013 in order to determine the occurrence and assess the size of the colonies. The number of occupied nests, the number of chicks and the juveniles were recorded. Each colony site was surveyed at least twice during the breeding season. 47 possible breeding clusters (colony sites) were identified and breeding was confirmed in 45 out of 47 colony sites. The breeding range of Mediterranean shags are wide, covering a large coastal stretch beginning from Kiyiköy in Thrace extending to Hopa at the Georgian Border. Our findings indicate that the range of Mediterranean shag is almost continuous along Turkish Black Sea coasts with absence at the shores covering sand or pebble beaches. The colonies with the highest number of pairs were in the coastline from Eregli to Zonguldak with 152 pairs, followed by Strait of Istanbul (so called Bosporus) with 88 and Sile Islets with 53 breeding pairs. Comparison of our results with the earlier IBA inventory indicates that the number and distribution of the colonies has shifted to west with a

decline in Sinop and Sile, followed by recent colonisations in Haydarpasa and Kiyikoy. Based on our results, we have updated the borders of the Black Sea Marine IBA's, according to guidelines in the Marine IBA Toolkit. Our study was the first application of the Marine IBA Methodology in Black Sea.

**PS11.8 The status of the Damara Tern in the Eastern Cape, South Africa**

Philip Whittington[1], Anthony Tree[2], Maelle Connan[2], Elizabeth Watkins[3]
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The Damara Tern Sternula balaenarum is one of the world's smallest terns. It is considered Near Threatened globally but is listed as Endangered in the South African Red Data Book due to a decline in numbers and area occupied and deterioration in the quality of some breeding habitat. The majority of the global population breeds in Namibia with small numbers in Angola and approximately 6% of the world total in South Africa. Outside of the breeding season, they migrate to the shores of the Gulf of Guinea, West Africa. The easternmost part of the breeding population occupies part of the Alexandria dunefields, Algoa Bay, in South Africa's Eastern Cape Province. This small population comprises between 6% and 45% of the South African population and is isolated from the next nearest breeding birds by approximately 550 km. The Eastern Cape population was estimated to be 25-29 pairs in 2009/2010, although this may be an under-estimate, and appears to be stable, perhaps having increased slightly since the early 1990s. The main density of nest sites was found to be 5-10 km further east than in the 1990s. The mass of breeding adults averaged 12% greater than birds handled in Namibia and egg masses recorded in the Eastern Cape were 11%-22% greater than fresh egg masses measured in Namibia. Six breeding adults were caught on the nest and colour-flagged and 10 chicks were also colour-flagged. Stable isotope analysis of scapular feathers showed no significant difference between breeding adults from the Eastern Cape and those in Namibia, suggesting that they may have a common wintering area. Up to 20 Damara Terns have been recorded during the winter months in the Eastern Cape. None of the birds colour-flagged as adults or as chicks were recorded in winter flocks but the sample size of birds ringed is too small to allow any firm conclusions to be made regarding the origin of over-wintering individuals.

## PS12 Radar and Green Energy

**PS12.1 Ship-based radar technology sheds light on seabirds distribution and collective feeding strategies**

Camille Assali[1], Nicolas Hanuise[1], Julien Lebranchu[1], Hervé Demarcq[1], Nicolas Bez[1], Yann Tremblay[2]
*[1]IRD, [2]IRD - IMARPE*

Radar technology is broadly used by tuna purse-seiners to monitor bird activity in their vicinity. Still, little or no use of these ship-based radar data have been made so far for the study of seabirds ecology at sea. Radars are non-intrusive and allows for the recording of a large number of individuals at great distances and over long periods of time. However, their disadvantages are that seabirds species composition cannot be determined with certainty and that data analysis is not trivial. Using a large set of radar screen captures comprising about 25 millions echoes, as well as purpose-made image analysis and target-tracking routines, we identified trajectories of the whole detectable seabird community around a tuna purse-seiner over a range of about 30 km around the vessel and during a 66 days period. From this dataset, we report here clusters of trajectory characteristics as well as patterns of foraging groups of pelagic seabirds and we document the dynamics of sets of trajectories (fusion, fission, etc.) in a multi-scale spatial context. From the study of synchronous

trajectories, we show that collective feeding strategies are central in the ecology of pelagic seabirds. While a mutual influence exists between fishing vessel and seabirds at sea, we discuss the potential biases existing in ship-based seabird observations. We show that ship-based radar data can be valuable for the long term monitoring of seabirds at sea. We finally list the conditions for successful application of such methods for operational routine monitoring programs.

**PS12.2 Clustering of trajectories from radar data as a possible proxy for the diversity of the seabird community**

Nicolas Hanuise[1], Camille Assali[1], Nicolas Bez[1], Erwan Roussel[2], Vincent Delcourt[2], Yann Tremblay[2]
*[1]IRD, [2]Biotope*

Large amount of seabirds travel in the air, in order to forage or migrate, thus impacting marine populations, communities and ecosystems. Although technically challenging, monitoring these movements at a large scale is now possible using radar technology. Single individuals or groups of birds can be detected as echoes on radar images, and their movements can be reconstructed by linking echoes in successive images. The radar technology consist in recording the backscatter of an emitted electromagnetic pulse. Different objects placed in the detection range of the radars are expected to backscatter different levels of energy, depending on their physical characteristics. In addition, different backscattering objects might have different types of "behaviour". For example, in the marine environment, seabirds and vessels might provide very different signatures. For example one could expected that seabirds might provide echoes that are fast moving, variable, small and weak, whereas vessels might provide echoes that are slow, steady and strong. Following this principle, we hypothesized that different types of seabirds might also provide different types of echoes, due to the diversity in seabirds sizes and behaviours. Our goal was to assess if radar monitoring can be used to provide an index of the diversity of the avian community. Using a large dataset of radar images at sea, obtained from radar placed on-board purse-seiners and on an instrumented buoy, we identified thousands of individual seabirds movements records. These trajectories were characterized by several parameters such as speed, sinuosity, echo intensity and echo variance...). Statistical clustering was then used to regroup the movement records into homogeneous groups, and the total number of homogeneous group was then used as a proxi for the diversity of the seabird community. We show how this proxy varies in time and space, and discuss the pros and cons of using radar technology to monitor seabird diversity.

**PS12.3 Radar and hydro-acoustic technologies help understanding patterns of seabirds distribution in the humboldt system**

Yann Tremblay[1], Marceliano Segura-Zamudio[2], Gary Vargas-Canales[2], John Robles[2], Ricardo Oliveros-Ramos[2]
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The Humboldt current system is one of the most productive marine system in the world and it sustains the largest mono-specific fishery in the world: the anchovy fishery. The Peruvian anchovy is the key forage fish in the ecosystem and constitutes by far the major dietary item of most seabirds and marine mammals along the Peruvian coast. Anchovies form aggregations at various scales, in response to both intrinsic and environmental factors such as age, breeding stage, oxycline depth, temperature etc. The responses to the upper-trophic levels to these aggregations is not well understood, due in part to the lack of concurrent observations between prey and their predators.

We analyzed more than 100000 images obtained from an on-board S-Band Furuno radar in order to describe the patterns of seabirds distribution around the research vessel every 10 seconds. At the same time, a continuous multi-frequency hydro-acoustic survey was performed, allowing to assess both the density and 3D distribution of prey. Using these data we first described and compare the respective distributions of seabirds and their prey. In a second step, we built a statistical model including prey and others extrinsic parameters such as bathymetry, prey depth, and distance to the closest seabird colony. The models allowed to assess the relative importance of prey distribution in shaping the distribution of the avian community. These results are discussed with respect to 1) the possible effects of the fishing industry and of the climate change on seabirds, 2) on the top-down and bottom-up controls between seabirds and anchovy populations, and 3) an ecosystem-approach to fisheries management.

**PS12.5 Acoustic detections of avian power line collisions: A novel monitoring solution for a global problem**

Marc Travers[1], Andre Raine[1], Matthew McKown[2]
*[1]KESRP/PCSU, [2]Conservation Metrics*

Power line collisions are a threat to birds worldwide, with strike estimates in the 100's of millions per year. Reliable methods to quantify collision rates are necessary to help wildlife managers and power companies identify line sections that pose a threat to birds, especially endangered species such as Hawaii's endemic seabirds. To date, most strike estimates are based on the number of carcasses found under wires. However, ground searching is limited by the fact that many habitats are effectively unsearchable due to steep terrain, thick vegetation, or remoteness of power lines. In addition, ground searching is ineffective at quantifying 'wounding' bias, where birds collide with lines but continue to fly. We tested the effectiveness of using autonomous acoustic recording devices to monitor for the sound of avian power line collisions. We placed acoustic devices at the base of power poles for 1-10 months each year between 2012 and 2014. To validate the technique, observers visually and acoustically monitored bird collisions with power lines and strikes heard by observers were compared with audio files. After 1,800 hours of human visual and aural monitoring we have recorded 71 incidents where birds collided with power lines and produced an audible strike sound. Using these 71 collisions, we report the reliability of acoustic devices for recording the sound of a bird striking a power line and the effectiveness of computer analysis for detecting strike sounds present on the audio files. To compare the sound produced by different line and pole types, we conducted a simulated collision test, where linemen struck the power lines recreating the sound produced by bird collisions. These tests also allowed us to compare the recording quality produced by different types and positions of microphones. Finally, we discuss the broader application for acoustic monitoring of avian power line collisions.

**PS12.8 Inter-annual variation in the use of proposed windfarm sites by northern gannets: Individual based modelling using NetLogo**

Victoria Warwick-Evans[1], Phil Atkinson[2], Louise Soanes[1], Roland Gauvain[3], Leonie Robinson[1], John Arnould[4], Jonathan Green[1]
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Marine Renewable Energy Installations (MREIs) are becoming increasingly prevalent as we strive to meet targets to obtain energy from renewable sources. However, many of these devices are still in

the early stages of development and, therefore, the effects of these installations on the behaviour and productivity of seabirds has yet to be ascertained in detail. A first step is to determine quantitatively how dependent seabirds are upon proposed areas for development. With this in mind we assessed the frequency of visitation to offshore wind farm development areas off the south coast of England and the north coast of France by the population of Northern gannets from the Les Etacs colony, Alderney, UK. We also assessed the proportion of time spent in the development areas as we have previously shown that for this species the amount of time spent in an area can be used as a proxy for the amount of foraging behaviour occurring in that area. We incorporate GPS data collected over 4 breeding seasons during the chick rearing period and consisting of 13 - 18 individuals per year. We show considerable inter-annual variation in the use of these sites. We are using this information in order to parameterise spatially explicit individual based models, using the NetLogo software, and we will use these models to make predictions about the effect that the proposed wind farms will have on this population of Northern Gannets. This type of spatially explicit individual based model is novel in the context of assessing the interactions between seabirds and MREIs.

## L1 Tracking Database Legacy Workshop

### L1.2 Tracking bird interactions at offshore industrial sites: using telemetry to study bird movements around oil and gas platforms

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Difficulties associated with direct observations from offshore platforms and the episodic nature of bird-platform interactions mean that there is poor documentation of bird activities at offshore industrial installations. Assessment of bird-platform interactions could be improved by incorporating instrument-based approaches with traditional environmental monitoring. Using a range of telemetry and bio-logging technologies, we studied Leach's Storm-petrels (Oceanodroma leucorhoa) and two gull (Larus) species to quantify the frequency, timing, and duration of bird interactions with offshore natural gas platforms in Atlantic Canadian waters. We developed open-source, automated VHF receivers (sensorgnome.org) which were deployed in a network array on vessels, seabird colonies, and coastal sites to quantify colony attendance and track the movements of radio-tagged birds around offshore platforms. Only one petrel was detected briefly (< 1 min) near platforms suggesting transient use of these areas. Though lacking in spatial accuracy and temporal resolution, geolocation sensing tags deployed on petrels likewise identified very little spatial overlap with offshore platforms but high transit rates through the lease sites. VHF-tagged gulls showed frequent associations with platform supply vessels, and predictors of detections rates included weather, season, platform location, and time of day. GPS-satellite telemetry tracked gull foraging trips ranging from 5 to 275 km from the colony and apparent "specialization" by a few individuals attending platforms regularly. We demonstrate the versatility of telemetry devices to quantify landscape-scale movement patterns and seabird interactions with offshore industrial installations. New approaches with inexpensive, open-source, automated radio-telemetry offers the potential for larger sample size and better quantification of temporal patterns of interactions.

### L1.3 Identifying areas of ecological importance through multi-species seabird habitat modelling around the Prince Edward Islands, Southern Indian Ocean

Ryan Reisinger[1], Ben Raymond[2], Robert Crawford[3], Mark Hindell[4], Peter Ryan[5], Ben Dilley[5], Stefan

Schoombie[5], Kim Stevens[5], Otto Whitehead[5], Pierre Pistorius[1]
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Marine ecosystems are rapidly changing worldwide and seabirds - as high trophic level species - can be used as bellwethers of such change. However, their trophic level also makes them particularly vulnerable to ecosystem change. Understanding their biogeography is therefore valuable for conservation and management of seabird species in their own right, as well as for the broader ecosystem. Albatrosses, penguins and petrels have been studied at the Prince Edward Islands, Southern Indian Ocean, since the 1960s, but mainly on a single species basis. By considering multiple species, broader inferences can be made, particularly about community-level habitat use. We use existing data and a multi-species approach to identify important environmental predictors of seabird distribution around the Prince Edward Islands and to model suitable habitat. We collated data from more than 440 platform transmitter terminal (PTT) as well as global positing system (GPS) tag deployments on five albatross species, two petrel species and four penguin species. Remote-sensed environmental variables along real tracks were compared to those along a set of simulated tracks using generalised additive models (GAMs), giving a description of habitat use relative to availability. A transformed prediction map was generated to facilitate comparison among species. We present these results, highlighting areas of overlap as well as significant habitat partitioning among species, and identifying important common environmental drivers of distribution.

**L1.4 Quantifying intra-population variation in the year-round distribution of a tropical, pelagic seabird.**

Katherine Booth Jones[1], Malcolm Nicoll[1], Garth Holloway[2], Carl Jones[3], Norman Ratcliffe[4], Vikash Tatayah[5], Ken Norris[1]
*[1]Zoological Society London, [2]University of Reading, [3]Durrell Wildlife Conservation Trust, [4]British Antarctic Survey, [5]Mauritian Wildlife Foundation*

Understanding the level of intra-population variation in seabird distribution throughout their annual cycles is essential to understanding their ecology, and is important for facilitating seabird conservation and the designation of protected areas. Here we present a novel analytical approach for quantifying intra-population variation in seabird distributions. We demonstrate the potential broad application of our approach by examining the distribution of the tropical Round Island petrel during two distinct periods in its annual cycle; the pelagic migration and colony-based breeding season. We used location data recovered from 116 geolocators deployed between November 2009 and November 2012 at the breeding colony (Round Island, Mauritius) and the R package 'TripEstimation' to generate 136 migratory distributions and 156 colony-based foraging distributions. During migration Round Island petrels ranged over most of the Indian Ocean north of 40ºS, and whilst colony-based ranged up to 2900km from the colony. To quantify the amount of between-individual variation in each of these seasonal distributions, we developed a bespoke Bayesian mixtures analysis. The analysis, which groups individuals into mixtures based on similarities in their distribution of locations across pre-defined regions of their range, identified 21 mixtures in the migration tracks. Colony-based distributions were divided into an early and late season (based on breeding ecology), in which 13 and 14 mixtures were identified respectively. The identification of these mixtures provides compelling evidence for substantial intra-population variation in the year round pelagic distribution of petrels within the Indian Ocean. Our approach can be applied at a

range of spatial scales and stages of the study species' annual cycle to answer specific questions, making it a flexible tool for quantifying variation in seabird distributions, and could be particularly useful for prioritising areas for protection.

**L1.5 Foraging areas of macaroni penguins (Eudyptes chrysolophus) in the south Atlantic and south Indian Ocean**

Annette Scheffer[1], Charles-André Bost[1], Ben Lascelles[2], Maria Dias[2], Philip Trathan[1], Norman Ratcliffe[1]
*[1]British Antarctic Survey, [2]BirdLife International*

Macaroni penguins are the most important avian consumer of marine resources on the planet, but their population has declined substantially and consequently is regarded as Globally Endangered by BirdLife International and the IUCN. A better understanding of this decline and the implementation of effective protection is dependent on the identification of the bird's key foraging areas and the oceanographic features characterizing these areas. We analysed GPS, Argos and GLS tracking data of macaroni penguins breeding at South Georgia, Crozet and Kerguelen, where approximatively 80% of their entire world population breed. We identified key foraging areas at sea, and recognized most important marine habitat features during different stages of the breeding cycle using Generalized Additive Models. The Antarctic Polar Front and Sea Surface Height appeared to play an important role for foraging macaroni penguins during incubation and pre-moult, whereas birds during the broodguard and crèche stage explored oceanographic features often related to bathymetry and regional circulation in proximity of the colony. Our maps of marine habitat use of these breeding sites will be used to delimit the boundaries of most important at-sea areas of macaroni penguins and list these as marine Important Bird Areas (mIBAs) according to BirdLife International criteria.

## S8 Forage Fishery Impacts I

**S8.1 Possible entrapment of forage fish stocks in predator pits ? empirical and model evidence from seabirds**

Claire Saraux[1], Robert Crawford[2], Lynne Shannon[3], Tycho Anker-Nilssen[4], Sophie Bertrand[5], Robert Furness[6], Olof Olsson[7], Henrik Osterblom[7], Jonas Sundberg[7], James Mills[8], John Piatt[9], Jean-Paul Roux[0], William Sydeman[11], Philippe Cury[5]
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Forage fishes typically have life spans that are relatively short compared to some of their predators. The prey species often undergo large fluctuations in abundance but, if periods of food scarcity are short, predators may be buffered against them by their delayed maturity and longevity, which ensure their breeding populations consist of several cohorts. However, fishing may deepen troughs in prey abundance and extend their duration beyond those that naturally occur, with potential adverse consequences for predators. Off Norway, South Africa, Peru, in the Baltic Sea (Sweden) and at the Shetland Islands (Scotland), the proportion of fish prey consumed by seabirds increased at low levels of prey abundance. Similarly, output from a trophic model of the southern Benguela ecosystem off South Africa suggested that the proportion of forage fishes eaten by four groups of predators, including seabirds, would increase as forage fish abundance decreased. Thresholds in prey abundance, below which empirical estimates of the proportion of prey species eaten by seabirds increased rapidly, ranged from 5-14% of the maximum regional biomass (mean 10%). A

trophic model of the southern Benguela ecosystem suggested somewhat higher thresholds (35-41% of maximum biomass, mean 37%) at which the proportion of sardine Sardinops sagax consumed by four groups of predators would increase sharply. In order to prevent possible entrapment of forage fish species in a predator pit and unnaturally long troughs in forage fish abundance, management of fisheries on forage fishes should be especially cautious when prey abundance falls below these thresholds.

**S8.2 Seabirds in the Humboldt Current System: Competing with the world largest forage fish fishery in an ever changing climate**

Sophie Bertrand[1], Christophe Barbraud[2], Arnaud Bertrand[1], Marilou Bouchon[3], Charlotte Boyd[4], Ramiro Castillo[3], Alexis Chaigneau[1], Karine Delord[2], Hervé Demarcq[1], Ronan Fablet[5], Rocío Joo[3], Giannina Passuni[6], Claire Saraux[7], Yann Tremblay[1], Henri Weimerski
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The upwelling off the Peruvian coast, a champion ecosystem for forage fish productivity and climatic variability, hosts remarkable seabird populations. In this ecosystem, relationships between seabirds and humans shifted from commensalism, with commercial guano harvesting since the 19th century, to competition, with the development of the industrial fishmeal anchovy fishery in the 1950's. Seabird populations significantly declined since then and many questions arose: was climatic variability (e.g. Niño events) or fishery removals the dominant factor? Are seabirds able to mitigate these pressures and to what extent? How much anchovy should be left in the sea for seabirds; when and where? TOPINEME, a French-Peruvian multidisciplinary research project initiated in 2007, addressed these questions. Efforts were focussed on rescuing historical data on seabird demography, developing routine telemetry fieldwork to document seabirds' at-sea behaviour, and confronting these data with the invaluable ecosystem monitoring data from the Peruvian Sea Institute (IMARPE). We implemented a wide portfolio of statistical modelling approaches for relating short-term behavioural and long-term demographic seabird data to corresponding oceanographic, biological and fishery data. We found evidence for: the great importance of the vertical structuring of the water masses by the oxygen minimum zone; the relevance of the spatio-temporal pattern of fishing activity and local depletion, in addition to the global quota; and inter-specific differences in the ways that seabirds adapt their breeding and foraging behaviours to buffer adverse effects from the environment or the fishery. Based on this research, we provide recommendations for managing the fishery, while taking into the needs of seabirds into account.

**S8.3 Twenty years below one-third: contrasting responses in a NW Atlantic seabird community**

Tony Diamond[1], Lauren Scopel[1]
*[1]University of New Brunswick*

Tony Diamond and Lauren Scopel University of New Brunswick, Canada Machias Seal Island (MSI), New Brunswick, Canada, is the largest seabird colony in the Gulf of Maine (GOM) in the Northwest Atlantic Ocean. Throughout our monitoring program (1995-2015), biomass of the highest-quality forage fish (Atlantic herring (Clupea harengus)) has been below one-third of their historical abundance. Two tern and three auk species have responded differently to bottom-up changes in the marine food web, including changes in herring availability. Once home to the largest tern (Arctic and

Common (Sterna paradisaea and S. hirundo) colony in the GOM, and the largest colony of Arctic Terns in North America, the MSI tern colony collapsed in 2006 and is only just beginning to recover. Over the same period, Atlantic Puffin (Fratercula arctica) numbers have been stable, Razorbills (Alca torda) have greatly increased, and Common Murres (Uria aalge) colonized rapidly beginning in 2003. How is it possible that five species of seabirds - all considered strong bioindicators - can react so differently to these conditions? We explore several commonly-measured seabird responses (phenology, breeding success, chick growth rate, survival) at our colony to changes in herring availability, including the link between seabird provisioning data and fishery-independent herring estimates, the sensitivity of different seabird species to food availability, and the potential for some species to be better indicators of top-down processes. We conclude that monitoring a suite of top-down and bottom-up environmental factors and their effects on multiple seabird species may offer more robust insights into ecosystem change.

**S8.4 Feast or famine? Prey biomass at sea required for successful breeding vastly exceeds prey biomass actually consumed by seabirds**

John Piatt[1], Robert Furness[2]
*[1]USGS Alaska Science Center, [2]University of Glasgow*

How much forage do we need to leave in the sea to sustain healthy seabird populations? Many fisheries organizations use a mass balance approach to determine the needs of predators and to manage forage fish. Such models usually show that the biomass flowing to marine birds is an order(s) of magnitude smaller than what flows to large predatory fishes or commercial forage-fish fisheries. When forage stocks collapse, one might suppose that seabirds would be the last group affected because of their smaller nutritional demands-- but paradoxically, seabirds are often leading indicators of declining forage stocks. A recent study revealed that seabird breeding success begins to decline after forage fish abundance falls below its long-term average value (Cury et al. 2011). Calculations show that the threshold quantities of prey abundance at sea needed to foster successful breeding are much higher than those needed to meet the simple metabolic demand of the animals themselves. For example, black-legged kittiwakes at the Shetland Islands, North Sea, may need 100 times more sand eels at sea than they actually consume in order to sustain high chick production (Furness 2006). In this presentation, we contrast nutritional and environmental biomass requirements of seabirds from eight different marine ecosystems, and consider how differing life history traits of seabirds (e.g., body size, foraging mode, diet) may influence both nutritional and environmental prey biomass needs. From these results we can suggest some fishery reference points which may be used to manage stocks of forage fish.

**S8.5 "1/3 for the birds" revisited: meta-analysis of seabird survival relative to prey abundance**

William Sydeman[1], Claire Saraux[2], Sarah Ann Thompson[1], Tycho Anker-Nilssen[3], Sylvain Bonhommeau[2], Robert Crawford[4], Philippe Cury[2], Anthony Diamond[5], Robert Furness[6], James Mills[7], Henrik Osterblom[8], Daniel Oro de Rivas[9], John Piatt[0], Jean-Paul Roux[11], Ly
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Potential competition between fisheries and seabirds is a long-standing concern. One key aspect of the ecosystem-based approach to fisheries (EAF) is protection of non-target species and their ecological functions. To implement EAF, estimating ecological thresholds is required. However, thresholds may vary by species, parameters, or ecosystem examined. Previously, based on seven ecosystems and 14 seabird species, Cury et al. (2011) concluded that when forage fish abundance fell below 1/3 of the maximum fish abundance observed, seabird breeding success declined. In this paper we extend the concepts and meta-analysis of Cury et al. to the survival of adult seabirds to test the hypothesis that the threshold of response in survival is lower (< 1/3 of maximum) than the threshold of response for breeding success. To test this hypothesis, we compiled contemporaneous seabird and forage fish data sets and modeled survival relative to prey abundance across the globe. Unlike with breeding success, obtaining robust survival models was difficult, presumably due to lack of data on forage fish abundance during the non-breeding season. For the cases where robust predator-prey numerical responses could be developed, we found little support for our hypothesis for a lower threshold of response. Instead, the threshold was similar to the threshold for breeding success. Thus, maintaining "1/3 for the birds" appears to be a reasonable target for both breeding success and survival, indicating that this benchmark may be more significant to seabird population stability and conservation than previously appreciated.

**S8.6 The Predator?s Dilemma: investigating the effects of changes in prey availability on seabird foraging success**

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Understanding relationships between predators and prey is a central question in ecology and ecosystem management. Reduced prey availability has been identified as a potential threat to seabirds, especially in regions where large commercial fisheries target forage fish during the breeding season. The design of effective conservation responses depends on understanding the effects of changes in various aspects of prey availability on foraging success. Our goal was to strengthen this understanding. For central place foragers, such as seabirds, prey availability can be defined in terms of abundance, accessibility, concentration, and distance from the colony. We developed a spatially-explicit individual-based foraging model (IBFM), guided by the foraging ecology of two species: the Peruvian Booby and Guanay Cormorant. Seabird movement patterns were based on analysis of tracking data. The prey field was based on the acoustically-determined distribution of their main prey during breeding seasons with contrasting foraging conditions. Decision rules were informed by analysis of foraging site selection by the two seabird species in terms of the abundance and depth distribution of their prey. We explored the effects of different assumptions about search strategies used by seabirds to locate ephemeral prey patches. We then used the IBFM to investigate the effects of changes in the abundance and distribution of prey on the foraging success of Peruvian Boobies and Guanay Cormorants. The results highlight the importance of the depth distribution of prey for surface-foraging seabirds, and provide insights into differences in the vulnerabilities of the two species to changes in the abundance and distribution of their prey. More broadly, the results have implications for the potential effectiveness of marine protected areas and other fisheries management strategies in safeguarding seabird foraging success in the context of global change and environmental variability.

**S8.7 Changes in the breeding seasonality of Peruvian guano producing seabirds in relation with environmental variability**

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Seasonal breeding is frequent in seabirds and two-hypotheses have been proposed to explain its timing. One states that breeding season is constrained by the physiological condition of adults while the other states that breeding season is adapted to maximize food availability for chick rearing. The Northern Humboldt Current System (NHCS) is a low latitude upwelling ecosystem, subjected to a strong climatic variability from intra-seasonal to interdecadal scales. The NHCS sustains large guano-producing seabird populations feeding on an extremely productive anchovy stock. Using long-term census data collected at Pescadores island (11.77°S, 77.26°W), we examined the temporal variability of the breeding season for the Guanay cormorant (Phalacrocorax bougainvillii) and the Peruvian booby (Sula variegata) among three decadal periods corresponding to contrasted ecosystem states: 1952-1968 with high anchovy availability, a developing industrial fishery and high levels of seabird populations; 1977-1990 with low anchovy availability, fully developed fishery and declining seabird populations; and 2003-2014 with high anchovy availability and low seabird populations. Using a dynamic occupancy models and presence/absence of breeders within a Bayesian framework, we estimate the probability of initiation, termination and occurrence of breeding. Furthermore, we relate the timing of the seabird breeding seasons to that of the ecosystem in terms of oceanographic conditions (sea-surface temperature, chlorophyll-a concentration and depth of the lower oxycline) and biomass of anchovy. We show that seabirds modified the timing and extent of their breeding season among the three interdecadal periods, and that boobies and cormorants differed in the way they adjusted their breeding season. We provide evidence that according to the decadal scenarios of prey availability, the timing of the breeding season may be adjusted in order to favour pre-breeding adult condition or chick rearing stage.

**S8.8 Seabird indicators highlight population condition of marine birds in the North-east Atlantic**

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The coasts and seas of the North-east Atlantic Region are home to one of the largest and most diverse marine bird communities in the world. They include densely packed colonies of seabirds often on steep cliffs and vast flocks of wintering and migrating waders and wildfowl, many of which are reliant on the coastal and marine environment for food. These birds have been monitored across the region through a number of different schemes. For the first time, we bring these data together to develop two indicators to assess the population health of marine birds across the North-east Atlantic. The first of these is based on the abundance of breeding and non-breeding marine birds, and the second on the occurrence of breeding failure in marine birds. For the abundance indicator, species-specific thresholds, informed by the life history of the species concerned, were identified. The indicator then considered the proportion of species for which abundance exceeded the

threshold level. Preliminary assessments of the indicator showed that a greater proportion of species were at their target levels in the Celtic Seas (61%) than in the Greater North Sea (48%). In both sub-regions, wintering marine birds were doing relatively well when compared with breeding marine birds. The second indicator assesses variability in breeding failure over time (defined as failure of a colony to produce at least 0.1 chicks on average per nest per year). As long-lived species, changes in productivity of marine birds are expected to reflect changes in environmental conditions before they are evident in changes in population size. In both the Celtic Seas and the Greater North Sea, the frequency of breeding failure was found to have increased in recent years. This increase was most evident amongst birds feeding at, or just below, the water surface and has been linked to fishing activity.

**S8.9 Shag Phalacrocorax aristotelis breeding performance as indicators of forage fish abundance**

Svein-Håkon Lorentsen[1], Tycho Anker-Nilssen[1], Kjell Einar Erikstad[1]
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Svein-Håkon Lorentsen1, Tycho Anker-Nilssen1 & Kjell Einar Erikstad2, 3 1. Norwegian Institute for Nature Research, NO-7485 Trondheim, Norway 2. Norwegian Institute for Nature Research, FRAM - High North Research Centre for Climate and the Environment, NO-9296 Tromsø, Norway 3. Centre for Conservation Biology, Department of Biology, Norwegian University of Science and Technology, NO-7049 Trondheim, Norway We have shown that European shags Phalacrocorax aristotelis in two colonies situated in the Norwegian Sea, Sklinna (65º N) and Røst (67º N), seem to depend on young saithe Pollachius virens for successful breeding. Using ICES abundance estimates of young saithe , we found close correlations between the availability of 1-year old saithe and the annual rate of population change, timing of breeding and hatching brood size of shags over a 21 year period. As the ICES abundance estimates are based on recruitment of 3-year old saithe to the adult population, we collected shag regurgitates in the same colonies during 2007-2013 to assess the dietary importance of saithe more directly and explore 1) if our findings were direct results of the shags consumption of young saithe, and 2) if the proportional occurrences of the different saithe age groups in the shag diet correlate with the ICES abundance estimates of 3-year old fish. If the latter is true, shag breeding performance and diet may be robust early indicators of saithe reqruitment and prove useful for stock assessments and the management of pelagic fisheries in the Norwegian Sea.

## W1 Tackling Seabird By-Catch in Small-Scale Fisheries

**W1.1 Seabird bycatch in small-scale fisheries: an ACAP (Agreement on the Conservation of Albatrosses and Petrels) perspective**

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Since ACAP came into force in February 2004, seabird bycatch has been a high priority topic that has received considerable attention, especially by its Seabird Bycatch Working Group (SBWG). One of the core responsibilities of the SBWG is to conduct reviews of bycatch mitigation research, and to use these to inform the development and updating of best practice advice. This work has focussed largely on the industrial components of longline and trawl fisheries. Although the principles of mitigating seabird bycatch in industrial fisheries may be extended to small-scale or artisanal fleets, there has been little consideration of how the technical aspects of mitigation gear and methods

developed for industrial vessels can be adapted for use in small-scale fleets. Now that seabird bycatch mitigation is relatively well established for industrial fleets, greater attention is being focussed on small-scale fisheries. There are a number of challenges associated with developing bycatch mitigation advice for small-scale fisheries. These include the diverse nature of the gear and fishing methods, the smaller size of vessels, reduced size and capacity of crew, and lack of mechanisation. These, and other, factors necessitate a more flexible approach to providing advice on seabird bycatch mitigation for small-scale fisheries than has been adopted for industrial fleets. Consequently, ACAP is working towards a model of advice that involves the development of a 'toolbox' of effective mitigation methods, rather than a more prescriptive list. In order to support and advance this process, ACAP has identified a number of priority research needs.

**W1.2 Sensory review of species susceptible to gillnet bycatch**

Rory Crawford[1]
*[1]BirdLife International*

Gillnets are among the most prevalent gears used by small-scale fishers globally, utilised in the inshore waters of every continent except Antarctica. One of the major impediments to reducing seabird mortality in this fishery - estimated at 400,000 birds each year - is the lack of any best practice technical mitigation measures, as exists for longline and trawl fisheries. Developing such measures is thus a conservation priority. As the vast majority of gillnet bycatch occurs underwater, it is0critical that we understand the sensory and perceptual attributes of animals foraging in this environment before designing prospective mitigation measures. A review of the sensory ecology literature indicates that in order to reduce bycatch, the use of visual cues are required to alert individuals to the presence of nets. Characteristics of a visual warning stimulus must accommodate the restricted visual capacities of the species susceptible to bycatch in these fisheries, a consequence of the relatively dark environment. These requirements mean that warning stimuli on the net should have high contrast (i.e. comprised of adjacent black and white sections, akin to checkerboard or 'grating' patterns) to maximise the chances of detection. These are likely to be detectable across a range of underwater light environments by all bycatch prone taxa (not just seabirds). Field-testing should focus on whether this results in the reduction of bycatch, and should also examine any impact on the catch of target fish species.

**W1.3 Identifying and interpreting bycatch in small scale fisheries in Portugal**

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Competition with fisheries and incidental capture in fishing gear are the major current threats for seabirds at sea. Fishing is a traditional activity in Portugal and is mainly composed of a great number of small vessels. Given the lack of knowledge on effects of the Portuguese fishing fleet on seabird populations, bycatch was assessed in mainland coastal waters for 2010-2012. Interviews and on-board data were divided into 5 strata, according to fishing gear: Bottom trawling, Bottom longline, Purse seine, Beach seine, Polyvalent (≥12 m) and Polyvalent (<12 m). Polyvalent included Setnets, Traps and Demersal longlines. Overall, 68 birds were recorded to be bycaught. The average catch per unit effort (CPUE) was 0.05 birds per fishing event. Polyvalent (<12 m), Polyvalent (≥12 m) and Purse seiners had the biggest seabird bycatch rates, with 0.5 (CPUE=0.1), 0.11 (CPUE=0.05) and 0.2 (CPUE=0.11) birds per trip, respectively. Within Polyvalent gear, Setnets captured the largest

diversity of seabird species (CPUE=0.06), while Demersal longline had the highest CPUE (0.86). Northern gannet was the most common bycaught species. Although more observation effort is required, our results suggest that substantial numbers of Balearic shearwater might be bycaught annually, mainly in Purse seine and Setnets.

**W1.4 Developing innovative line setting mitigation measures for a small-scale longline fisheries in Ecuador**

Hannahrose Nevins[1], Giovanny Suárez Espín[1], Nigel Brothers[2]
*[1]American Bird Conservancy, [2]Humane Society international*

We demonstrate the effectiveness of new line-setting device developed to reduce seabird bycatch in small boat, artisanal hake (Merluccius gayi) fishery in Ecuador. The demersal hand-deployed longline fishery operates with small boats out of 26 ports around the Santa Elena Peninsula and is known for the incidental bycatch of rare seabirds. Of greatest conservation concern are two ACAP listed seabirds: The Critically Endangered Waved (Galapagos) Albatross (Phoebastria irrorata), and Vulnerable Parkinson's Petrel (Procellaria parkinsoni), and third species proposed for ACAP listing, the Pink-footed Shearwater (Puffinus creatopus). The risk to these species from the hake fishery is significant: previous work has documented 19 incidental captures of Waved Albatross during Aug - Oct, with one in December (2008-2014) despite minimal observer coverage (<0.3% of trips). Previous tracking studies of both WAAL and Parkinson's Petrel indicate a high level of overlap with the area used by this fishery. We quantified the effectiveness of this mitigation technique through measuring differences in line sinking rates measured with a Time-Depth-Recorder (TDR) and line-setting time for a 400 hook set. We found TDR measured sinking rates to 10 m were less with NISURI (87 to 64 sec, n = 3). As expected, increased line weighting (450 to 900g) further increased sink rate. We found total line setting time was decreased from 12-15 to 1.3 minutes, a ten-fold decrease. To implement this promising mitigation, we conducted fishermen workshops where NISURI was introduced to participants with other best practices for reducing seabird interactions. We do not anticipate this change in line setting to greatly increase effort as the fishermen are generally limited by the number of hooks and bait they carry; typically one to three sets of 400 to 1200 hooks. Trials with 10 fishermen in one port indicate this low-tech mitigation technique has broad application to other fishing areas.

**W1.5 Seabirds, fishermen and fishing gear: collaboration on technical innovation towards the reduction of seabird bycatch in purse seine fisheries**

Cristián Suazo[1], Patricio Krause[2], Luis Cabezas[1], Juan González-But[1], Oliver Yates[3]
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Purse seine fisheries are wide-spread in the world's oceans. However, this gear type has received less attention in terms of seabird bycatch, in contrast with the international efforts focused on longline, trawl and gillnet fisheries. During the characterization of bycatch in small-scale purse seine fisheries (vessels of 15-17 m total length) that target Anchoveta in the north (18° S) and Araucanian herring in southern-central Chile (36-39° S), we identified different hotspot points of seabird interaction with fishing nets. Interactions affected plunge diving species such as boobies (northern fleet) and pursuit divers as shearwaters (southern-central fleet). We identified an excessive net hanging ratio (>40%) as a contributing factor, resulting in: i) drowning of pursuit divers in a net

ceiling of the net during setting, and ii) entanglement and trauma of seabirds with net folds during hauling. We also identified entangled birds on zippers (connecting section between the body of the net and buoy line) during hauling. In southern-central Chile, we recorded 12 seabird species associated during setting and 6 species during hauling operations on purse seine sets (n=9) with an average operation duration of 47 min. Of these species, the Pink-footed and Sooty shearwaters (81% and 19%, respectively) reached a maximum combined bycatch of 13.3 birds/set. A collaborative approach with fishermen and local net manufacturers has led to experimental trials of a modified net with a reduced mean hanging ratio of 27% and a reduced zipper mesh size of 1 ½ inches. Comparing simultaneous sets (n=9) with a control vessel using standard gear (hanging ratio >40% and zipper mesh size of 3 ½ inches), the experimental treatment resulted in no mortality associated with the interaction hotspots versus 0.8 birds/set for the control treatment. This project is funded by the Royal Society for the Protection for Birds and the National Fish and Wildlife Foundation.

**W1.6 Reducing seabird mortality in the Namibian demersal longline fishery**

Clemens Naomab[1]
*[1]Namibia Nature Foundation*

Fishing activities in Namibia are negatively affecting marine birds, with around 22 000 seabirds killed each year by the demersal longline fishery, the majority of which are white-chinned petrels Procellaria aequinoctialis. Seabirds are attracted by baited hooks deployed during setting operations on longline vessels, and become hooked and drown. However, simple and affordable measures exist to prevent this mortality, including the use of bird-scaring (tori) lines, night setting and line weighting. Following the introduction of new fishery regulations that make these measures mandatory, the Albatross Task Force in Namibia is working with the Ministry of Fisheries and Marine Resources to implement the use of mitigation measures throughout the fleet of longline vessels. To date nine of the 13 active longline vessels have adopted these measures. We provide new observer data collected at sea, demonstrating the efficiency of these measures and the associated reduction in incidental seabird mortality.

## S9 Green Energy Impacts

**S9.1 Planning for offshore renewable energy development within the Pacific continental shelf: assembling new information about seabirds in the Pacific**

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Commercial leases within the US Outer Continental Shelf (OCS) region require assessing environmental impacts to resources, including seabirds protected under the US Migratory Bird Treaty and Endangered Species Acts. We are working to build knowledge to plan infrastructure siting that would minimize deleterious impacts to species and habitats at sea. We focused on several areas to provide up-to-date information about seabirds in the Pacific OCS. Initial efforts focused on quantifying recent patterns in distribution and abundance of seabirds using vessel-based surveys. New aerial survey programs augment historical aerial surveys motivated previously by oil and gas development and ongoing surveys conducted periodically during ship-based fisheries oceanography. Vessel-based surveys have increased capacity for collecting in situ environmental data (hydrography, prey availability) and these now are incorporated into species-prediction models to improve static

representations of discrete patterns in density at sea. Additionally, rapidly increasing capacity for GPS and sensor technology applied to seabirds of the Pacific OCS, coupled with new analyses, is providing unique information about individual-based ranging behaviors at sea. With increased information about behavior and distribution at sea, similar to efforts in the Atlantic, we have developed a multi-species seabird vulnerability index for the Pacific OCS applied to offshore wind infrastructure to integrate with measures and models of distribution and abundance to better plan for offshore development. Here, we present our framework and new information regarding seabird vulnerabilities at sea within the Pacific OCS. In the wake of planned development, we compare our framework and information with efforts to evaluate seabird/alternative energy issues in the Atlantic and North Sea---regions where planning for new infrastructure has been rapidly superseded by fully-capitalized, commercial-scale wind-energy development.

**S9.2 Baseline seabird research efforts to aid in siting of development of offshore wind energy off the eastern United States**

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*[1]Biodiversity Research Institute*

There are currently no operational offshore wind energy developments in the United States, although projects may initiate construction in 2015. Federal regulatory agencies (including the Bureau of Ocean Energy Management, Department of Energy, U.S. Fish & Wildlife Service) have largely focused on technology advancement, developing siting and permitting procedures, and filling information gaps and establishing ecological baselines prior to development. While recognizing the unique characteristics of U.S. marine ecosystems, regulators and researchers have generally looked to the European experience for guidance on many aspects of offshore wind development, particularly in identifying the hazards of offshore wind development to wildlife, and identifying seabird species with particular vulnerabilities to these hazards. On the east coast of the U.S., research effort has centered on coastal shelf waters of the mid-Atlantic states, between New York and West Virginia, close to large energy markets. Offshore survey methods applied in this region have also largely followed European examples, utilizing traditional boat and aerial platforms, and introducing high-definition digital video. Individual satellite tracking of potentially vulnerable species that use the mid-Atlantic region in winter has also been underway for several years. Overall, the challenges faced by offshore wind regulators, developers, and other stakeholders in the U.S., include (1) combining satellite tracking data and survey data in a meaningful way, (2) identifying areas of persistently high densities of seabirds to inform siting, (3) predicting environmental variables and biological conditions that support these aggregations, and (4) understanding the cumulative effects of offshore wind developments. We present results from several federally funded studies to highlight recent progress, and identify remaining analytical and policy gaps to be addressed as the development process continues in North America.

**S9.3 Seabird Research Priorities: A marine renewables perspective from Europe**

Jared Wilson[1]
*[1]Scottish Government*

To meet targets for a reduction in CO2 emissions, many Governments are encouraging the development of renewable energy generation using offshore wind farms. Legal protection of species and habitats has the potential to constrain marine renewable development so there is a strong

incentive to improve understanding of the effects of wind farms on the marine environment, particularly seabirds and their populations. As a result of this, the Scottish Government has commissioned a range of seabird research projects to help address these knowledge gaps, and actively encourages applied research that increases our understanding of the potential impacts of marine renewables upon seabird populations. As an introduction to the "Green Energy Impacts" Symposium, this talk will briefly summarise the legislative and policy drivers in Scotland and the European Union for research on the effects of marine renewables on seabirds. It will then provide examples of the seabird research commissioned to date before identifying current knowledge gaps and research priorities from a marine renewables perspective. It is hoped that this will stimulate discussion in the wider seabird community that will identify opportunities for better targeted and/ or collaborative research.

**S9.4 Displacement of seabirds by offshore wind farms in the German North Sea**

Jorg Welcker[1], Georg Nehls[1]
*[1]Bioconsult SH*

The number of operational and projected offshore wind farms in Europe and elsewhere has substantially increased in recent years. This rapid development has raised concerns about the impact on marine wildlife, particularly on seabirds, that can be negatively affected through collision and displacement. Yet, information about the response of seabirds to offshore wind farms is still scarce and ambiguous. Here we present data from survey programs that aimed to determine potential displacement of seabirds by offshore wind farms in the German Bight. Data were collected by aerial and ship-based line transect surveys during construction of the wind farms and the first years of operation. Comparing the number of observations within and outside the wind farms we found significant negative effects on abundance in several species during construction and operation. Numbers inside the wind farm were up to 90% lower than outside in species sensitive to disturbance such as divers (Gavia spp.). However, other species such as gulls (Larus spp.) seemed to be attracted to the wind farm sites. The response distance to the outer turbines was estimated to be up to 2.5 km. Such a response increases the impact area of a medium sized wind farm to about twice the size of the actual footprint of the site. While it seems unlikely that small-scale displacement by single wind farms can have an impact on population levels, the extent of the proposed development of offshore wind energy together with the magnitude of the avoidance response of some species warrants further research into cumulative effects and their biological significance for seabird populations.

**S9.5 Determination of avoidance rates for seabirds in relation to offshore wind farms using a novel combination of radars, digital cameras and rangefinders**

Henrik Skov[1], Mark Desholm[2], Ian Ellis[3], Stefan Heinänen[1], Robin Ward[3], Ramunas Zydelis[1]
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Reliable information on avoidance rates for seabirds at offshore wind farms is scarce although urgently needed. The Offshore Renewables Joint Industry Programme (ORJIP) Bird Collision Avoidance Study has been launched by the Carbon Trust, UK to improve the evidence base available with respect to specific collision and avoidance rates. The study which has been carried out at the Thanet Offshore Wind Farm in the United Kingdom is an integrated, multifaceted research programme enabling the investigation of avoidance behaviour and collision impacts at multiple

scales day and night. Since summer 2014, the project has been monitoring macro, meso and micro avoidance behaviour and collision impacts of seabirds using a novel combination of high-resolution digital (visual/infrared) camera, radar and laser rangefinder technologies. A TADS camera system is applied in digital communication with surveillance radar systems within the Thanet offshore wind farm, and combined with laser rangefinders, surveillance and high performance radars at the periphery of the wind farm. The detection system within the wind farm has collected data at the species level on micro avoidance and recorded collision events automatically. The detection system at the periphery of the wind farm has collected detailed data on meso and macro avoidance and flight altitudes. Spatially explicit flight models has been applied to the monitoring results to allow for extrapolation of estimated responses and flight altitudes to other sites and regions with different weather conditions as well as to other projects with different lay-outs. The data collected during the ORJIP project, which will continue until the end of 2016, will improve collision risk modelling for seabirds by providing the first detailed and reliable data on micro, meso and macro avoidance rates of a range of seabird species.

**S9.6 The importance of survey scale for finding displacement effects of wind farms on seabirds in the Greater Wash, United Kingdom**

Andrew Webb[1], Monique Mackenzie[2], Darren Kidney[2], Carl Donovan[2], Kit Hawkins[1], Ben Coulston[3]
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The UK has embarked on an ambitious programme to construct offshore wind farms in order to reduce dependence on fossil fuels and increase energy security. The construction and operation of offshore wind farms are likely to affect seabirds in a number of ways, with habitat loss through displacement likely to be one of the most significant. Proper studies of the environmental effects of such projects are required under UK and European legislation. Wide-ranging visual aerial line transect and digital video aerial strip transect surveys were carried out off the east coast of England between 2003 and 2015, spanning the pre-, during- and post-construction phases of the Lynn, Inner Dowsing and Lincs projects contained within the Greater Wash. Separate spatially-explicit density surface models were created for each of these phases, using a Complex Regional Spatial Smoother and Generalized Estimating Equations for obtaining realistic error estimates. Bathymetry and month were used as co-variates. These models were used to create prediction grids of seabird abundance across the study area in each construction phase. For most species, significant changes in relative distribution between phases appeared to be unrelated to the location of the wind farms. However, red-throated diver Gavia stellata, showed an order of magnitude increase in overall abundance in the Greater Wash between the baseline and post-construction periods, except in an area confined to the location of the wind farms. This points to a clear displacement effect for this species. The impact of displacement for this species from construction and operation of both projects is complicated by the considerable changes in overall abundance in the wider area; the factors driving such large changes are likely to be considerably more important in determining survival than habitat loss. Displacement effects such as this are difficult to expose unless monitoring takes place at appropriate scales.

**S9.7 A review of seabird diving behaviour to inform underwater collision risk with tidal stream turbines**

Alex Robbins[1], Chris Thaxter[2], Aonghais Cook[2], Robert Furness[3], Francis Daunt[4], Elizabeth Masden[5]

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The marine renewable energy industry is growing rapidly the world over, often driven by government targets for sustainable electricity generation. With a quarter of Europe's tidal power in the seas around Scotland there is a strong desire to harness tidal energy through tidal stream turbines in this region. These underwater turbines have the potential to affect diving birds through collision with turbine blades. However, few tidal stream turbines have been deployed, so the magnitude of this effect is not known. In the absence of empirical evidence, collision risk modelling can been used to estimate the risk of bird collisions. The approach has been used widely in the context of terrestrial and marine wind farms and, intuitively, a similar method can be used when assessing the risk of underwater turbines to diving birds. Underwater collision risk models calculate the likely exposure of a bird to a tidal turbine array while foraging underwater. Such models require data on the foraging and diving behaviour, including dive depth, duration and frequency, descent and ascent speeds and foraging trip duration and frequency. In this study, we reviewed the peer-reviewed literature for estimates of these diving parameters for each seabird and other marine bird species that occurs in UK waters (divers, grebes, shearwaters, gannet, cormorants, seaducks and auks). We present a summary of these values for use within underwater collision risk models, and an associated measure of confidence in the data. We also highlight knowledge gaps for these species and parameters that should be prioritised for future research. The review can be used by researchers as a "one stop shop" in assessments of impacts of tidal stream developments.

**S9.8 Characterise seabird foraging behaviour to understand interactions with renewable energy devices**

Marianna Chimienti[1], Ellie Owen[2], Mark Bolton[2], Ian M Davies[3], Justin M.J. Travis[1], Beth E Scott[1]
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Diving seabirds move and forage in complex marine environments. The combination of their movements, physiological constrains, energy budgets and the characteristics of the environment, shapes different foraging strategies between species. The development of new technologies, the miniaturisation of electronic components and the creation of 3-D models have allowed the study and prediction of consequences of behaviours that have been difficult to observe. Novel technologies allow to identify and combine the different phases that characterise animal`s foraging behaviour. Hence, it is0possible to start to answer key questions about seabirds' movement ecology and foraging strategies at very fine behavioural scales. Field data was collected with a combination of GPS and Time Depth Recorder, and GPS and three-axis Accelerometers deployed on two seabird species: razorbill (Alca torda) and common guillemot (Uria aalge). The combination of GPS locations and diving activities provide information about the space used and at which behavioural scale the two species search for prey. Unsupervised clustering algorithms where used to classify accelerometer data quantifying body postures and behavioural states at different foraging scales. The clustering analysis highlighted general behavioural modes such as flying, sitting on land, floating and diving, as well as specific behaviours within dives; descending, searching and ascending phase and a prey chasing/catching phase. Defined behaviours and parameter values extracted for this analysis will be used in a 3-D model to predict how foraging seabirds respond particularly to environmental complexity and changing distribution of resources due to disturbances caused by

human activity. This modelling tool will represent a starting point for understanding the mechanisms and consequences of seabird behaviour underwater and exploring predator responses to environmental change and possible future scenarios involving renewable energy devices.

**S9.9 The importance of tidal stream energy among coastally foraging seabirds highlights indirect effects of tidal stream turbine arrays**

James Waggitt[1], Pierre Cazenave[2], Paul Bell[3], Ian Davies[4], Ricardo Torres[2], Benjamin Williamson[1], James Bowcott[2], Peter Miller[2], Beth Scott[1]

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The anticipated increase in tidal stream energy extraction worldwide will place unprecedented levels of anthropogenic activity and infrastructure in the high-energy environments required for economically viable projects. However, identifying potential impacts on seabirds is hampered by a generally poor understanding of how seabirds exploit high-energy environments; both regarding their behaviour within these habitats and also the significance of these habitats at population levels. These studies show the importance of tidal stream energy for foraging seabirds at regional and local scales. Firstly, analysis of a long-term distributional dataset in the north-western North Sea, UK found that the probability of encountering foraging seabirds was highest in habitats (10km²) characterised by high mean current speeds (>1.5 m/s).Secondly, intensive vessel surveys within a high-energy environment in Orkney, UK found that foraging seabirds generally associated with microhabitats (500m²) characterised by either fast currents (> 2 m/s) or dynamic hydrodynamic features (turbulence, convergences/divergences) originating from interactions between these fast currents and bathymetry. Multiple and/or large-scale installations of tidal stream turbines could cause changes in current regimes at both regional and local scales. Therefore, whilst collisions and displacements are commonly mentioned as the main threat posed by installations, these results suggest that there is a need to understand the possible effects of reduced tidal stream energy when estimating potential impacts on seabirds.

## W2 Using Tracking Data to Define MPAs

**W2.1 Integrating telemetry data into spatial decision-making and prioritization frameworks.**

Jennifer McGowan[1], Alienor Chauvenet[1], Elliott Hazen[2], Maria Beger[1], Hugh Possingham[1]

*[1]The University of Queensland, [2]NOAA*

Spatial planning strategies for conserving mobile marine species primarily focus on the protection of nesting or breeding sites and predictable coastal foraging habitats. Yet, conservation of these areas alone does not protect migratory life stages, where many threatened mobile species continue to face population declines and mortality at-sea. Although some protection of pelagic and key foraging habitats occurs incidentally, most pelagic pathways where species experience incidental mortality from artisanal fishing, commercial bycatch or targeted consumption remain exposed. We address this conservation deficiency by developing novel, quantitative methods to incorporate telemetry and tracking data into conservation planning approaches. Our case-studies illustrate how conservation planners can translate spatiotemporal variability in individual seabird movements into quantitative spatial planning objectives for highly-mobile marine species. We investigate optimal spatial management strategies for pelagic protected areas (static/seasonal closures and gear modification

zones) that minimize the probability of mobile species bycatch occurring across all taxa. Combining individual movement data with at-sea threats from artisanal and commercial fishing, we identify areas and conservation actions that reduce the likelihoods of mortality from anthropogenic pressures.

**W2.2 Spatially explicit prioritization of conservation actions for seabirds**

Hugh Possingham[1], Maria Beger[1], Jennifer McGowan[2]
*[1]The University of Queensland, [2]ARC Centre of Excellence for Environmental Decisions*

Decisions about the spatial location of conservation actions are starting to use rigorous decision science approaches that deliver the greatest conservation outcome for the least impact on other human activities. However this return-on-investment thinking, that is pervasive across engineering, medicine and business, is not common for bird conservation. Most spatially explicit prioritisations for seabird conservation make one or more of the six common mistakes of conservation priority setting (Game et al. 2013 Conservation Biology 27:480-485). In this talk we will define the six common mistakes of conservation priority setting, provide examples from the seabird conservation literature, and give some indications of ways to logically integrate information about seabirds into spatially explicit priorities for conservation action and policy.

**W2.3 Predicting foraging hotspots for Yelkouan Shearwater in the Black Sea**

María Pérez Ortega[1], Süreyya Isfendiyaroglu[1], Hayri Dagli[1], Emil Todorov[2], Lavinia Ruducescu[2], Anna Staneva[3], Minko Madjarov[3], Jakob Fric[4], Aris Manolopoulos[4], Thanos Kastritis[4]
*[1]Doga Dernegi, [2]Romanian Ornithological Society (SOR), [3]Bulgarian Society for the Protection of Birds (BSPB) , [4]Hellenic Ornithological Society (HOS)*

Yelkouan Shearwater (Puffinus yelkouan) is a vulnerable species endemic in Mediterranean Region and there is little detailed information of its ecology and the threats that it is facing, particularly when at sea. To address this gap, we assessed the habitat use by Yelkouan Shearwater in the Black Sea during its breeding (March-July) and non-breeding period (August-February) using vessel-based surveys and coastal counts. We used a species distribution modeling (SDM) to identify those environmental variables that most accurately reflected the oceanographic habitat of this species by delineating foraging hotspots where it concentrates. Our habitat modeling analyses suggest that shearwaters respond to complex bio-physical coupling, demonstrated by their association with distance to coast, sea surface temperature and bathymetry. The foraging range during breeding-period mainly comprised the western Black Sea continental shelf, indicating that shearwaters were present in shallow, cold and coastal waters. This coastal behaviour is in line with expectations, since during its breeding period it breeds on rocky coastal and offshore islets. In non-breeding period, Yelkouan foraging range covered besides Black Sea continental shelf, a wide pelagic extension of sea, indicating that shearwaters were present mainly in deep, warm and pelagic waters. These results agree with previous studies, which identify the Black Sea as an important non-breeding area for this species, season in which it shows a behavior more pelagic. This study highlights how the integration of vessel-based survey data, coastal counts and modeling can provide a wider understanding of the predictability of hotspots and the key oceanographic habitats of pelagic seabirds. Future work should be directed at repeating surveys and modeling over the coming years during all seasons in the Black Sea, to validate these identified hotspots and to obtain trends of this species.

**W2.4 The BirdLife International approach to identifying marine IBAs from tracking data: Major achievements and future challenges**

Maria Dias[1], Ben Lascelles[1], Cleo Small[2], Phil Taylor[2], Mark Miller[3], Steffen Oppel[2], Leigh Torres[4], April Hedd[5], Mathieu Le Corre[6], Richard Phillips[7], Scott Shaffer[8], Henri Weimerskirch[9]
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Tracking data provide unparalleled information on seabird distribution, but so far few attempts have been made to provide guidelines that ensure these data are analysed in a consistent manner to identify biodiversity hotspots and inform marine management decisions. BirdLife International has developed a method to standardise the analysis of tracking data to identify sites of particular conservation importance at global and regional scales. Our approach takes into account the ecological requirements of the species and the appropriateness (temporal and spatial resolution) of the tracking data for population-level inference. Our method is based on a set of well-established statistical procedures, such as kernel density estimation, first passage time analysis and bootstrapping. It has developed new tools to tackle known challenges specifically related to tracking data analyses; these include an objective approach to define species-specific smoothing parameters (h values) for kernel estimation based on area-restricted search behaviour, and an analysis of representativeness to determine whether sites identified from tracked individuals also hold true for the wider population. This approach provides a consistent framework for using animal tracking data to delineate areas of global conservation importance, allowing greater integration into marine spatial planning and policy. The approaches we describe were developed for pelagic seabirds, but are applicable to a range of taxonomic groups and habitats. The results of the application of these methods to the largest available compilation of seabird tracking data (covering 51 species from more than 60 colonies and in 9 different life history stages) will be also presented.

**W2.5 Shearwater foraging site fidelity highlights the relevance of fixed high-sea MPAs for seabird conservation**

Clara Peron[1], Matthieu Authier[2], David Gremillet[3]
*[1]Institute for Marine and Antarctic Studies, University of Tasmania and Australian Antarctic Division, [2]Observatoire PELAGIS UMS 3462, Université de La Rochelle, [3]Centre d?Ecologie Fonctionnelle et Evolutive*

Marine Protected Areas are being designed and implemented across the planet as a response to the rapid erosion of marine biodiversity and to the degradation of marine ecosystem functioning. The relevance of Marine Protected Areas for highly mobile animals such as pelagic seabirds is often debated because of enforcement issues in the high-sea and lack of foraging site fidelity in some species. Based on an extensive tracking dataset (>500 GPS tracks) collected on two endemic pelagic seabird species breeding in the Western Mediterranean Sea - Yelkouan Puffinus yelkouan and Scopoli's shearwaters Calonectris diomedea - we proved the relevance of tracking data to refine conservation measures within existing coastal MPAs and assessed foraging site fidelity in the high-sea using state-of-the-art habitat modeling techniques. Foraging behavior along each GPS track was characterized using dive recordings and state-space models and then matched with 10 remote-sensing oceanographic variables to model the distribution of foraging habitat. We used INLA (Integrated Nested Laplace Approximation) to fit spatially-explicit linear models and assess foraging

site fidelity. Our results revealed colony-specific habitat associations and a relative stability of the most profitable foraging zones over years in the Gulf of Lion, Mediterranean Sea. We conclude that fixed high-sea MPAs are relevant to shearwaters conservation in the Mediterranean Sea, but long-term tracking data are important to update habitat models regularly, and track potential changes in foraging habitat. Adaptive marine management based on spatio-temporally flexible MPAs nonetheless remains relevant for other marine top-predators showing stronger behavioural plasticity in marine habitat use.

**W2.6 When one size doesn't fit all: scientific and policy challenges in the application of tracking data to Marine Protected Area identification.**

Mark Bolton[1], Ellie Owen[1], Adam Butler[2], Tessa Cole[1], Jonathan Green[3], Louise Soanes[3], Tim Guilford[4], Akiko Shoji[4], Stephen Newton[5], Julia Baer[5], Sarah Wanless[6], Francis Daunt[6], Mark Newell[6], Gail Robertson[7], Stephen Votier[8], Ewan Wakefield[1], Jeremy Wilson

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Whilst the legal framework for establishment of offshore Marine Protected Areas (MPAs) for seabirds in the European Union has existed for many decades, progress on designation of such areas has been slow, largely as a result of an inadequate evidence base upon which to identify qualifying areas. The recent increase in seabird tracking studies has substantially improved our knowledge of the foraging areas of breeding seabirds and is anticipated to provide the evidence needed to identify MPAs. However, important questions remain regarding the level of sampling effort, in terms of number of individuals, trips, colonies and years, that are required to adequately characterise temporally persistent foraging areas. Here we present GPS data from over 1,300 individuals of four species, tracked from 30 colonies in the British Isles during five years. We found that the major sources of variation in foraging range varied considerably among the species studied. For two (common guillemot and razorbill), there was a 10-fold difference in foraging range according to colony, but little variation among individuals within a colony. In contrast, for the other two species (European shag and black-legged kittiwake) there was little variation among colonies, but considerable variation among individuals, and particularly among trips by the same individual. These findings highlight the need for improved understanding of factors, such as colony size, which may drive differences in foraging behaviour, and also the need for species-specific considerations in designing efficient tracking studies to furnish the evidence required to meet statutory criteria for MPA designation.

## S10 Forage Fishery Impacts II

**S10.1 Prey abundance and Competition with fish as drivers for kittiwake population in subarctic**

Joël Durant[1], Yuri Krasnov[2], Nathalia Nikolaeva[3], Dag Hjermann[4]

*[1]University of Oslo, [2]Murmansk Marine Biological Institute, [3]Lomonosov Moscow State University, [4]Norwegian Institute for Water Research (NIVA)*

It has long been recognized that seabirds are affected by prey availability, a fact that has implications for an ecosystem approach to fisheries when prey are small pelagic fish. However, not only fishermen but also predatory fish may compete with seabirds for small pelagic fish. We analysed

long-term changes in the size of a breeding colony of black-legged kittiwakes in the Barents Sea with respect to effects of prey abundance, abundance of predatory fish and ecosystem state. The population analysed is situated off the Kola Peninsula, Russia (Kharlov Island, Seven Islands Nature Reserve). Using a state-space model implemented in BUGS, we found that after egg harvesting ceased in 1960, the carrying capacity of the breeding colony has been positively affected by a high abundance of two main prey fish species (capelin and herring), but also negatively affected by the abundance of cod, a major predator of these species. This is, to our knowledge, the first time it has been demonstrated that a seabird is directly affected by competition from a predatory fish. The results clearly show the importance of ocean-wide fish abundance and ecosystem state on a local colony.

**S10.2 Changes in the abundance and distribution of small pelagic fish in the southern Benguela**

Carl van der Lingen[1], Janet Coetzee[1]
*[1]Branch: Fisheries Management, DAFF*

Anchovy Engraulis encrasicolus and sardine Sardinops sagax are ecologically important small pelagic fish in the southern Benguela ecosystem where they are preyed upon by several upper trophic level predators, including seabirds. These fish are also economically important and have been targeted by purse-seiners over the past 65 years. Hydroacoustic surveys to estimate the biomass and map the distribution of anchovy and sardine off South Africa have been conducted annually since 1984 and results are described in this presentation. Estimated annual biomass of the two species combined has ranged between 0.69 million t (in 1996) and 9.03 million t (in 2001), and was markedly lower for first half of the time series (1984-1998; 1.8 million t) compared to the second half (1999-2014; 4.6 million t). Whereas both species have shown variability in population size over the time-series anchovy have dominated the forage fish biomass in 24 of the past 31 years, with sardine at a roughly equivalent or larger population size than anchovy in most years between the mid-1990s and mid-2000s. In addition to changes in population size, both species have also shown changes in their distributions. Adult anchovy showed an abrupt eastward shift in the mid-1990's, from being predominantly (>50% of biomass) located to the west of Cape Agulhas from 1984-1995 to being predominantly located to the east of Cape Agulhas in 1996. This situation has persisted since, and comparisons with environmental data suggest that the changed anchovy distribution may have been environmentally-mediated. Sardine showed a gradual eastward shift in their relative distribution that started in the late-1990's and continued through the 2000's, with only 7% of the sardine biomass observed to the west of Cape Agulhas in 2005. Since then, however, the relative sardine biomass has been more equally distributed west and east of Cape Agulhas.

**S10.3 Evidence for a benefit of fishing closures around breeding colonies of African Penguins**

Antje Steinfurth[1], Richard Sherley[2], Lorien Pichegru[3], Res Altwegg[1], Christina Hagen[4], Astrid Jarre[1], Azwianewi Makhado[5], Alistair McInnes[1], Lize van der Merwe[6], Herman Oosthuizen[5], Kate Robinson[1], Peter Ryan[1], Leslie Underhill[1], Waller Lauren[7], Ross Wanless[4], Henning Winker[8], Robert Crawford[5]
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While an increasing number of Marine Protected Areas (MPAs) are declared to limit the impact of fishing on marine ecosystems, little evidence exists that MPAs benefit high trophic level predators. The population of African Penguins Spheniscus demersus, endemic to southern Africa, is at its lowest recorded level. Following a population decrease of 60% in 6 years (2001-2007), and responding to suggestions that fishing pressure had contributed to the population decline, the South African government in cooperation with the Pelagic Fisheries Association approved a study in 2008 to determine whether closures to fishing around colonies could yield detectable benefits to penguins. Closures were alternated between four main breeding islands on the west (Robben and Dassen islands) and south (Bird and St. Croix islands) coasts of South Africa. By monitoring penguin foraging behaviour (trip duration, path length and maximum distance from the colony) using GPS telemetry we investigated whether the closures reduced the foraging effort of breeding birds. Concurrently, chick condition, chick growth and fledging success were assessed to examine whether energetic savings would translate into benefits in other demographic processes. Using linear-mixed-effects models, with closure as a dichotomous variable, and accounting for changing prey abundance, we found predominantly positive effects of closures; however, traits and islands differed in their responses. Clear benefits to chick condition or foraging behaviour were apparent at three of the four islands and fledging success improved at one colony. Hence, the results thus far suggest that by enhancing breeding conditions for penguins, closures will likely benefit juvenile and adult survival in the long run, leading to improved population trajectories. We therefore support fishing closures around penguin breeding colonies as an important component in the multi-faceted efforts to reverse the global decline of the African Penguin.

**S10.4 Establishing suitable indices for the management of seabirds, fisheries and their prey: the case of African Penguins and purse-seine fisheries in Algoa Bay, South Africa.**

Alistair McInnes[1], Lorien Pichegru[1], Miguel Lacerda[1], Wayne Goschen[2], Julie Deshayes[3], Peter Ryan[1]
*[1]University of Cape Town, [2]SAEON, [3]Laboratoire de physique des océans (LPO)*

Knowledge of the spatio-temporal dynamics of pelagic fish abundance is critical to understand prey thresholds for the conservation of seabird species that depend on this food source and thus inform the sustainable management of fisheries that compete for the same fish species. Assessing such thresholds requires concurrent data on prey distribution and abundance as well as seabird performance indices, such as activity budgets, breeding success and survival. However, knowledge of prey abundance is often limited to annual surveys that do not adequately address these interactions at the appropriate temporal scale of predator response. We present data on fine-scale (temporal and spatial) pelagic fish surveys in Algoa Bay, South Africa, conducted between 2011 and 2014, and the response of African Penguins Spheniscus demersus, an endangered seabird endemic to the Benguela upwelling ecosystem, to this variability. We use data from a network of underwater temperature recorders and wind data to infer habitat suitability for African Penguins by modelling the response of fish distribution and abundance to environmental conditions. We then compare the influence of different habitat conditions on African Penguin foraging and breeding success. Our results are compared to the allocation of fishing quotas to the local purse-seine fishery with an emphasis on the potential for a mismatch between results of fish abundance surveys conducted at different temporal scales. We recommend a finer-scaled approach, using near-real time indices of top predators' responses to prey availability, which is firmly embedded in the principles of an ecosystem-based approach to fishery management.

**S10.5 "Seas of plenty", a conundrum of sorts for African Penguins.**

Janet Coetzee[1], Dagmar Merkle[1], Johan Rademan[1]
*[1]DAFF*

Endangered African Penguins Spheniscus demersus are dependent on a reliable source of food, in close proximity to their nests, throughout the duration of their breeding season. Off the West Coast of South Africa, the numbers of African Penguins has been decreasing at an alarming rate despite several initiatives to arrest this decline. Numerous studies have indicated relationships between the decline in penguin numbers and indices of pelagic fish abundance or fishery landings. A study was initiated in 2008 to investigate whether the suspension of fishing around African Penguin breeding islands might improve the prospects for this species. Central to this study was alternation between periods of fishing and closure to fishing coupled with intensive monitoring of various penguin demographic indices and an attempt to measure the abundance of forage fish at a high temporal and spatial resolution within the foraging range of these birds. Here we report results obtained from small boat hydro acoustic surveys, conducted regularly since 2009 during the winter breeding season around Robben and Dassen Islands. We describe patterns in the local distribution, density and biomass of anchovy, the main prey item of breeding African Penguins, and its association with restrictions on fishing and regional annual recruitment indices. Despite high variance in biomass estimates obtained, we show that forage fish were abundant and available close to the islands throughout the breeding seasons of most years. Importantly, though in the context of the larger study, we suggest that the availability of anchovy to African Penguins was not significantly impacted on by fishing, but largely driven by the strength of anchovy recruitment on a regional scale.

**S10.6 African Penguin foraging behaviour and chick condition linked to local fish abundance**

Kate Robinson[1], Richard Sherley[2], Antje Steinfurth[1], Dagmar Merkle[3], Janet Coetzee[4], Les Underhill[1], Azwianewi Makhado[5], Robert Crawford[5]
*[1]University of Cape Town, [2]University of Exeter, [3] Department of Agriculture, Forestry and Fisheries, Republic of South Africa, [4]Department of Agriculture, Forestry and Fisheries, Republic of South Africa, [5]Department of Environmental Affairs, Republic ofSouth Africa*

The integration of bio-logging technology, colony-based monitoring and hydro-acoustic surveys has the potential to illuminate predator-prey interactions at fine temporal and spatial scales. On the west coast of South Africa, the population of the Endangered African Penguin (Spheniscus demersus) has decreased by c. 90% over the last decade. To separate the effects of environmental change and localised fishing pressure, the South African government instigated experimental purse-seine fisheries closures around penguin colonies from 2008 to 2014. Small-scale hydro-acoustic surveys were conducted during the penguin's breeding season within a 20 km radius around Robben Island, closed to fishing from 2011 to 2013. These gave temporal snapshots of the fish distribution and estimates of their abundance. Concurrently, chick body condition was monitored and foraging behaviour of breeding adults was measured using GPS-TDlog devices. A difference in foraging effort was apparent when comparing the extremes of local pelagic fish abundance. A linear mixed-effects model was used to establish whether chick condition varied in response to local pelagic fish abundance using the fish survey as a random effect to account for any environmental variation. At a temporal window of 14 days either side of a survey there was a positive relationship between local fish abundance and chick condition ($t_{11} = 2.58$, $p = 0.03$). The model predicts chick condition

increases by 0.02 BCI per 10000 tonnes of pelagic fish around the island, indicating a 245% increase over the range in fish abundance observed: 186,500 tonnes. Despite the variability in this system, foraging effort increased and chick condition decreased when preferred prey were locally scare. These findings are important for demonstrating the effect of local prey biomass on foraging effort and central to future assessments of whether fisheries closure zones or MPAs could benefit African Penguins.

**S10.7 Starving seabirds: Unprofitable foraging and its fitness consequences in Cape gannets competing with fisheries in the Benguela upwelling ecosystem**

David Gremillet[1], Lorien Pichegru[2], Peter Ryan[2], Clara Peron, Akiko Kato[3], Françoise Amélineau[4], Yan Ropert-Coudert[1]

*[1]CNRS, [2]FitzPatrick Institute, University of Cape Town, [3]Percy FitzPatrick Institute, University of Cape Town, [4]Institute for Marine and Antarctic Studies, University of Tasmania and Australian Antarctic Division*

Fisheries are often accused of starving vulnerable seabirds, yet evidence for this claim is scarce. Foraging energetics may provide efficient, short-term indicators of the fitness status of seabirds competing with fisheries. We used this approach in Cape gannets (Morus capensis) from Malgas Island, South Africa, which feed primarily on small pelagic fish in the southern Benguela upwelling region, thereby competing with purse-seine fisheries. During their 2011-2014 breeding seasons, we determined body condition of breeding adult Cape gannets and measured their chick growth rates. In addition to these conventional fitness indices, we assessed the daily energy expenditure of breeding adults using a high-resolution time-energy budget derived from GPS-tracking and accelerometry data. For these same individuals we also determined prey intake rates using stomach temperature recordings. We found that adult body condition and chick growth rates declined significantly during the study period. Crucially, most birds (73%) studied with electronic recorders spent more energy than they gained through foraging, and 80-95% of their feeding dives were unsuccessful. Our results therefore point to unprofitable foraging in Cape gannets, with a longer-term fitness cost in terms of adult body condition and reproductive performance that corresponds with a local population decline. Based on this evidence, we advocate a revision of regional fishing quotas for small pelagic fish, and discuss the possibility of an experimental cessation of purse-seine fishing activities off the west coast of South Africa. These measures are needed for the conservation of Benguela top predators, and for the ecological and socio-economical persistence of the broader southern Benguela upwelling ecosystem.

**S10.8 Using seabirds to steer low trophic level fishery policy towards ecosystem-based approaches ? hard lessons from South Africa**

Ross Wanless[1]

*[1]BirdLife South Africa*

Low trophic level (LTL) fish, particularly in upwelling systems, are highly productive and are typically food for a vast array of predators. Therefore managing LTL fisheries sustainably is important not only for the fishery, but equally for the sustainability of the predators that depend on them, many of which have significant economic value. The African Penguin Spheniscus demersus is a specialist predator of LTL fish, and conservation bodies have gone to extraordinary lengths to mitigate all pressures acting on this species, which is currently listed as Endangered. In South Africa, the species

is used as an umbrella species to steer the LTL fishery management away from stock-focussed approaches to include other ecosystem considerations. Addressing the risk of competition from the LTL fishery is currently done through state processes, including negotiating the implementation, in 2008, of a closure experiment to test possible benefits of closing fishing around penguin breeding islands. However the entire paradigm required proving that fishing has significant negative impacts - an extremely challenging task, and tantamount to pitting penguins against a fishery. The process is characterised by adversarial approaches and a generally distrustful atmosphere. The vision, that African Penguins are probably a sensitive indicator of LTL fish stock health, representing an index of broad ecosystem health, was completely lost. A key lesson after seven years is that it is a long-term, high-risk, high-cost exercise, which is not yet completed. Alternative approaches should be considered which do not place the burden of evidence on top predators. Negotiating directly with fishing companies or industry representatives, finding common ground and a common language to achieve the common understanding that a healthy ecosystem is a prerequisite for sustainable fishery, and is in everyone's best interest, may well prove more cost effective and achieve more satisfactory results faster.

**S10.9 Seabird conservation efforts in West Africa subregion**

Justine Dossa[1], Ross Wanless[1], Julien Semelin[2]
*[1]BirdLife International, [2]MAVA Foundation*

Seabirds are especially abundant in upwelling areas, where vertical water movements bring nutrient-rich water to the surface resulting in high biological productivity. The West African eco-region, which extends from Mauritania to Guinea, is an example of an upwelling system. This attracts a huge diversity and abundance of seabirds breeding in the region, passage migrants and wintering species. This makes the region globally important for seabird conservation. In order to face these challenges to conservation and potential threats to seabirds and marine biodiversity in general, the Alcyon project is being implemented. The first step is to generate knowledge of selected species' at-sea distributions, in order to define critical resources and habitats, or offshore Important Bird Areas (IBAs), as well as potential threats, and to propose appropriate measures for conservation and resource management. We started several research and monitoring activities in 2013: GPS tracking of wintering species (northern gannets and Audouin's gulls) and breeding species (Cape Verde shearwaters; red-billed tropicbirds, royal and Caspian terns and slender-billed gulls). Dietary studies will also identify main prey types, and we will overlay IBAs with fishing data to identify where IBAs either support existing marine protected areas (MPAs) or where new MPAs could be created for both seabird conservation and spatial management of extractive industries (fisheries, oil and gas, sediment mining, etc.). The objective of this presentation is to show how tracking and dietary studies contribute to a better knowledge of foraging areas of selected seabirds. We thendiscuss how conservation measures for seabirds can be achieved, through implementing no-take MPAs or seabird bycatch mitigation measures where foraging areas overlap with fishing hotspots.

## S11 Host-Parasite Interactions

**S11.1 Seabird ticks as model systems to study the evolution of host specialization and its cascading effects on arthropod-borne infectious agents.**

Karen McCoy[1]
*[1]CNRS*

Nest ectoparasites are common components of the seabird breeding environment whose presence can have major consequences for seabird reproductive success and population dynamics. Ticks are among the most frequent of these parasite inhabitants and are known to have direct impacts on birds in the case of high infestations, as well as indirect effects via the transmission of infectious agents. As seabirds show strong seasonality in colony attendance and these parasites are temporary, i.e., associated with the host only during the bloodmeal, ticks have evolved well-adapted life history strategies to successfully exploit both their biotic (seabird) and abiotic (colony) environments. However, different seabird species frequently breed within the same colony setting up an interesting dilemma for a parasite: specialize to exploit a single host type, or remain a generalist and exploit less well each host type ? In this talk, I address this question by focusing on work that we have carried out on a model system involving a ubiquitous seabird ectoparasite, the tick Ixodes uriae. I present patterns of contemporary population genetic structure of this tick at the within-colony scale from distinct regions of its worldwide distribution and link this structure to phenotypic patterns of host-associated specialisation. As this tick transmits an array of vector-borne disease agents, including human Lyme disease bacteria, I follow up with a discussion on how adaptation to the seabird host may cascade down to alter the epidemiology and evolutionary pathway of tick-borne microparasites. Finally, I outline how comparative studies that we are currently developing with another widespread seabird tick, the soft tick Ornithodoros capensis, should help us identify key seabird traits driving parasite diversification at different spatial scales.

**S11.2 Temporal persistence of antibodies in shearwaters, petrels, albatrosses, kittiwakes, shags, auks and penguins: a comparative approach of a neglected life history trait.**

Thierry Boulinier[1], Raul Ramos[2], Ana Sanz-Aguilar[3], Sarah Burthe[4], Maud Poisbleau[5], Henri Weimerskirch[1], Petra Quillfeldt[6], Jacob Gonzalez-Solis[7], Audrey Jaeger[8], Karine Delord[1], Emma Cunningham[9], Francis Daunt[4], Torkild Tveraa[0], Vincent Staszewski[11], Jérémy Tornos[1], Romain Garnier[12]

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Birds have been key species for the study of the immune system of vertebrates. B lymphocytes, which are responsible for the production of antibodies, have for instance taken their name from the 'Bursa of Fabritius' of chickens. But birds are not only chickens and comparative approaches of the immune system of particular species such as seabirds may reveal insight of relevance for evolutionary ecology, eco-epidemiology and biomedicine. Here we report results of field studies on the temporal persistence of maternal antibodies in seabird nestlings. Maternal antibodies transferred to the newborn are expected to play various roles and they may reveal how evolution has shaped the persistence of antibodies. The temporal persistence of those antibodies has recently been shown to last more than several weeks post-hatching in the Cory's shearwater, a long lived Procelariiform species which displays a long chick rearing period. In order to explore further to what extent species differ in the persistence of maternal antibodies, we implemented comparable transgenerational vaccination experiments in a set of seabird species. Our result show that the rate of decay of antibodies against a vaccine was also slow in two other Procelariiform species, notably the European storm petrel, but that it did not differ from what was known for quail and chickens (half-lives of about 5 days) for a set of seabird species from other taxa. These results call for further

work on the evolutionary ecology of this immunological trait, which could have implications in biomedicine but also for conservation

**S11.3 Role of seabirds in the global epidemiology of influenza A viruses: reservoirs or spillover hosts?**

Michelle Wille[1], Andrew Lang[2], Camille Lebarbenchon[3], Andrew Ramey[4], Gregory Robertson[5], Jonas Waldenström[1]

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Although wild birds are the recognized reservoir for all subtypes of avian influenza A viruses (AIV), seabirds have been largely understudied, and only sampled haphazardly. To elucidate the role of these birds as hosts, we have collected and examined the available data for AIVs in seabirds, which for the purposes of this study are defined as birds that exhibit a largely or exclusively pelagic lifestyle, with the exclusion of waterfowl, gulls, shorebirds, and terns. Close to 20,000 samples have been collected over the past 40 years and screened for evidence of active or previous AIV infection. From these surveillance data, the overall prevalence of active infection across all species has been very low, but serological data provide evidence that some seabirds are more commonly infected with AIV. In particular, murres (Uria spp), Wedge-tailed Shearwaters (Puffinus pacificus), and Adelie Penguins (Pygoscelis adeliae) were revealed to warrant continued investigation, based upon relative frequency of virus detection and isolation, serologic data suggesting exposure to AIVs, and the identification of rare antigenic diversity and genetic lineages of viruses. More consistent sampling, temporally and spatially, and characterization of more viruses are required to better understand the role seabirds play in AIV dynamics. Thousands of seabirds are handled each year, around the globe, and we encourage researchers to include AIV sampling as part of their data collection efforts.

**S11.4 Influenza A virus on oceanic islands: host and viral diversity in seabirds in the Western Indian Ocean**

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Ducks and seabirds are natural hosts for influenza A viruses (IAV). On oceanic islands, the ecology of IAV may be affected by the relative diversity, abundance and density, of seabirds and ducks. Seabirds are the most abundant and widespread avifauna in the Western Indian Ocean and, in this region, oceanic islands represent major breeding sites for a large diversity of potential IAV host species. Based on serological assays, we assessed the host range of IAV and the virus subtype diversity in seabirds of the Western Indian Ocean islands. We further investigated the spatial variation in virus transmission patterns between islands and identified the origin of circulating viruses using a molecular approach. Our findings indicate that terns represent a major host for IAV on oceanic islands, not only for seabird-related virus subtypes such as H16, but also for those commonly isolated in wild and domestic ducks (H3, H6, H9, H12 subtypes). We also identified strong species-associated variation in virus exposure that may be associated to differences in the ecology

and behaviour of terns. We discuss the role of tern migrations in the spread of viruses to and between oceanic islands, in particular for the H2 and H9 IAV subtypes.

**S11.5 Endoparasitism of offspring has carry-over effects on parents' winter foraging effort and subsequent breeding performance: an experimental approach**

Hanna Granroth-Wilding[1], Sarah Burthe[2], Sue Lewis[1], Emma Cunningham[1], Francis Daunt[2]
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The costs of parasitism can reduce fitness as hosts allocate resources towards defence. Infection costs may arise directly via effects of the host's own parasite burden, and also indirectly via effects of other individuals' infections, if infection alters hosts' interactions with conspecifics. Such indirect effects are rarely considered, yet have important implications for population processes: breeding adults may pay costs of their own infection as well as that of their offspring, particularly if there are carry-over effects on overwinter behaviour and subsequent breeding performance. Here, we experimentally investigate immediate and longer-term impacts of family-wide nematode infection on adult European shags (Phalacrocorax aristotelis), including cross-seasonal links in individual performance. Shags are widely infected with costly endoparasites, whose confinement within hosts allows us to confidently isolate effects of infection in different individuals. We treated parents and/or chicks with an anti-parasite drug in a fully crossed experimental design to separate the effects of each generation's infection. Parents were more strongly and persistently affected by parasitism in their chicks than in themselves. Parent treatment (direct effect) only marginally influenced breeding success, while chick treatment (indirect effect) significantly altered parents' condition during breeding. Indirect, but not direct, effects on parents of treated chicks persisted beyond the breeding season, reducing overwinter foraging effort and advancing subsequent timing of breeding, associated with improved success, compared to controls. This shows that parasites can have immediate and downstream effects on host traits fundamental to life-history decisions and demography, with a causal carry-over effect mediated by foraging effort. The relative strength of indirect parasite impacts suggests that past studies may have substantially underestimated the fitness consequences of parasitism.

**S11.6 The effects of parasites and mercury on breeding eider ducks in the Canadian Arctic**

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Many wildlife species are currently experiencing changing environmental conditions at northern latitudes that may affect condition, reproduction, and survival of individuals. For example, rising temperatures in polar environments has been shown to lead to an increase in parasite prevalence and abundance in some wildlife as parasite lifecylces are altered. Additionally, warming climatic conditions have increased the release of mercury stored in glaciers and permafrost. These trends are disconcerting as mercury is a known toxin that can negatively affect both body condition and reproductive success of wildlife: traits which are themselves affected by the degree of parasitism experienced by individuals. We explore how factors such as mercury concentrations and degree of parasitism interact to affect breeding of a sea duck species, the northern common eider (Somateria mollissima). To do this, we manipulated the degree of parasitism of female eiders by administering them with either an anti-parasite treatment or a placebo treatment (distilled water), upon their

arrival at a nesting colony in northern Hudson Bay, Nunavut (East Bay Island). The mercury concentration of the same females was assessed by analysis of a blood sample taken before they were released and subsequently observed on the breeding colony. Although we detected no difference in the timing of nest initiation between anti-parasite treatment and control groups among birds that arrived early, we found that anti-parasite treatment increased the likelihood that females arriving later would lay eggs. Collectively, our preliminary findings suggest that the degree of parasitism and mercury levels at arrival influence breeding decisions among female eiders in Arctic Canada, particularly among those arriving late and in poorer body condition.

**S11.7 PARASITES, PATHOGENS AND DISEASES IN ANTARCTIC PENGUINS**

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Parasites are the most extended life style in the Earth. Almost without exception all the individuals harbor several species of parasites and it is estimated that there are 10 fold more species of parasites than any other group of animals. In spite of the isolation of the Antarctic continent Antarctic birds are not free of parasites. There are 46 bird species in Antarctica and there is published information about their parasites in 38 species. However the information about these parasites is scarce and fragmented. In a recent revision we found information about the presence of bacteria in 15 bird species, viruses in 9 species, protozoa in 14 species, gastrointestinal parasites in 20 species and ectoparasites in 37 species. However, most of the published information is just related to the parasite presence and there is little information about basic parameters such as prevalence or intensity of parasitization and almost no information about the effects of parasites on its hosts. Penguins are the seabirds more studied in Antarctica in any biological aspect and this is also the case in relation to parasites. Here we present first a compilation of the published information about parasites, pathogens and diseases present in Antarctic penguins and second a revision of the effects of different kind of parasites (ectoparasites as ticks and gastrointestinal parasites).

## S12 Tropical Seabird Foraging Ecology

**S12.1 Contrasted foraging strategies of frigatebirds ranging from nearby inshore and offshore islands.**

Rowan Mott[1], Rohan Clarke[1]
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The restrictions imposed by central-place foraging mean that the waters surrounding large seabird colonies are often heavily exploited by foraging individuals. Different foraging strategies are exhibited by different species thereby acting to partition resources. Similarly, nearby colonies of conspecific individuals often target different areas for foraging. We sought to investigate patterns of resource partitioning between species at a single location, and between inshore and offshore breeding sites located in close proximity to one another. Two species of frigatebirds were investigated using a combination of GPS tracking data, stable isotope analysis and regurgitated prey sample collection. Frigatebirds are pelagic foragers consuming a diet primarily consisting of flying fish. This diet specificity limits opportunities for partitioning of resources. The foraging ecology of frigatebirds then poses the challenging question - how does such a large degree of ecological overlap reconcile with traditional niche partitioning theory? This research is significant because the study

sites were located off the north-west coast of Australia in the understudied eastern Indian Ocean. A number of BirdLife International Important Bird Areas are located in the area and the tracking data indicate that frigatebirds frequently forage well beyond existing marine protected area boundaries and cross international borders. This suggests that current management measures are not sufficient to adequately protect the resources utilised by frigatebirds.

**S12.2 Movement patterns and foraging activity of tropical seabirds during their post-breeding migration**

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In seabirds, the post-breeding period is of major importance to rebuild body-condition after a breeding season, to moult, and to prepare the birds for the following season. Bad oceanic conditions during the post-breeding season can have detrimental effects on foraging efficiency and thus on adult survival and population dynamics. For technical reasons, little attention has been paid until recently on the migrations and foraging strategies of seabirds during this crucial part of their life cycle, especially in the tropics. As part of a regional project on tropical seabirds of the western Indian Ocean, we investigated the movement patterns and foraging activity of 6 species of seabirds using miniaturised geolocators equipped with activity sensors (wet-dry sensor). These 6 species cover a wide range of seabird's at-sea ecology and include species of the 3 main groups of tropical seabirds: two procellarids (the Barau's Petrel (Pterodroma baraui) and the wedge-tailed shearwater (Puffinus pacificus)), two tropicbirds (the red-tailed tropicbird (Phaethon rubricauda) and the white-tailed tropicbird (Phaethon lepturus)) and two terns (the brown noddy (Anous stolidus) and the sooty tern (Onychoprion fuscatus)). All species (except the brown noddy) left the western Indian Ocean after breeding, most birds migrating towards the central and eastern Indian Ocean (Barau's Petrel, red-tailed tropicbird) or towards the northern Indian Ocean (sooty tern, white-tailed tropicbird, wedge-tailed shearwater). Brown noddies dispersed around their breeding place within an average migration range of less than 1500 km. Foraging activity (as inferred from dry-wet data) was influenced by the species, the timing of migration, the time of the day and the lunar cycle. These results will be discussed in relation to the specific adaptations of tropical seabirds to their marine environment.

**S12.3 Individual variability and seasonal differences in the foraging strategy of Ascension Frigatebirds**

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Most tropical seabirds forage in unpredictable environments, and acquiring sufficient food to raise offspring requires different foraging tactics than for temperate seabirds that can rely on persistently productive marine features. While many tropical seabirds appear to utilise a large proportion of the marine environment within the accessible flight range from a breeding island, there is little information on individual consistency within populations. We used the Ascension Frigatebird Fregata aquila to examine whether foraging trip characteristics were more consistent within individuals and seasons than expected by chance given the range of foraging strategies present in the population.

We tracked 54 different individuals for up to 5 months using PTT and GPS loggers during the hot and cool seasons in 2013 and 2014 and recorded 697 foraging trips. Birds travelled in all directions from Ascension, and there were no differences in the mean foraging direction between sexes, breeding stages, or between the hot and the cool season. We found that individal specialisation in trip duration (within-individual component/total niche width WIC/TNW = 0.71), maximum distance from the colony (0.78), total trip distance (0.76), and trip direction (0.86) was low and indicated generalist foraging behaviour. Similarly, individual repeatability for trip characteristics was generally low, but varied significantly between seasons, with much more variable trip lengths in the hot season than in the cool season. Trips during the cool season were on average about 50 km further away from the colony and 180 km and 11 hrs longer as during the hot season. Seasonal differences in prey abundance or distribution may require longer foraging trips during certain parts of the year, during which more consistent behaviour may be more beneficial than at times when prey availability allows short foraging trips.

**S12.4 Tracking Atlantic and Caribbean Seabirds**

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The Caribbean and Gulf of Mexico support ca. 25 breeding species of seabirds that nest on ca. 800 islands in 39 countries. The area spans nearly 20 degrees of latitude and 35 degrees of longitude. As such it is jurisdictionally and ecologically complex. To date research efforts for the species breeding in the region have been limited primarily to baseline surveys, investigations of reproductive ecology, and threats to colonies. Details about the marine range or habitat used during either the breeding or nonbreeding seasons is limited to band recoveries and scant and irregular at-sea observations. We have initiated efforts to track seabirds breeding in these regions and to date have tagged 7 species in 8 countries. Although sample sizes for some species are small it is apparent that both breeding and nonbreeding ranges are more extensive than previously thought. For example, Black-capped Petrels regularly used waters off the north coast of South America as well as pelagic waters east of the Gulf Stream, White-tailed and Red-billed Tropicbirds wintered in pelagic waters from the mid-Atlantic ridge to the Azores, and Brown Pelicans regularly migrate across pelagic waters of the Gulf to the Yucatan Peninsula and also cross Mexico to the Pacific. The extent of the marine zone used exposes these species to a wide array of threats. For example, the Gulf of Mexico supports high levels of oil and gas extraction, and areas within the South Atlantic Bight of the USA and wider Caribbean have been proposed for oil and gas extraction as well as wind development. The accumulation of individual tracking data allow us to better understand the conservation threats faced by these species at sea, and allow us to explicitly link these threats to breeding colonies for the purposes of risk and damage assessment. Furthermore, tracking projects are serve as opportunities for capacity building in the region.

**S12.5 Seabirds in hot water: linking seabird foraging success and oceanography in the Southwestern Pacific**

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*[1]James Cook University, [2]University of Queensland, [3]Australian Istitute of Marine Science*

Previously we have shown that intense El Niño events cause almost total nesting failure of impacted seabird colonies on the Australian Great Barrier Reef (GBR), and that significant decreases in prey availability also occur in association with small-scale increases in sea-surface temperature, independent of El-Niño conditions. These findings raise significant conservation concerns for GBR breeding species under current climate-change scenarios. Effective management of these populations requires detailed information on foraging resources and links to oceanography, without which it is impossible to identify or mitigate anthropogenic threats that occur outside nesting colonies. We have recently mapped core foraging areas for GBR breeding seabirds at multiple spatial scales using wedge-tailed shearwaters as the principal model species. Our results show that adults forage in near-colony waters (<300km) to provision chicks, but that at regular intervals they also travel to distant foraging grounds for self-provisioning. In addition, GBR shearwaters migrate and overwinter in Micronesia. Foraging activity at all sites is linked to steep bathymetry and localised frontal systems and eddies. Some near-colony sites are also heavily influenced by river outflows and associated terrestrial inputs. Many important foraging areas are outside current management zones and overlap significantly with commercial fisheries, a finding that raises further conservation concern. Our results provide new insight into the factors determining seabird foraging success in tropical systems and provide a basis for predicting how climate variation or other anthropogenic stressors may impact these populations into the future. Importantly, they demonstrate the dynamic nature of oceanic features important to tropical seabirds, highlighting the need for a quantitative assessment of the effectiveness of traditional Marine Protected Area Design at capturing and conserving these features.

**S12.6 Learning to survive in poor tropical water: Frigatebirds foraging**

Henri Weimerskirch[1], Aurélien Prudor[1]
*[1]CNRS*

Frigatebirds present a series of extreme life history traits among seabirds such as the lowest wind loading among birds, the inability to land on water or the extended parental care period that is primarily taken in charge by the female. We studied in juvenile Great Frigatebirds the changes in flight characteristics during one year period of transition from the first flights of the young bird, to the progressively longer foraging trips until the spectacular ocean wide dispersal, and compare them with adult movements. We show the importance of wind for the specific dynamics soaring flight of frigatebirds at small scale and for the large scale dispersive movement of juvenile, and examine the change in flight efficiency of the yound individuals. We discuss the flight adaptions of frigatebirds in relation to the various oceanic habitats used in the tropics by this atypical seabird species.

## PS13 Habitat Selection

**PS13.1 Comparing seabird marine habitat use from concurrent Eulerian and Lagrangian perspectives**

Elizabeth Phillips[1], John Horne[1], Jeannette Zamon[2], Josh Adams[3]
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Seabird use of the marine environment can be quantified using Eularian (fixed grid) and Lagrangian (moving particle) sampling strategies. Ship-based seabird counts, in situ environmental measurements, and prey density estimates are typically conducted using a Eularian approach. Satellite-based tracking studies typically treat seabird movements as particle trajectories. These two

approaches are often used in isolation, although they offer potentially complementary insights into seabird movement and habitat use. Concurrent data collected from at-sea surveys and satellite tagging of two seabirds in the northern California Current are compared. The northern California Current is a highly productive region along the west coast of North America that is strongly influenced by a large river plume. It supports a wide variety of forage fish species, seabirds, and some of the largest populations of Pacific salmon. We analyzed seabird counts, environmental data, trawl densities of fish, and acoustic backscatter collected from research vessels to determine scale-dependent density distributions and habitat use of sooty shearwaters (Puffinus griseus) and common murres (Uria aalge). Concurrent distribution patterns and residence times of tagged seabirds were compared to results from ship surveys. We found that both species utilize the region influenced by the river plume. Sooty shearwaters utilize habitats of intermediate salinity, ranging from mixed plume to oceanic waters, where high densities of forage fish occur. In contrast, common murres utilize the central river plume habitat, where recently discharged river water creates low salinities and juvenile fish are located. The river plume appears to be an easily identifiable and predictable feature for both species, but especially for the murres, which are central-place foragers. By combining Eularian and Lagrangian approaches, we identified spatial and temporal scales at which seabirds respond to their marine habitat.

**PS13.2 Disentangling the effects of environmental conditions and pelagic prey availability in driving the spatial patterns of highly migratory seabirds while refueling**

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During the non-breeding season, highly migratory seabirds follow prevailing oceanic wind patterns to reduce flight costs on long-distance commutes and most likely to enable birds to exploit rich summer food supplies. Meanwhile, migrating birds move through different marine ecosystems and stop at few key locations for increasing their refueling opportunities, associated to major productivity hotspots. For numerous species, the Bay of Biscay (BoB) represents a key feeding area during certain periods of the year, when seabirds perform seasonal feeding migrations into the area. This is the case of the great and sooty shearwaters Puffinus gravis and P. griseus, respectively, breeding in the southern Atlantic Ocean. Within this framework, we studied the spatial co-occurrence of southern shearwaters and pelagic prey based on the JUVENA multidisciplinary oceanographic cruises. The JUVENA research survey series is an annual monitoring survey programme that studies the pelagic ecosystems in the Bay of Biscay. Based on the small-scale distribution patterns of shearwaters, we disentangled the effects of environmental conditions and pelagic prey availability in driving the distribution patterns of seabirds in this biogeographic area. Integrative studies combining predator observations and pelagic prey can provide a comprehensive picture on the importance of refueling areas in determining migratory pathways with important implications in conservation strategies and climate change studies.

**PS13.3 Habitat associations of the seabird community in the northeastern Chukchi Sea**

Adrian Gall[1], Tawna Morgan[1], Robert Day[1]
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We examined relationships between oceanography and the distribution and abundance of 8 species of seabirds in the northeastern Chukchi Sea during 2011-2012. We used ship-based surveys to

sample seabird abundance in the Greater Hanna Shoal study area, which extended over ~39,000 km². Concurrently with the seabird surveys, we measured temperature, salinity, and zooplankton biomass at stations located on a systematic grid throughout the study area. The distribution and abundance of all 8 seabird species were associated most strongly with temperature in the top 10 m of the water column, whereas associations with other habitat characteristics varied with the preferred prey and foraging method. Planktivorous seabirds (auklets, shearwaters, and phalaropes) were more abundant within 20 km of thermal surface fronts and omnivores (gulls and murres) were more abundant far from fronts. Birds that fed primarily by pursuit diving were more abundant in warm, weakly stratified water and surface-feeding birds were more abundant in cold, strongly stratified water. The distribution of seabirds, particularly the planktivorous species, is strongly influenced by advective processes that transport oceanic species of zooplankton from the Bering Sea to the Chukchi Sea. For 5 of the 8 seabird species, information about prey biomass improved predictions of seabird abundance, although the relationships were not as clear as they were for the physical habitat characteristics indicative of processes that aggregate prey. These models are an important step in understanding species-habitat relationships and providing reliable estimates of seabird distribution and abundance in an area of interest for oil and gas development.

**PS13.4 Adjustment of seabirds ecological preferences in response to ocean seasonality**

Charlotte Lambert[1], Emeline Pettex[1], Sophie Laran[1], Léa David[2], Eric Stephan[3], Ghislain Dorémus[1], Olivier Van Canneyt[1], Vincent Ridoux[1], Auriane Virgili[1]
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Marine ecosystems are characterized by a strong heterogeneity and variability, both spatially and temporally. In particular, the seasonal variations may lead to severe constraints for seabirds, which have to cope with these variations, for example through migration to avoid unfavorable season, or adaptation to local modification of the ecosystem. In the Bay of Biscay and English Channel, ecosystem seasonality is well marked, especially over the shelf. A similar situation is observed within the northwestern Mediterranean Sea, although to a lesser extent. Seabird communities within these two areas (Bay of Biscay/English Channel and northwestern Mediterranean Sea) were studied during aerial surveys, conducted in winter 2011-2012 and summer 2012, following a strip-transect methodology deployed from the coast to oceanic waters. We explored seasonal variations of ecological preferences of six seabird groups in both regions through Generalized Additive Models, using physiographic variables and weekly- and monthly-averaged oceanographic predictors (SST, altimetry, currents, chlorophyll and NPP) for both seasons. Our results provided the first overview of the adjustment of ecological preferences in response to the seasonality of the ocean by seabirds in that region, at such a large scale. Habitat models resulted in deviances from 13 to 54%. Seabirds answered the seasonality of their environment in different ways. While some species selected year round productive systems with low seasonality (Yelkouan/Balearic shearwaters in Mediterranean), other species modulated their ecological preferences between seasons, mainly linked to reproductive constraints (gannets, auks, fulmars in Atlantic). Finally, for some groups, the seasonality had an extreme impact, inducing migration from the region during the unfavorable season (e.g. shearwaters, kittiwakes in Atlantic; Cory's shearwaters, storm petrels in Mediterranean).

**PS13.5 Cape Gannets in Contrasting Environments: Inter-annual Responses to Fluctuations in Prey Availability and Oceanographic Conditions**

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Pistorius[1]
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Prey distribution and availability to avian predators is primarily influenced by physical oceanography. The foraging distribution and foraging effort of the Cape gannet Morus capensis in South Africa are greatly affected by small pelagic fish stock dynamics. Not only are these stocks of economic importance, but they have also been largely impacted by climate-mediated regime shifts. We investigated behavioural responses of two Cape gannet colonies subjected to contrasting environmental conditions. One population on Malgas Island, in the Benguela bioregion, is characterised by a declining population trend and sub-optimal diet, whilst the other on Bird Island in the Agulhas bioregion has been increasing with an apparently healthy prey base, despite greater intra-specific competition. GPS tracks of foraging Cape gannets were collected from both colonies during four consecutive breeding seasons and linked to oceanographic conditions and prey availability (assessed through coarse-scale hydro-acoustic surveys as well as fine-scale surveys at Bird Island). Biophysical features associated with foraging were compared against those of a random point dataset to identify important predictors of foraging distribution. Movement-based kernel estimation was used to assess and compare inter-island and inter-annual variability in foraging distribution. Although sea-surface temperature was important in predicting gannet distribution in some years, this was not consistent in all years. Prey distribution varied substantially between years resulting in associated shifts in commuting distances and foraging effort. As the Cape gannet is threatened by reductions in prey biomass and availability, understanding how gannets respond to changes in environmental conditions provides insight into how best to manage these populations. In this way appropriate and effective monitoring and mitigation recommendations can be made to support broader conservation goals.

**PS13.6 Seasonal influences of a warm boundary current on the foraging success of little penguins**

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The east coast of Australia is situated in a dynamic oceanographic environment, where nutrient upwelling is driven by the highly seasonal flow of the East Australian Current (EAC). This western boundary current system is changing rapidly, with increases in the strength and penetration of the warm EAC causing sea surface temperature (SST) to rise faster in this region than the global average. Understanding how upwelling processes drive the abundance and distribution of prey is important for predicting how meso-predators such as little penguins (Eudyptula minor) may be affected by environmental change. Using a supervised machine learning technique that we developed to identify prey capture by little penguins from accelerometry, we assess variability in the number of prey caught by breeding penguins both within a season (Sep - Dec) and across years (2012 - 2014). We then explore how this variability is related to environmental covariates, including chlorophyll a concentration and ocean temperature. We also assess the role of oceanographic features, such as eddies and current-driven upwelling, in altering prey availability. We found that the mean number of prey caught per unit time varied substantially both within and across years. 2012 was a 'good' year, a time of high prey capture when ocean temperature was comparatively low and chlorophyll a was

elevated relative to 2013 and 2014. In September, prey capture rates were nearly three times higher in 2013 than 2014. September 2013 coincided with a strong southerly penetration of the EAC but cooler sub-surface temperatures and elevated chlorophyll a, suggesting that EAC-induced upwelling may have brought nutrient-rich water onto the shelf. Our findings identify relationships between EAC dynamics, primary productivity, prey availability and predator behavior that will enable us to better understand the capacity of warm boundary current systems to support predators in a changing environment.

**PS13.7 Are river plumes hot-spots for seabird abundance and diversity?**

Elizabeth Phillips[1], Jeannette Zamon[2], Brian Burke[3], Elizabeth Phillips[1]
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Where large rivers meet the sea, freshwater discharge can form buoyant surface plumes which affect stratification, mixing, primary productivity, and secondary productivity in the coastal ocean. How river plumes affect seabird distributions or their fish prey is not well understood. We studied seabird distributions relative to the plume of the Columbia River, USA, one of the largest river systems in North America. Our May and June surveys revealed that the most numerous piscivorous birds, common murres (Uria aalge) and sooty shearwaters (Puffinus griseus), occured in consistently higher densities within the plume region compared to adjacent areas in the Olympic Coast National Marine Sanctuary. We propose that the Columbia River plume is a previously undocumented foraging "hot spot" for seabirds in the Northern California Current ecosystem. Given the global distribution of large rivers, we hypothesize there are other river systems which are also "hot spots" for seabird abundance or diversity, and we discuss some conservation concerns that may be important for seabirds in river plume habitats.

**PS13.8 Where to forage in the absence of sea-ice? Bathymetry as a key factor for Little Auks foraging during the breeding season.**

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According to the IPCC, the Arctic is one of the regions facing the most significant climate change. Sea-ice extent has been shown to decrease, and is predicted to decline even more in the future. In this context, it is0crucial to evaluate how species will adapt to the loss of their sea-ice habitat. Some seabird species, such as the little auk (Alle alle), are known to forage preferentially within the marginal ice zone. We tested the hypothesis that their foraging behaviour and subsequent breeding performance are significantly affected by the presence or absence of sea-ice in the vicinity of their breeding colony. Our study site was situated in East Greenland, where the East Greenland current transports arctic sea-ice towards the Atlantic Ocean. Such transport shows high interannual variability and allowed us to study little auk foraging strategies in the presence/absence of sea-ice within their foraging zones. Birds were equipped with GPSs or time-depth recorders to record their foraging behaviour, while their diet and chick growth were being monitored. In addition, an at-sea survey was performed in the absence of sea-ice in 2014, to collect little auk prey (zooplankton) and to verify the spatial distribution of foraging little auks. Surprisingly, sea-ice conditions did not affect little auk behaviour, and they always foraged on the continental shelf and on the continental slope,

with highly directional foraging paths towards these areas. Energy-rich prey was particularly abundant on the continental shelf and the continental slope, probably due to upwelling. Chick growth and breeding success were similar in the presence/absence of sea-ice, yet little auk diet contained 10% more lipid-rich ice-associated prey when birds foraged in the marginal-ice zone. Our results demonstrate the major importance of bathymetry for little auk foraging behaviour, irrespective of the presence/absence of sea-ice. Overall, Little Auks may be capable of surviving in a sea-ice free Arctic.

## PS14 Breeding Biology 1 – Colony Structure and Mate Relationships

### PS14.1 MHC variation in a Leach's storm-petrel colony: implications for mate choice and selection

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The Major Histocompatability Complex (MHC) is a multi-gene complex associated with immune function, and is known to be highly variable between individuals of the same species. Variation in MHC genes has also been shown to influence individual body odor, and may impact recognition and mate preference in some species. MHC-based mate selection in wild populations has not been conclusively proven, however, likely due to insufficient sample sizes. Procellariiformes are an ideal model for investigating the role of MHC in a natural population, as they are highly olfactory, long-lived, and form lifelong pair bonds, and our research group has previously shown that some species can differentiate between individuals using only odor. Using a robust five-year dataset (n=1350 genotyped individuals) of monitored Leach's storm-petrels (Oceanodroma leucorhoa) in Nova Scotia, Canada, we genotyped partial genomic fragments of two MHC Class IIB gene duplicates (Ocle-DAB1 and Ocle-DAB2) to characterize the MHC variability in a natural population and test for evidence of MHC-based disassortative mating. We used randomization tests to compare observed and bootstrapped medians of three MHC similarity metrics (pairwise heterozygosity differences, band-sharing coefficients, amino-acid substitutions) in 294 established pairs and found no significant evidence of disassortative mating at either locus. This sample size is unprecedented in any MHC study of a wild population and the probability of detecting a Type 1 error is <0.05, providing the first definitive characterization of the role of MHC in a natural population. MHC genes are recognized as a proxy for local adaptation within a sub-population, and baselines of genetic variability can be valuable considerations for prudent population management and conservation. Furthermore, this study highlights the need to use appropriate sample size to allow for the meaningful interpretation of results.

### PS14.2 Assessing the significance of social networks in a large colony of Sooty Terns Onychoprion fuscatus on Ascension Island, South Atlantic

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Seabirds often congregate to breed in huge numbers with social information transfer having important consequences for colony dynamics. However, understanding the variables that drive coloniality is still limited. Long-term studies of seabird populations offer an excellent opportunity to study social group dynamics in great detail due to their life-history traits, with many species being long-lived, producing small clutch sizes and having extended maturation periods (K-selected

species). Our research focuses on a breeding population of c.450,000 Sooty Terns Onychoprion fuscatus on Ascension Island in the South Atlantic. Monitoring and ringing of this population since 1990 by the Army Ornithological Society (AOS) have resulted in an extensive mark-recapture dataset comprising thousands of individuals. Although their breeding range on the island has decreased substantially in the last 25 years, the population inhabits two main breeding locations, approx. 1km apart. Ours is the first study to interrogate this dataset by exploring the spatial and social structure of the Sooty Tern breeding population. We used ringing and re-trap data collected over many breeding seasons to examine the: consistency of membership within the Mars Bay or Waterside colony; long-term associations of individuals with others; the relative position of individuals within the colony in relation to colony edge; movements of birds between and within colonies; and the effects of increasing age (and experience) on the above parameters. This research has enabled us, for the first time, to investigate in more detail the plasticity of a large, seabird colony in both space and time. Our findings provide an important basis from which to investigate the factors which drive heterogeneities in social structure, such as timing of breeding, breeding success, foraging strategy and predator avoidance.

**PS14.4 Experimental and correlative evidence for condition-dependent sexual signals in breeding king penguin (Aptenodytes patagonicus)**

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In seabirds, both parents strongly rely on each other to raise the offspring. Thus, selection is expected to favor mutual mate choice for high quality partners. How individual quality is advertised to social conspecifics however, remains an intriguing question of evolutionary biology. In this regards, many seabirds display elaborate ornaments in both sexes, thought to have evolved under sexual and/or social selection. Behavioral/physiological traits linked to fitness would then be advertised to conspecifics by means of honest ornamental traits, guiding both males and females in their pairing decisions. In addition, ornamental traits may be used in social (non-sexual) contexts, e.g. signaling aggressiveness to social conspecifics and helping birds acquire high quality breeding territories. King penguins have bright yellow-orange auricular feather patches, a yellow to rusty-brown breast feather patch, and yellow-orange bill spots that also reflect UV. The auricular patch is known to be associated with bird aggressiveness and has been suggested to evolve under social selection. Of particular interest are findings that beak coloration is implicated in mutual mate choice during courtship, and is thought to be under sexual selection. However we lack knowledge on how variable and dynamic this trait is, to what extent it reflects intrinsic individual quality, whether it is influenced by environmental factors, and how it ultimately shapes fitness. Here, we examine both correlative and experimental data on both short- and long-term dynamics in beak spot coloration, how it relates to individual body condition and parasite loads, and its genetic and environmental influences (via an experimental cross-fostering design) on offspring phenotype. We will present results that show the condition-dependence of this trait in king penguins and highlight how such traits may be crucial in assessing partner quality for monomorphic seabirds.

**PS14.5 Enhanced coordination over the pair bond relaxes parental investment of female blue-footed boobies**

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Many seabirds form socially monogamous pair bonds in which male and female contribute to parental care. Although conflict over parental investment can arise as a result of each parent attempting to reduce its own share of parental care, it is0increasingly recognized that persistent cooperation between partners can enhance coordination in parental tasks over the duration of long-lasting partnerships. However, the costs and benefits related to such behavioral adjustments remain largely unknown. To address this issue, we examined the relationship between pair bond duration and relative parental investment in the blue-footed booby, a long-lived socially monogamous seabird with extended biparental care. By equipping chick-rearing pairs of known bond duration with temperature and depth recorders (TDRs), we were able to quantify the overall investment of each partner in both parental and self-maintenance tasks, and the growth of chicks. Our results indicate that, for females, the cost of brood care declines during the first years of the pair bond, hinting at a process of improvement in coordination and cooperation between partners. We will discuss our data in the light of the mate familiarity hypothesis and sexual conflict theory.

**PS14.6 Optimizing parental care in the Brown booby Sula leucogaster.**

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Bird species that practice obligate siblicide (originally named cainism) lay two eggs, but almost never raise more than one offspring, because the first hatched chick kills the second soon after hatching. The adaptive value of this siblicidal behavior has puzzled naturalists since the times of Aristoteles. There is still no general satisfactory explanation for the evolution (or maintenance) of this behavior, although various mechanisms have been proposed to serve as tools for minimizing the negative impact of this mortality on parental fitness. According to the 'insurance' hypothesis, by laying an extra egg, the parents may be able to protect themselves from raising an under-sized brood (or no young at all) in a given season; specifically, they are buffered against complete reproductive failure that may arise from early mortality of eggs and chicks. This study aimed to test the insurance hypothesis for the laying of a second egg. We experimentally tested this hypothesis in pairs of adjacent 2-egg clutches in the brown booby, by removing one egg from experimental clutches while holding unmanipulated clutches as controls. As predicted, the experimental nests on average produced fewer hatchlings and a smaller proportion of them had a chick at 10days, i.e. 34% and 61% for experimentals and controls, respectively, and this difference was almost three-fold lower at 60days, i.e. 12% success for experimentals and 31% of all controls producing a fledgling. The insurance benefit of the second egg seemed to be most significant during the incubation phase, or for fertilization of the eggs, because there was no difference in success between parents that had hatched one versus two eggs among unmanipulated clutches. However, among nests that were deserted during chick rearing, parents that had hatched two eggs tended to remain longer than parents that had hatched only one egg. We conclude that the most important insurance benefit of a second egg is against egg hatching failure.

**PS14.7 Reproductive tug-of-war: males and females parental investments in the little auk**

Katarzyna Wojczulanis-Jakubas[1], Dariusz Jakubas[1]
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For many avian groups, with seabirds as notable example, bi-parental care is an obligatory breeding system, in which lack of one-parent's contribution leads to breeding failure. Bi-parental care increases also the parents' survival by conserving their energy resources. Nevertheless, due to basic sex differences in anatomy, physiology, and behaviour, the level of contribution to particular activities, or specific parental roles may vary between the sexes. We studied parental investments in the little auk, a seabird with transition from bi-parental to male-only care at the end of the chick rearing period. Given the transition, one might expect some sex differences in parental performance prior the female's departure. We examined birds behaviour (social interactions) and body condition (body mass, hormones concentrations, haematological variables) throughout the whole breeding period (several seasons) in two largest colonies in Svalbard. We did not find sex differences in basic parental activities. Both parents shared incubation/brooding equally, and fed the chick with similar frequency until the very end of the chick rearing period. There was also no sex difference in risk-avoidance behaviour (tested experimentally with neophobia test). The only noticeable difference was recorded during the pre-laying period when males spent more time in the colony guarding nest sites, while females spent their time mostly out of the colony, extensively foraging to produce the egg. Although distinct in nature, these sex-specific prior egg-laying activities seemed to be similar in terms of energetic costs. Given all this, one could conclude about very similar parental investments of males and females. However, examining multiple body condition variables, we found significant sex differences indicating that females are more susceptible to the negative effects of reproduction. This may be the reason, which for the females desert the brood before chick fledgling.

**PS14.8 Incubation routine of Saunders's Tern Sternula saundersi in a harsh environment**

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The Saunders's Tern Sternula saundersi is a small ground-nesting seabird, which breeds in the coasts and islands of the Red Sea, the Arabian Gulf, Madagascar, Socotra, Somalia and Sri Lanka. Despite having wide distribution, little information is available to understand the breeding biology of this species. This study was carried out on Farasan Islands to understand some aspects of the breeding biology of this species using a small trail camera. Such camera system can reveal the incubation routine of this species in such a harsh environment, where the midday ground temperature in March may reach up to 50°C, while the midnight ground temperature may reach 20°C, thus leaving the eggs unattended even for few minutes, especially during the hottest and coldest parts of the day, may cause nest failure.This huge variation in ground temperatures between day and night gave us an excellent opportunity to test the behavioural mechanism used by the parents for maintaining the optimal egg temperature so as to prevent their eggs from the adverse effect of temperatures. We found that nest attendance increases when the temperatures deviated from the optimal egg temperature and nests were incubated more than 90% of the time during the hottest and coldest parts of the day to prevent eggs from the harmful temperature.

## PS15 Disease

**PS15.1 Reproductive investment at a cost: higher physiological fattening leads to increased risk of mortality to a novel disease**

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In mixed (income-capital) breeding birds that reproduce in a seasonal environment, a combination of arrival date and arrival condition on the breeding grounds, where individuals that gain in condition the quickest lay earlier, invest in larger clutches and generally incur higher fitness. However, in the presence of a highly virulent disease higher reproductive investment has been associated with higher mortality risk, although the exact mechanisms for this link is unclear. We studied the pre-breeding energetic physiology of an Arctic-nesting colony of Common Eiders (Somateria molissima) at East Bay Island, Nunavut during an outbreak of avian cholera (Pasteurella multocida) first beginning in 2006. We collected blood samples from arrival female eiders, tracked them through reproduction, and recorded mortality in high and low cholera outbreak years. We used energetic metabolites (plasma triglycerides - TRIG) as a measure of the rate of condition gain and examined its relationship to breeding propensity, lay date and the downstream effects these traits had on survival. Higher TRIG individuals were more likely to breed and had earlier laying dates. However, individuals with higher TRIG had an increased risk of mortality regardless of breeding propensity or whether they timed reproduction to the peak of cholera outbreaks. We demonstrate that increases in physiological investment in reproduction can trade-off with survival in the presence of a highly virulent disease. Understanding how reproductive investment influences mortality will become increasingly important with the possible northward advance of this disease, potentially impacting other colonial, seabird species naive to this disease.

**PS15.2 Are zoonotic bacteria in Antarctic and Subantarctic seabirds from human or domestic origin?**

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Human presence in the southern Ocean has dramatically increased in the last few decades, increasing the likelihood to introduce zoonotic bacteria, such as Salmonella and thermophilic Campylobacter, in pristine regions, particularly through birds scavenging on human waste. On the other hand, Falkland Is. holds an important human settlement in close contact with subantarctic and Antarctic wildlife; here domestic animals, such as poultry, are often free ranging and regularly get in direct or indirect contact with wildlife. Despite the evident risk of spillover from farm animals to subantarctic and Antarctic wildlife, the occurrence of zoonotic bacteria in the southern Ocean seabirds or in domestic animals in localities such as Falklands is poorly known. We studied the occurrence, distribution and genetic diversity of Salmonella and Campylobacter in faecal samples from several seabird species (penguins, skuas, petrels, albatrosses, shags and gulls) at three Southern Ocean islands (139 from Livingston Is., 138 from Gough Is. and 125 from Marion Is.) as well as in seabirds (N=264) and poultry (ducks, hens and feral gooses, N=168) from Falkland Is., from 2008 to 2013. Salmonella was isolated in seabirds from Livingston and Marion Is. Campylobacter was isolated from all four localities (both from wild and domestic birds) and showed greater prevalence than Salmonella. Most Campylobacter were isolated from skuas, with prevalences greater than 70% in nearly all localities. Genotyping of the isolates showed that most strains differed among islands, suggesting there are different sources of pathogens at each locality with little connectivity across the

Southern Ocean localities. Within Falkland Is., very few common strains between domestic and wild birds were detected, suggesting a limited spillover between them. Overall, results suggest a possible spillover of these enteric bacteria from humans to seabirds in the southern Ocean, but other possibilities need to be ruled out.

**PS15.3 Rehabilitation centres' role in passive disease surveillance monitoring: using SANCCOB as an example**

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Disease can have significant impacts on population dynamics of wildlife; however health surveys of seabirds in their natural habitat often fail to detect any pathogens or signs of disease. This can be due to sampling constraints, feasibility of laboratory analyses, difficulties finding sick or recently-deceased birds and the inherently low prevalence of pathogens in breeding adults. However, rehabilitation centres receive compromised individuals with a higher probability of detecting pathogens and conservation-significant illnesses. From 2001 to 2014, SANCCOB admitted c. 13000 African penguins and c. 9700 other seabirds from c. 50 species. During this period, routine veterinary exams have led to the identification of novel blood parasite species in cormorants (Babesia ugwidiensis, Leucocytozoon ugwidi) and skuas (Haemoproteus skua), as well as bacteria (Relapsing Fever Borrelia) in African penguins. Other pathogens identified are Avipoxvirus, Herpesvirus and Cryptosporidium sp. in African penguins and Newcastle's Disease Virus and Pasteurella multocida in cormorants. The emerging penguin feather-loss disorder is a disease of yet unknown aetiology currently being studied. Five species of helminths have been recorded (Cardiocephaloides physalis, Cyathostoma phenisci, Renicola sloanei, Contracaecum spp. and Tetrabothius spp.). Most results show that compromised birds are susceptible to opportunistic infections both in rehabilitation and in the wild. These findings illustrate how rehabilitation centres can diagnose and identify pathogens and parasites as well as to communicate with conservation management playing a crucial role in disease surveillance. This passive surveillance is cost-effective, minimising the possibility of introducing pathogens into a susceptible wild population, and providing conservation-relevant data on the epidemiology of particular diseases within a wild population.

**PS15.4 Four novel herpesvirus occurring in Seabirds along the South American Atlantic Coast**

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Different herpesviruses have been identified and associated to respiratory and enteric diseases and mortality among seabirds. Some examples described in the literature are the duck plague and other herpesvirus affecting storks, cranes, cormorants, African penguins in captivity, frigatebirds and loons. Since migration, rehabilitation and translocation of birds can affect the spread and concentration of pathogens between different populations, we decided to investigate the occurrence of herpesvirus in asymptomatic, free living, 144 reproductive active and 31 nestling Spheniscus magellanicus in the Argentinean Patagonia and 23 Sula dactylatra, 20 Sula leucogaster and 33 Tropical seabids (Phaeton aethereus and Phaeton lepturus) in the Abrolhos Archipelago-

Brazil, as long as 12 Thalassarche chlororynchos, two Macronectes giganteus and 144 Magellanic penguins that were rescued and rehabilitated in Centers along the Brazilian Coast. In total, 409 samples were PCR analyzed by a consensus primer for the detection and analysis of diverse herpesviral species as described in the literature. Four different herpesvirus were identified in both free-living and rehabilitating seabirds named Thalassarchid herpesvirus 1, identified in a Thalassarche chlororhynchos, Sulid herpesvirus 1 identified in both Sula leucogaster and Sula dactylatra and two different herpesvirus identified in Magellanic penguins, being the Magellanic penguin herpesvirus 1 identified in penguins in rehabilitating process in Brazil and the Magellanic penguin herpesvirus 2 in free-living penguins in Argentinian Patagonia. As Sulid herpesvirus 1 is close related to the Frigatebird herpesvirus 1 that caused mortality in those seabirds population in an Atlantic island and Magellanic penguin herpesvirus 1 was associated with a big penguin die off in a rehabilitation Centre, these findings reinforce the necessity of seabirds populations monitoring programs as conservation tool of some species already threatened.

**PS15.5 Epidemiology and pathology of avian malaria in penguins undergoing rehabilitation in Brazil**

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Seabird rehabilitation is a valuable strategy to mitigate the impacts of oil pollution and other anthropogenic factors, and can significantly contribute to the conservation of penguins. However, infectious diseases such as avian malaria (Plasmodium spp.) can hamper the success of rehabilitation efforts. Four species of Plasmodium have been reported to infect penguins: P. elongatum, P. juxtanucleare, P. relictum and P. tejerai. We combined morphological and molecular diagnostic methods to investigate the epidemiology and pathology of Plasmodium in 774 Magellanic penguins (Spheniscus magellanicus) at rehabilitation centres along 2500 km of the coastline of Brazil. Plasmodium infections of penguins occurred throughout the Brazilian coast, from Bahia to Rio Grande do Sul. In all cases, it was concluded that infection occurred in the rehabilitation facilities, and not prior to admission. True prevalence of malarial parasites was estimated between 6.6% and 13.5%. We identified five species: P. elongatum, P. tejerai, and three species that had not been described infecting penguins (P. cathemerium, P. nucleophilum, P. unalis). An additional five distinct Plasmodium lineages were also distinguished, and albeit unidentified these clearly correspond to species that also have not yet been reported in penguins. Gross and histological lesions were generally consistent with those previously reported in the literature, and were consistent among lineages; the most prominent pathological processes were granulocytic pneumonia and splenitis and mononuclear hepatitis. Our results indicate that the diversity of plasmodia that may infect these birds is greater than previously recognised. Considering the well-defined seasonality observed in this study, it is0clear that rehabilitation centres could benefit by narrowing their preventative efforts on

penguins maintained or admitted during the austral spring-summer, particularly by preventing mosquitoes from coming into contact with penguins.

**PS15.6 Morphometric Evaluation of Hepatic Hemosiderosis in Magellanic Penguins (Spheniscus magellanicus) naturally infected by Plasmodium spp.**

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While foraging on the Brazilian continental shelf during winter migration, sick and/or debilitated Magellanic Penguins (Spheniscus magellanicus) found ashore are directed to rehabilitation centers along the coast. Whilst at these facilities this species may develop avian malaria, one of the most important diseases of captive penguins, also reported in wild populations. Caused by protozoans of the genus Plasmodium, it is0transmitted by hematophagous mosquitoes. Hemosiderosis is defined as the excessive deposition of yellow-brown iron pigment (hemosiderin) in Kuppfer cells, hepatocytes, cells of the reticuloendothelial system, parenchymal cells or in free circulation in the blood. We analyzed 23 liver samples from penguins naturally-infected by Plasmodium spp. from three rehabilitation centers in Brazil. Plasmodium lineages had been previously identified morphologically on blood smears and/or by phylogenetic analysis of the mitochondrial cyt-b gene. Perls-stained slides were analyzed under a microscope equipped with a digital camera and a computerized image analysis software. The center of the sample (reference field) was captured under 40X. Eight images were captured 50µm from this point, at 45 intervals, under the same lighting conditions. Areas of hemosiderin deposit were semi-automatically outlined, under a maximum zoom of 50%. The mean percentage of these areas was the index of hepatic hemosiderosis (IHH). ANOVA/Kruskal-Wallis and t-tests identified no significant differences in IHH with regards to individual history (age group, sex or origin) or Plasmodium lineages/species. This is the first study that attempts to correlate the individual history and Plasmodium lineages/species to hepatic hemosiderosis in penguins. Our next step is to employ the same methods to evaluate hepatic hemosiderosis in Magellanic penguins with similar individual history and exposed to the same conditions, but negative for Plasmodium.

**PS15.7 Zoonotic pathogenic viruses of beringian seabirds**

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About 70% of the emerging pathogens infecting humans originate from animals. Most were due to RNA viruses due to their higher mutation rates compared with other types of microbes and their capability for unique genetic change, either by genetic recombination in positive-sense RNA viruses or genetic reassortment in RNA viruses with segmented genomes. Those with the greatest impact include coronaviruses and orthomyxoviruses (influenza) which, including other viral groups, birds serve as their natural reservoirs. Waterfowl are now routinely surveyed for the presence of certain types of influenza, but few seabirds, and fewer still for coronavirus, orthoreovirus, paramyxovirus, or other known zoonotic pathogens. Almost nothing is known about the prevalence, identity, titres, or host/reservoir distribution from breeding seabirds of the central and western Aleutians. We report here the results of viral survey of auklets, puffins, kittiwakes, and cormorants collected in 2013 and 2014 using genomic and gene-specific markers. Preliminary results indicate that influenza was not

detectible in any of our samples, while as expected coronavirus and orthoreovirus were present. We discuss the implications of these baseline studies and how they may be interpreted compared to similar studies in other regions.

**PS15.8 Avian influenza in Icelandic gulls**

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Avian influenza viruses (AIV) are commonly found in wild birds, especially water birds, around the world. However, even though these viruses are found in long distance migrants such as northern pintail (Anas acuta), that can migrant from Alaska to wintering grounds in parts of Asia or North America, there has been a clear development of two separate lineages of AIV, an American lineage and a Eurasian lineage, although genetic material, but not a complete genome, from each lineage had been found in AIV's from the other region. With the emergence of the highly pathogenic (HP) AIV H5N1 in Asia, both in domestic and wild birds, and subsequent periodic spread to Europe and Africa it has become increasing important to understand the mechanisms for AIV transport between continents. This raised the question of the importance of wild migratory birds, such as seabirds, facilitated the spread of HPAIV H5N1 throughout Asia, Africa and Europe and whether they will be the mechanism for introduction of this virus, or future HPAIV, into the Americas. In this study cloacal swab samples were obtained from gulls (Charadriiformes) of various species in Iceland and then tested for AIV. From these, we isolated and fully sequenced the genomes of AIV from wild caught gulls. We detected viruses that were entirely of American lineage, viruses that were entirely of Eurasian lineage, and viruses with mixed American-Eurasian lineage. This finding of AIVs of entirely American lineage and Eurasian lineage, as well as reassortant viruses, together in the same geographic location indicates the processes behind movements of AIVs. Our study demonstrates the importance of the North Atlantic as a corridor for the movement of AIVs between Europe and North America as well as the potential role gulls play in the intercontinental movement of AIVs.

# Thursday October 29 2015

## PS16 Demography 1 – Climate and Life History

**PS16.1 Prey availability strikes first year survival: Cohort effect as a source of survival variability on a long-lived seabird species.**

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Abstract Cohort effect is the impact of early life conditions on the individual's life history traits. Despite being theoretically well described its effect on seabird populations survival has been rarely explored. Cohort effect environmental divers, its extent through individuals lifespan and its consequences for population dynamics on natural populations remains obscure and a real challenge for ecologists. We used long-term data from a breeding colony of the emblematic Audouin's Gull (Larus audouinii) to address these questions. Using multi-event capture-recapture-recovery models we assessed whether there were differences on survival among cohorts, the temporal extent of those differences and the potential influence of several environmental covariates (e.g. global climatic indices, food availability proxies corrected for density-dependence). Our results reveal that:

1) survival was significantly different for each cohort, 2) these differences were only retained for the first age classes and 3) prey availability explained nearly 40% of survival variability among cohorts. Moreover, we demonstrated that it was the combined effect of early life (cohort effect) and winter conditions which determines survival during the first year of life. This suggests that cohorts must experience underlying mechanisms -- such as selection filters--to compensate for a bad start in life.

**PS16.2 Population dynamics of a tropical pelagic seabird facing climate change: the case of Audubon's shearwater colony from the Caribbean region**

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El Niño events that occurred over the last two decades had severe impacts on seabird populations and much less is known in tropical regions compared to temperate or polar regions. In the central Atlantic, especially in the Caribbean region, the remote effect of ENSO on oceanographic and climatic conditions appears to be complex. In this context, we studied for the first time the Audubon's shearwater Puffinus lherminieri lherminieri adult survival in response to climate change and its population dynamics. Using mark-recapture methods and two banding data sets between 1995 to 2014 (one on adult birds, the other one on fledglings), we found a mean annual estimate for juvenile survival of0.57 ±0.23 (SE), and 0.88 ± 0.024(SE) for both adults and immatures. We then analyzed the effects of climatic and environmental covariates such as SOI, NAO and SST, Amazon River discharge on adult survival. By providing the first data on foraging distribution using geolocators, we found that shearwaters forage in the Lesser Antilles region during the breeding season while they shift along the coast of Northern South America near from the Amazon mouth during the non-breeding period. We detected a strong negative effect of Amazon River discharge on survival rate, which we interpreted as a strong trophic asynchrony caused by a temporal mismatch between nutrient supply in marine primary production's region and the breeding period of the shearwaters. Finally, we used population viability analyses to simulate the demographic response in regard to climate change (based on IPCC scenarios). A stochastic simulation model suggested a slight declining trend for the colony. We discuss how these findings may support the current policy for managing the seabird colony.

**PS16.3 Density and climate shape early life survival and recruitment in a long-lived pelagic seabird**

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Early life demographic traits are poorly known in seabirds. Yet survival of juvenile and immature individuals is critical for the recruitment into the population and thus for the whole population dynamic. This bias currently restrains our ability to fully understand seabird population dynamics and life history evolution. In this study we estimated the early life demographic parameters of the wandering albatross Diomedea exulans to test for sex and age effects on these parameters, and to identify the environmental factors encountered during the period of immaturity that may influence survival and recruitment. Using capture-mark-recapture multi-event models allowing us to deal with uncertain and unobservable states, we analysed a long-term data set. Our study provides for the first time an estimate of annual survival during the first two years at sea for an albatross species (0.801±0.014). Both age and sex affected early live survival and recruitment processes. Survival

during early life and recruitment were highly variable through time although the sensitivity of young birds to environmental variability decreased with age. Early life survival was negatively affected by sea surface temperature and recruitment rate was positively related to both Southern Annular Mode and sea surface temperature. We found strong evidence for density dependence mortality of juveniles. Population size explained 41% of the variation of this parameter over the study period. These results indicate that early life survival and recruitment were strongly age and sex dependent in the wandering albatross. In addition, early life demographic parameters were affected by natal environmental conditions and by environmental conditions faced during the period of immaturity. Finally, our results constitute one of the first demonstrations of density dependence on juvenile survival in seabirds, with major consequences for our understanding of population dynamics in seabirds.

**PS16.4 Climate and the demography of Manx shearwaters: a long-term study**

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Seabirds have been studied for effects of climatic change on their population dynamics, because long-lived species with k-selected life-history strategies spending much of their lives at sea should be sensitive to environmental perturbations. Such stochasticity should affect breeding success more than survival rates, yet climate has been found to affect survival rates more frequently than reproductive success. This may be due to fixed, low reproductive rates and subsequently limited capacity to respond, however most studies have largely ignored intermittent breeding. We utilised a 36 year, individual-based, capture-recapture dataset from Manx shearwaters (Puffinus puffinus) on Skomer island to test how climatic variability affects survival, using a multi-state mark-recapture modelling framework. Knowledge of the trans-equatorial migration of the population from geolocator studies allowed us to investigate the influence of climate on demography at both large and local scales, during both the summer breeding season in the Irish Sea and the wintering season off the southern Argentinian coast. Reproductive status was known for 21 years of the study, allowing us to investigate reproductive skipping decisions and the effect of breeding status on associations between survival and climatic variation. We found tentative evidence that climate is more strongly related to breeding success than survival in this species: survival of breeders and non-breeders and transitions between breeding/non-breeding were relatively unrelated to climatic variables, while breeding success was weakly but significantly associated with stronger wind speeds in wintering areas, and warmer breeding waters two years prior to breeding. However, these effects on reproduction are too weak to be biologically meaningful in this system. We discuss potential explanations for our results from an ecological and evolutionary standpoint.

**PS16.5 Foraging behaviour in a generalist species: fitness consequences of a dietary bias**

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While many foraging theories are based on assumptions representative for a population, individuals within populations tend to specialize on a particular prey type or niche. More specifically, generalist populations are often made up of individuals that use a small subset of the population's potential

resource base. Dietary specialization and intra-specific habitat partitioning are widespread phenomena, with a few examples documented in seabirds. However, the fitness implications of specialization in seabirds are not well understood. The effects of dietary specialization on the reproductive output, for example, is not always clear. Furthermore, the role of specialization in a changing world has received little attention so far, but modern tracking techniques have opened up unique research opportunities for studying foraging specializations. In this paper, data from a longitudinal study on Herring Gulls (Larus argentatus) breeding at Texel (The Netherlands) will be used to illustrate the level of specialisation in this generalist seabird and to link individual behaviour with breeding success. The effect of specialization in niche use will be studied in the context of a changing environment (e.g. natural changes in food quality and supply) on an extremely fine scale using GPS loggers. The combination of state of the art technology and traditional techniques such as individual dietary analysis, visual observations and reproductive output measures will enable us to gain a unique insight into the individual differences and foraging motives of seabirds in a changing world.

**PS16.6 Life history of long-lived seabirds: effects of El Niño on annual variability of key demographic parameters**

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Survival, recruitment, breeding and skipping probabilities are main demographic parameters in the life history of seabirds, and may be age- and sex-dependent. Extensive banding databases (over 20 to 28 years) of five seabirds breeding in the tropical Pacific (4 species of boobies and the red tailed tropicbird) provide an opportunity to assess similarities and differences in the way different species respond to the strong environmental variability of El Niño Southern Oscillations (ENSO). Life history theory predicts that long-lived birds should favor a bet-hedging strategy, involving a reduction of annual breeding performance during harsh conditions in order to maintain high adult survival that will allow reproduction over more years. We applied multi-state models to capture-recapture data to estimate the responses of vital rates of all five species to ENSO. Results will be presented and discussed.

**PS16.7 Local and oceanic environmental drivers of demographic trends in an albatross community.**

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Using 35 years of mark-recapture data (1980-2015) for four albatross species (Diomedea exulans, Pheobetria palpebrata, Thalassarche melanophrys, T. chrysostoma) from subAntarctic Macquarie Island (MI, 54°30'S, 158°57'E), we assessed the influence of fisheries, climate and breeding habitat change as environmental drivers of demographic trends. At sea, the effect of climate induced variations in prey availability and changes in fisheries effort on breeding and survival of MI albatross are largely unknown. While locally, nesting sites on MI have experienced dramatic changes in vegetation cover over the last four decades caused by management driven fluctuations in the

introduced European Rabbit (Oryctolagus cuniculus) population, varying the availability of breeding sites and potentially influencing breeding success. Quantifying the links between environmental variation and demographic rates across multiple species that occupy different ecological niches increases the capacity to identify major determinants of population trends. Using a multi-event framework to model individual histories with uncertain states, demographic parameters of survival, return and breeding probabilities and breeding success were modelled with covariates including climate indices, remotely-sensed oceanographic data, fisheries effort, local weather conditions and rabbit population abundance as a proxy for habitat quality. The habitat usage of 41 tracked individuals (1999-2009) was determined and oceanographic and fisheries covariates were sampled within this region. Preliminary modelling of a single species; D.exulans, indicated the effectiveness of the approach finding oceanographic variations in sea surface temperature and sea surface height anomaly were significant factors influencing the return and breeding probability of this species. Identifying past demographic drivers will enable the prediction of future albatross population trends under varying climate, fisheries and habitat scenarios.

**PS16.8 Divorcing immediate and longer term impacts of a marine heatwave on Little Penguins from the effects of coastal development- is it possible?**

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The largest colony of Little Penguins in Western Australia is located on Penguin Island, 50 km south of Perth, and the breeding performance of a nestbox subpopulation has been monitored for over 20 years. From our long term data set, high SSTs in April and May, both offshore and close to the colony, have been correlated with fewer chicks per pair and lower masses of chicks at fledging. In the summer of 2010 and throughout 2011, the waters along the south-western coast of Western Australia were impacted by a record strength Leeuwin Current and above average sea surface temperatures. In 2011, mark-recapture indicated fewer penguins returning to the island; breeding participation and success were the lowest observed since monitoring began; four times the average number of penguins was found dead, mainly from starvation; and diet composition studies revealed that whitebait (Hyperlophus vittatus),the major constituent of their diet in previous years, was absent. It is likely that the anomalous oceanographic conditions impacted the presence of the whitebait in the local coastal waters. However the construction of a boat ramp adjacent to the major whitebait nursery in 2010 may have also played a role. Slightly cooler, but still elevated temperatures persisted in 2012 and 2013. Studies on diet, population and foraging habitat in subsequent years have shown that the penguins are still being impacted. These data highlight the ability to use penguins as sentinels of climate change but also the difficulty in decoupling environmental and anthropogenic causes of change.

**PS16.9 Linking reproductive parameters with oceanographic variability in tropical seabirds with different life history traits: implications for their use as bioindicators**

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We related the inter-annual variability in reproductive parameters of six tropical seabird species with different life histories, with local (SST - sea surface temperature and CC- concentration of clorophylla) and large scale (El Niño Southern Oscillation/La Niña, and the Indian Ocean Dipole) oceanographic variables. Our study comprises 4 to 10 years of data from 5 species, along a gradient from 1) synchronous and fast chick-growing with inshore and specialized foraging habits to 2) asynchronous, slow chick-growing with offshore and generalist foraging habits: Roseate Tern, Sterna dougalli, Lesser Noddy, Anous tenuirostris, Brown Noddy, Anous stolidus, Sooty Tern, Onychoprion fuscatus, and White-tailed Tropicbird Phaethon lepturus. Two types of environmental variation were registered: 1) short-term and local-scale events, without a relationship with any measured oceanographic parameters, and 2) long-term and large scale events characterized by strong SST anomalies, i.e with higher and lower SST than normal, possibly induced by El Niño and La Niña, respectively. The first event affected only inshore species with fast chick-growth rates and the second event affected all species, but those with fast chick growth rates were affected first. The breeding participation of most species during years with large-scale environmental perturbations was low and breeding success of all species was strongly negatively affected, with white-tailed Tropicbirds being the least affected. The average food intake rate by Roseate Tern chicks, and the chick body mass increments of Lesser Noddy chicks averaged over 7-day periods were both positively related with lagged CC values, and negatively related with lagged SST values. These two species are the most suitable organisms to indicate the effects of local changes in environmental conditions, whereas Brown Noddies, Sooty Terns and White-tailed Tropicbird are more suitable as indicators of effects from large-scale oceanographic perturbations.

## PS17 Migration and Orientation

### PS17.1 Consistency, diversity and connectivity in migration strategies of an omnivorous seabird

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For many species, migration is an essential adaptation for living in seasonal environments. Yet migration strategies need not be equal among members of a population. In order to understand the consequences of diversity in migration we must first understand the differences between these strategies. Tracking individuals across multiple years is revealing a diverse array of migration strategies in a range of terrestrial and marine species. One example is the lesser black-backed gull, an omnivorous seabird, whose ecology has been changing over the last decades. We compare the migration strategies and connectivity of adult lesser black-backed gulls, tracked using GPS over multiple years, from breeding populations on the eastern and western North Sea coast. A broad range of migration strategies co-exists within these populations, from long distance migration of 5000 km to Mauritania, to migratory distances of only 150 km. Individuals are very consistent in their migration routes and site faithful at the fine scale between years. We show a few examples of how weather experienced en-route results in inter-annual variability in migration routes. The timing of migration, especially departure in autumn, appears to be relatively flexible. The omnivorous nature of this seabird and a shift to more terrestrial environments enables this species to exploit a broad range of habitats in the winter and we identify several sites in western Europe and northwest Africa that support connectivity between the populations during the non-breeding season. We

discuss the potential consequences of these migration strategies at the individual and population level.

**PS17.2 North to the Arctic: the late summer and fall migration of seabirds from the Bering Sea into the Chukchi Sea**

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In northern regions, many marine birds move south after breeding to replenish energy stores prior to winter, seeking foraging opportunities with less extreme conditions. Here we describe a 'reverse migration' of millions of seabirds - a broad-scale seasonal shift in distribution from the eastern Bering Sea in summer, northward into the Arctic in late summer and early fall. Our findings are based on ~190,000 km of vessel-based transect surveys in the eastern Bering, Chukchi, and western Beaufort seas, 2007 - 2014, June - October. As the sea ice retreats north of the Bering Strait in June, seabird species richness and abundance increase in the Chukchi Sea from July through September and decrease quickly in October, although there is interannual variation. Numerically dominant species are Aethia auklets and short-tailed shearwaters Puffinus tenuirostris, which consume macrozooplankton (copepods and euphausiids). Additional migrants include other alcids, larids, and phalaropes. Most of these seabirds do not nest on the coast of the Chukchi Sea and must have migrated from breeding sites inland or from coastal Bering Sea, Aleutian Islands, or Gulf of Alaska, and shearwaters breed in the southern hemisphere. Possible advantages to traveling thousands of km north in late summer include more hours of daylight and late seasonal plankton blooms that result in abundant copepods and euphausiids. Presumably the hundreds or thousands of km they travel north for this brief period is energetically worthwhile. Seabird densities were highest near breeding colonies in summer, and in fall near underwater canyons, slopes, and shoals. Bering Strait links the Bering and Chukchi seas and had high seabird densities throughout the ice-free period. The Arctic is undergoing rapid warming, which may be affecting seabird community structure and the timing or duration of late summer migration. This brief, late-summer Arctic phenomenon is likely an important aspect of regional seabird ecology.

**PS17.3 Thick-billed murres from the High Arctic have the luxury of being lazy!**

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Aquatic environments in the temperate, boreal and arctic climate zones are highly seasonal in terms of biological productivity. Many poikilothermic aquatic organisms survive the winter, when food availability is low, by reducing their activity levels and/or performing vertical migrations to deep cold waters where energy consumption is low. This causes potential problems for homoeothermic predators, which require constant access to nutritious prey to survive or large body lipid reserves. Diving birds are particularly vulnerable to periods of low prey availability and many species therefore resolve this by migrating to warmer waters, where locating food is energetically less challenging. Migration by flight however, is extremely energetically costly for birds with wings specialized for underwater swimming. Little is known of how they manage to obtain sufficient energy during migration. In this study we used time-depth recorders (recording pressure, temperature, wet/dry

and light every 10th sec. for ~365 days) to investigate the activity budget and locations of thick-billed murres during the non-breeding season. Fall migration by male parent and chick was conducted solely by swimming and covered distances of ~3000 km. Females and non-breeding males conducted the first part of their fall migration by flight (~800 km) and the rest of the migration (~2000 km) by swimming. Movement by flight is the most costly form of locomotion for Thick-billed murres and we found thick-billed murres to spend remarkably little time flying (between 0-5.3% on a 24h cycle) during the period between the fall (Aug/Oct) and spring migration (Apr/May). The longest period of continuous flight during the non-migration months was 1.6 hours. The murres dived the deepest during the months of Dec- Feb, with a maximum recorded dive depth of 191 m. Diving effort increased toward the end of the non-breeding period, most likely in preparation for the energy expensive spring migration conducted by flight.

**PS17.4 Differential migration, site fidelity and sexual segregation of the critically endangered Balearic shearwater during the non-breeding season**

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The Balearic shearwater (Puffinus mauretanicus), Europe's only critically endangered seabird, is currently experiencing significant pressure at sea, yet we know little about its migratory behaviour and non-breeding ecology. Here, we integrated data from miniaturised light-level loggers and stable isotopes of bird and prey tissue to investigate individual migration strategies, non-breeding site fidelity and trophic habits. Over four consecutive years (2010-2014), birds from one of the species' largest colonies, in the Mediterranean Sea, exhibited a strong pattern of differential migration, moving to coastal waters in two main non-breeding areas in the northeast Atlantic. Individuals showed high levels of site fidelity amongst years, returning to remarkably similar core non-breeding grounds. Furthermore, almost all birds that migrated to higher latitudes were female, indicating sexual-segregation in non-breeding distribution. Feather stable isotope values from tracked birds suggested that dietary habits differed in the two non-breeding areas. While only small differences in δ13C values were found, δ15N values varied with location, and when interpreted in relation to potential prey isotope values (collected during the moult period) suggested a higher probability that northern-summering birds consumed prey that would not be naturally accessible, indicating a role of discard scavenging. We relate individual migratory behaviour to phenology of individuals, fisheries activity and potential carry-over effects between the non-breeding and breeding phases. By integrating different strands of data we highlight the vulnerability of this threatened species to anthropogenic activity throughout its non-breeding range, and provide dietary information that will be useful for future assessment of seabird responses to changing fisheries discard practices within Europe.

**PS17.5 Migratory connectivity at high latitudes: Sabine's gulls from a High Arctic colony migrate to different oceans.**

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The world's Arctic latitudes are some of the most recently colonized by birds, and an understanding of the migratory connectivity of circumpolar species offers insights into the mechanisms of range expansion and speciation. Migratory divides exist for many birds, however for many taxa it is unclear where such boundaries lie, and to what extent these affect the connectivity of species breeding across their ranges. Sabine's gulls (Xema sabini) have a patchy, circumpolar breeding distribution and overwinter in two ecologically similar areas in different ocean basins: the Humboldt Current off the coast of Peru, and the Benguela Current off the coast of South Africa and Namibia. We used geolocators to track Sabine's gulls breeding at a colony in the Canadian High Arctic to determine their migratory pathways and wintering sites. Our study provides evidence that birds from this breeding site disperse to different oceans during the non-breeding season. Remarkably, one breeding pair showed divergent migration pathways to overwinter in opposite oceans. This suggests that a migratory divide between wintering populations of this species exists and the colonization of favourable breeding habitat may be one of the strongest drivers of range expansion in the High Arctic.

**PS17.6 Repeatability of migration routes and timing in a long-distance migratory seabird, the Long-tailed Skua Stercorarius longicaudus**

Rob van Bemmelen[1], Borge Moe[2], Sveinn Are Hanssen[2], Niels Schmidt[3], Olivier Gilg[4]
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During the non-breeding period, seabirds utilize ocean resources to restore energy reserves spent on reproduction and to prepare for the next breeding season. Selecting the migration routes and wintering sites that allow an individual to fulfil these needs is thus critical to its fitness. Flexibility in migratory traits may hereby allow individuals or species to successfully cope with changing resource availability or weather conditions experienced during the non-breeding season. Using geolocators to track individuals over multiple non-breeding seasons, we report on individual consistency in migratory route, wintering site and timing in an Arctic-breeding seabird, the Long-tailed Skua (Stercorarius longicaudus). Migration trajectories from two subspecies breeding in the North Atlantic ranged widely over the Atlantic Ocean, south to the Agulhas Current. Between-individual variation in trajectories and site selection was substantial, whereas individuals were highly consistent in migratory trajectories and especially in wintering site selection. Timing of autumn migration was highly variable, in particular for Scandinavian birds, these patterns are tigthly linked with breeding effort. Routes and timing of spring migration showed little variation. This study shows that Long-tailed Skuas are relatively inflexible in their migration routes. Closer inspection of deviations from individual routes may enhance our understanding of the impact of year-to-year variation in environmental conditions on an individual level. Such knowledge would improve our ability to predict the impact of environmental change on this species.

**PS17.7 Caspian Tern Migration and Overwintering Behavior in Western North America**

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The Caspian Tern (Hydroprogne caspia) is a cosmopolitan species displaying a range of migratory behaviors, from relatively sedentary to long-distance migrant. In western North America, Caspian Terns nest in coastal or interior freshwater habitats from Mexico to Alaska, but most nesting occurs

at temperate latitudes. From banding records, it is0presumed that a majority of this population overwinters along Mexico's Pacific Coast; however, specific migratory and overwintering behavior is largely unknown. To characterize the movements of Caspian Terns during this portion of their annual cycle, we used 12g solar-powered, satellite PTTs to track 23 adults captured prior to the 2014 breeding season at a colony site in the northwestern United States (47° N). Following an often lengthy post-breeding dispersal period, Caspian Terns displayed an incremental "stepping stone" southward migration. Migration routes were initially variable, with individuals tracked along the Pacific Coast and at various distances (up to 600 km) inland, but routes eventually converged on a large inland lake, the Salton Sea, just north of the U.S.-Mexico border (33° N, 125 km inland). Every tagged individual visited this site on their southward migration and most spent several weeks there before continuing south into Mexico. The most southerly overwintering location was in a coastal estuary near Acapulco, Mexico (17° N), approximately 3,800 km from the capture site. Other tern species display stepping stone migration strategies, but often perform rapid, long distance flights across pelagic or inland sea environments. Further investigation is needed to understand the factors responsible for incremental migration in Caspian Terns, such as the specific geography of western North America (migration across a portion of the species' breeding range), the extended parental care this species provides for young (extending into the winter period, longer than for any other tern species), or other factors.

**PS17.8 Variation in migration strategies of Leach's storm-petrels, Oceanodroma leucorhoa**

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In recent years, tracking devices have revealed important information about migratory routes and wintering areas of seabirds that had not been revealed by many decades of band recoveries. Depending on the species, colony origin may or may not predict wintering area. This variation in migration strategies can result in different carry-over effects. Here, we describe migration movements of Leach's storm-petrels, Oceanodroma leucorhoa, from two colonies in Nova Scotia, Canada. Although this species is the most abundant in Atlantic Canada, evidence is accumulating that Atlantic populations are experiencing significant declines. Identifying important stop-over and wintering sites may be important to understanding these declines. Birds tracked during winters of 2012-2013 and 2013-2014 from both colonies used two different strategies during fall migration independently of colony origin. One set of birds had a high latitude stop-over associated with a North Atlantic over-winter area that had low chlorophyll-a concentrations. A second set had an equatorial stop-over associated with a South Atlantic Ocean over-winter that had high chlorophyll-a concentrations. No stop-over sites were identified during spring migration. These data also identify coastal and pelagic habitats that are likely of importance to the ecology and conservation of a number of long-distance migratory seabird species.

**PS17.9 Recognising land helps you navigate in a pelagic environment, if you're a shearwater.**

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*[1]University of Oxford, [2]University of Amsterdam*

Manx shearwaters navigate proficiently over vast distances. While olfaction is likely to be crucial for at-sea navigation, it might not be sufficient to explain the extraordinarily direct commuting flight

exhibited by Manx shearwaters during the breeding season as they travel between their foraging grounds and breeding colonies. We tested whether seeing land is an important factor in Manx shearwater navigation by computing a grid of available visual information from a freely available topographic dataset accounting for the curvature of earth and atmospheric refraction of light. By overlaying more than 200 GPS tracks from Manx shearwaters on Skomer Island, Copeland and Rhum, UK, we found that Manx shearwaters actually spend the majority of their time within the maximum distance from which land can be seen and during commutes have better goalwards orientation when more visual land-information is available. We attempt to identify key visual landmarks and suggest that shearwaters therefore augment their olfactory map with visual information where available because of its inherent precision and reliability.

## PS18 Breeding Biology 2 – Performance and Experience

### PS18.1 Microclimate and chick production in artificial burrows used by Little Penguins (Eudyptula minor), compared with natural burrows.

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Microclimate is an important property of burrows used by many animals, including some seabirds that need to return to land to breed and moult. Appropriate microclimatic conditions in the burrow mean that more energy can be invested in growth rather than thermoregulation. This study investigated the thermal properties of artificial burrows in comparison to different types of vegetation and sand burrows used by little penguins (Eudyptula minor) during chick rearing. The thermal properties of these different burrows were quantified using the hourly variation of temperature and relative humidity over a period of time. Modelling showed differences between artificial and natural burrows in temperature, relative humidity, differences between inside and outside temperatures and temperatures exceeding the Upper Critical Temperature (27C). Further, the frequency of readings exceeding the Upper Critical Temperature (UCT > 27C), was also modelled and found to be highest in the artificial burrows. Of the natural nest sites, grass sites remained relatively cooler at higher and warmer at cooler temperatures, and the temperature rarely reached the UCT. Further four burrow types (grass, sand vine and artificial) were monitored over three breeding seasons: 2010 - 2013 and differences were found in chick production, defined as the ratio of the number of chicks produced to the total number of burrows in each burrow type, among the burrows. Artificial nest sites are widely used to supplement nesting sites in seabird colonies around the world. The potential for climatic warming to increase the frequency of UCTs during critical phases of the breeding cycle might need to be taken into account in the design and deployment of artificial nest sites when they are used as a conservation and management tool.

### PS18.2 The effects of supplemental feeding on parental investment of Atlantic puffins (Fratercula arctica) breeding in variable natural foraging conditions

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Previous research has shown that Atlantic puffin (Fratercula arctica) parents can use chick begging behaviour to make decisions related to parental investment. When resources are abundant, parents can allocate resources to lower quality chicks. When resources are scarce, parents need to assess

the costs associated with current reproduction to future reproduction and survival. Chick begging informs parents about a chick's hunger, but it can also inform a burrow nesting seabird about a partner's provisioning effort. Successful breeding depends on both individual and partner quality, therefore parents need accurate information about a partner's effort to make strategic decisions about investment. This study measures both behavioural and physiological responses of parents to chick begging in several years of varying prey availability. Using specialized infrared video/audio cameras, I observed chick begging behaviour and parental provisioning in eleven burrows in each year from 2011-2013 for 24 hours/day for four days prior to supplemental feeding (or no food for controls) and for four days during supplemental feeding. Prey availability during these years was low in 2011, high in 2012, and intermediate in 2013, allowing us to observe how different foraging conditions interact with supplemental feeding to affect parental investment. A unique tool for identifying individuals using Passive Integrated Transponder tags allowed us to monitor precise feeding information and show sex differences in parental investment. Levels of beta-hydroxybutyrate (BHB), which elevate with lipid utilization and mass loss, were measured and were higher in adults with more challenging conditions (low prey availability) than those with less challenging conditions (having supplementally fed chicks). BHB levels were lower in adult females with supplementally fed chicks compared to adult males, indicating that under natural conditions, energetic demands of chick rearing can be greater for females.

**PS18.3 Unravelling physiological and ecological determinants of albatross chick growth**

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Chick growth trajectories provide an integrated measure of physiological, behavioural (e.g. parental investment), and environmental processes (e.g. prey availability). We present an analytical framework grounded in metabolic theory to examine chick growth in four albatross species (Wandering, Black-browed, Grey-headed and Light-mantled Albatross). Bioenergetic models are applied to nestling mass and meal mass measurements that were collected at Bird Island, South Georgia for naturally raised chicks between 1963 and 2003, as well as chicks raised in interspecies cross-fostering experiments between 1976 and 1996. Our approach allows us to make a mechanistic link between energy intake and life history processes, such as growth, development, and survival. It further allows an examination of the ecophysiology of these taxa in an evolutionary context. The modelling approach can be extended to cover all life-history stages of each species, thereby providing a generic approach to study the impact of environmental conditions on the life cycle of these seabirds.

**PS18.4 Microbiota of Little Penguins and Short-tailed Shearwaters during Development**

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At hatching, the gastrointestinal (GI) tract of chicks is considered to be completely sterile, with colonisation occurring immediately after hatching. Immediately after birth, successional changes occur within the microbiota until a climax community is achieved. Factors such as microbial load on the eggshell, nesting environment and their first meal are all said to influence the microbial colonisation of the GI microbiota of the chick. To date, the development of the microbiota in seabirds has not been examined. Therefore, this study aimed to characterise the microbiota of little

penguins and short-tailed shearwater chicks throughout development, using Quantitative Real Time PCR (qPCR) and 16S rRNA pyrosequencing sequencing. Results from the qPCR analysis identified no significant differences or trends in the microbiota of short-tailed shearwaters during development, whereas, in little penguins a significant upward trend for Firmicutes and Bacteroidetes was observed throughout development. The pyrosequencing analysis identified that the GI microbiota of short-tailed shearwater chicks was dominated by gram positive facultative and obligate anaerobes from the phylum Firmicutes throughout development. In little penguins the 16S rRNA pyrosequencing data identified that there were significant fluctuations in the microbial composition from hatching until fledging. The newly hatched chick was quickly colonised by members of the family Enterobacteriaceae, followed by strict and obligate anaerobes, with members from the families Fusobacteriaceae and Clostridiaceae dominating. This study describes the first molecular examination of the microbial community of the faecal microbiota of little penguin and short-tailed shearwater chicks throughout development. Short-tailed shearwater and little penguin chicks display similar successional changes as other vertebrates with aerobic and facultative anaerobes being the first microbes to colonise the GI tract and slowly transitioning to

**PS18.5 Reproductive effort costs on oxidative status and physiological stress in Adélie penguins (Pygoscelis adeliae): an experimental study**

Roger Colominas-Ciuró [1], Andres Barbosa[1]
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Contact name: Colominas-Ciuró, Roger. Institution name: National Museum of Natural Science (MNCN-CSIC) Email: rcolominas@mncn.csic.es Summary: Based on the hypothesis that brood size increases reproductive costs, an experimental manipulation during breeding in Adélie penguins (Pygoscelis adeliae) was conducted comparing adults rearing one or two chicks at Hope Bay (Antarctic Peninsula). Nests with two chicks were randomly assigned to a high reproductive effort group (HRE, two chicks) and a low reproductive group (LRE, one chick) by removing one chick from some nests with two chicks. The removed chick was placed in a close nest with only one chick. We examined how oxidative status in blood plasma (total plasma antioxidant capacity and oxidant components), measured with both the oxidant and the antioxidant components, and the physiological stress, assessed using the heterophil/lymphocyte (H/L) ratio, respond in relation to a high production of offspring biomass (sum of chick body mass). We predict that a high reproductive effort should be positively related to a high oxidative stress. Our nest manipulation showed significant differences in the offspring biomass. The HRE group produced a total chick biomass higher than the LRE group showing that the HRE group worked harder than LRE. The results support our prediction as HRE group had a higher oxidative status than individuals in the LRE group, although this was only the case for total plasma antioxidant capacity in females, but not for males and neither in terms of oxidant components for any sex. Moreover, significant and positive relationships between H/L ratio and the offspring biomass, and negatively between H/L ratio and antioxidant values in the case of females were also found. In contrast, oxidant components did not show a significant relations

**PS18.6 Estimating annual reproductive performance of known-age Adélie Penguins: An exploration of life history theory**

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Life history theory posits that natural selection results in individuals optimizing the allocation of resources to maximize lifetime reproductive output (fitness). Because an individual's residual reproductive value decreases with age, life history theory predicts that iteroparous breeders should maximize their fitness by allocating investment between current and future reproduction. Various hypotheses have been proposed to explain observed patterns of age-based reproductive performance. These explanations and mechanisms are not necessarily mutually exclusive and in combination can produce a variety of age-related patterns. Because both within-individual change (e.g. intrinsic: experience, senescence; extrinsic: habitat, environment) and between-individual change (e.g. selective appearance and disappearance of phenotypes) influence fecundity, disentangling these effects can help us understand the patterns they produce. Ultimately, studies of age-dependent reproductive performance should take into account individual heterogeneity in life histories and encompass the entire lifespan of the individual. Differences in individual quality, age, or experience are not always evident under "average" environmental conditions; thus, life history studies of age-dependent reproductive success should incorporate and account for responses associated with the full range of environmental conditions that characterize the system. We used a 20-year mark-resighting data set on known-age Adélie Penguins to investigate patterns in age-based fecundity. Our study encompassed a range of sea ice conditions to investigate hypotheses proposed to explain age-based fecundity patterns and provide estimates to parameterize an agent-(individual-) based population model of the Ross Island, Antarctica Adélie penguin metapopulation.

**PS18.8 Mediterranean storm petrels rely more on nest position than on nest odour for homing: a test with artificial nest-boxes**

Gaia Dell'Ariccia[1], Laëtitia Blanc[2], Francesco Bonadonna[2], Ana Sanz-Aguilar[3]
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Petrels are highly phylopatric and return from migratory journeys of thousands of kilometres to breed in the same burrow year after year. During the breeding season, some burrowing petrel species rely on their sense of smell to locate their nest at night, but the mechanisms involved in the homing behaviour after several months at sea are virtually unknown. In the aim to understand whether the sense of smell is involved in nest finding also at the return from migration and the interplay with other positional cues, we explored the homing behaviour and nest choice by Mediterranean storm petrels (Hydrobates pelagicus melitensis). In a colony subject of a long-lasting population survey and provided with artificial nest-boxes, during two consecutive winters, we experimentally displaced previously occupied nest-boxes and we then checked for nest choice and occupancy by breeding individuals in the following breeding season. This experimental design allowed the manipulation of the location of the burrow, and the olfactory information contained in it, without manipulating other positional cues. We observed that almost all individuals nested in the box located at the same position as the year before, disregarding whether the box was the same already occupied before or another one, and so the possible olfactory cues linked to the boxes. During the breeding period, we also tested in a Y-maze the olfactory preference for the occupied

nest-box respect to another random one. Again, storm petrels did not show any olfactory preference for their nest. Our study evidences that storm petrels breeding in a cave rely on other positional cues than olfactory to home and suggests a mechanism combining tactile and proprioceptive cues to find the nest in the dark in this ecological setting.

**PS18.9 How blue Petrels find their scented burrow?**

Marianne Gabirot[1]
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Sensory ecology, bird olfaction and emissions of volatile organic compounds (VOCs) are understudied. The contribution of olfaction to avian behaviour has been largely ignored by ornithologists and emphasis has generally been placed on vocal and visual signals. However, recent studies provided evidence that olfaction plays a fundamental role in the avian ecology, especially in hypogean petrels. Petrels are known to return by night to the same nest with the same partner in the same colony each year. This nocturnal behaviour is probably driven by predation pressure from skuas and gulls. Latest investigations strongly suggest that birds use at least olfactory cues in nest and partner recognition with emission of specific and complex chemical labels. Olfactory cues that lead petrels towards the burrow entrance, might have a variety of sources such as owner's feathers and glandular excretions and plants. The chemical composition of nest odour, the nature of components that facilitate recognition even after a yearlong absence, as well as the extent and nature of variation between nests, years, seasons, etc. remain unknown. The ultimate carrier of these secretions is the plumage and the characteristic musky scent of petrels emanates only from it. Surprisingly, no study to date has focused on these scents. We proposed in this work to characterize chemically the composition and identity of VOCs emanating from plumage and nests to assess presence of such scent profiles. Samples of plumage and VOCs from nest were collected from breeding birds in the Kerguelen Islands, Southern Indian Ocean and analysed using GC-MS methods. Results suggested that nests carry a specific bouquet, but differ from bird scents. However, this is not excluding that some components of individual scents stay in the nest and help to the recognition of burrow each year.

## PS19 MPAs and Conservation Policy

**PS19.2 Large scale seasonal patterns of seabirds distribution fuels Pelagic Marine Protected Area's network designation.**

Emeline Pettex[1], Matthieu Authier[1], Hélène Falchetto[1], Léa David[2], Eric Stéphan[3], Ghislain Dorémus[1], Sophie Laran[1], Olivier Van Canneyt[1], Pascal Monestiez[4], Aurélie Blanck[5], Vincent Ridoux[1]
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Designing appropriate Pelagic Marine Protected Areas is a challenging process, often facing a lack of knowledge on species distribution. For the last decades, advances in telemetry provided considerable information on seabird's ecology, but still exclude a large proportion of the population (e.g. small species, non-breeding birds, individuals from inaccessible colonies) from a scientific investigation. To overcome this issue and investigate spatio-temporal variations in the seabird community, large-scale aerial surveys following a strip-transect method, were conducted in winter 2011-12 and summer 2012 over a 560 000 km2 area encompassing the English Channel, the Bay of Biscay and the northwestern Mediterranean Sea. Seabird sightings, belonging to 29 taxonomic groups, added up to 22 300 and 10 800 in winter and summer respectively, along a travelled

distance of 98 500 km. Using geostatistical methods, we investigated the spatial structure of species distributions and draw density maps for both seasons. Estimates of density and abundance were also produced. Most taxa showed seasonal variations of their density and distribution. Highest densities, however, were recorded during winter for all groups except shearwaters, storm-petrels and terns. The gulf of Lion in the Mediterranean Sea, the continental shelf and the slope in the Bay of Biscay, and the eastern Channel were identified as key areas for seabirds' conservation. Overall, this study of an unprecedented effort provides, for the first time, a synoptic view of the seabird community in the French EEZ waters. These exciting results highlight the pelagic distribution of many species and provide strong evidences that the importance of the winter season in conservation plans had been underestimated thus far. On the basis of these results, an important collaborative work gathering scientists and conservationists resulted in the designation of 10 areas forming a new network of pelagic Marine Protected Areas in France.

**PS19.3 Habitat modelling predictions : a tool for effectiveness assessment of MPAs network**

Auriane Virgili[1], Charlotte Lambert[1], Emeline Pettex[1], Vincent Ridoux[1]
*[1]University of La Rochelle*

According to European Union (EU) Habitats Directive and Birds Directive, EU Member States must extend the Natura 2000 network to pelagic ecosystems, through the designation of marine protected areas. However, the initial state of seabird communities across European waters is often poorly known. It is assumed that a Natura 2000 site is justified where at least 1% of the 'national population' of a species is present during at least part of its biological cycle. The aim of the present work was to provide new information about seabird distributions, evaluate the existing Natura 2000 network and finally, to propose offshore new MPAs. These results would serve as a scientific basis for the negotiation process involved in the designation of these new offshore MPAs. Extensive aerial surveys were conducted during the winter 2011-2012 and the summer 2012 across the Channel, Bay of Biscay and northwest Mediterranean sea (560,000 km²). Habitat modelling was conducted by using a GAM methodology, with a combination of physiographic and oceanographic variables. For each area, the ratio between species relative abundance predicted within its boundaries and the total relative abundance predicted across the whole French Exclusive Economic Zone was computed and compared to the 1% threshold. This evaluation also included a seasonal component, giving additional information to improve protected areas conservation plans. Our results showed that the existing network was efficient for most of coastal seabird species, but a clear lack was identified for more pelagic species. Moreover, the MPA's size is crucial: larger MPAs having higher effectiveness. Finally, we showed that proposed large offshore MPAs would be of great interest, with for instance less than 3% of northern fulmar population which was included within existing network, while the proposed MPAs would concern 42% of the French population.

**PS19.4 Pelagic seabirds tracking productive hotspots: relevance of existing protected areas for their conservation**

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Spatially explicit conservation measures are increasingly taking the central stage of conservation strategies and networks of marine protected areas (hereafter MPAs) are being used to manage fisheries and to protect threatened species and marine habitats around the globe. There is an increasing interest to extend the application of MPAs to encompass highly mobile species such as seabirds. These species forage within heterogeneous and dynamic environments, where the vertical and horizontal distributions of prey resources are governed by diverse oceanographic processes. Frequently mobile predators concentrate and forage at specific oceanographic features in response to elevated localized productivity and dense prey patches. Here, we explored whether a member of the highly pelagic Procellariiforms the Balearic shearwater (Puffinus mauretanicus), currently the most critically endangered Mediterranean seabird species, associated to productive oceanographic habitats across its wintering range in the NE Atlantic. Specifically, we identified overall foraging grounds and fine-scale foraging hotspots of birds from southern populations (Eivissa, Balearic Islands) all year round tagged with global location sensing (GLS), combining miniature archival light, salt-water immersion loggers and temperature sensors. We used an innovative data-processing method based on Markov Chain Monte Carlo and state-space modeling (Kalman filter) improved using sea surface temperature data. Our results suggested that bird spent more time in the main productive waters across the NE Atlantic, explained by remotely sense chlorophyll a values, centered in key contrasting marine areas off southern and northern NE Atlantic. We evaluated the relevance of the existing network of marine protected areas in encompassing the wintering oceanographic habitat of the most endangered Mediterranean seabird species.

**PS19.5 Coordinating seabird conservation along the east asian - australasian flyway**

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Over 150 seabird species inhabit the East Asian-Australasian Flyway (EAAF), some which have long trans-equatorial migration routes while others move at a smaller regional scale. Although some species have very large populations, such as Short-tailed Shearwaters (23 million individuals), several others have less than 100 individuals (Chinese Crested Tern). Many species are declining or are facing a high risk of extinction due to several ongoing threats at their breeding and wintering sites. To achieve positive conservation outcomes, a joint and equal responsibility for the conservation of seabirds is urgently required across the region. The East Asian - Australasian Flyway Partnership (EAAFP) was established in 2006 as an informal, voluntary international framework aimed at coordinating the conservation of migratory waterbirds and their habitat. In 2012, the EAAFP Seabird Working Group was formed to promote, facilitate, coordinate and harmonize seabird conservation, management, education, and research activities across the EAAF. The working group cooperates with all member countries, Partners, scientists and land managers interested in seabirds. Initial work of the group was to establish a Seabird Species Prioritization project, which included compiling known population data and the current conservation status of seabird species in the region. We present results of the Seabird Species Prioritization project and introduce regional priorities and conservation activities that will be led by the working group over the next several years. We discuss efforts to contribute seabird colony data to the Seabird Information Network (SIN) and the Global Seabird Colony Register.

**PS19.6 Far beyond the horizon - Maltese seabird tracks pointing towards transnational marine Important Bird Areas**

Benjamin Metzger[1], John Borg[2], Joe Sultana[1]
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Two Mediterranean endemic tubenose species are breeding in the Maltese Archipelago in significant numbers, the Yelkouan Shearwater Puffinus yelkouan and the Scopoli's Shearwater Calonectris diomedea. Due to multiple threats at land and at sea, both species show an overall unfavourable conservation status, with the Yelkuoan Shearwater having recently been uplisted to Vulnerable. Seabird conservation in the past focused on the terrestrial breeding grounds and most Maltese seabird colonies at land are legally protected as Special Protection Areas in the European Natura2000 network. However, less is known about the birds' movements and whereabouts at sea. Therefore, the identification of important off-shore bird areas and their designation as marine protected areas are the next important steps to safeguard Maltese seabirds and reverse their decline. To reach these aims, we were gps- and gls-tracking both shearwater species nesting in Malta during several years. Our results indicate that Maltese shearwaters regularly make use of foraging grounds situated in Libyan, Tunisian and Italian marine areas, and in international waters, far away from their nesting sites. Outside the breeding season, the birds carry out even larger movements to areas of high productivity. While the majority of Yelkouan Shearwaters spend the non-breeding season in the Aegean and Black Sea, Scopoli's Shearwater leave the Mediterranean basin westwards to winter in the Atlantic off the coast of western and south-western Africa. With the majority of the marine area used by Maltese seabirds being situated outside territorial waters, our findings highlight the importance of a multinational approach in marine IBA designation and further networking between countries to achieve effective species conservation measures. This study was carried out by BirdLife Malta in collaboration with the Maltese Ministry for Sustainable Development, the Environment & Climate Change, SPEA and the RSPB, co-funded by EU-Life.

**PS19.7 Are we rearranging the deckchairs on the Titanic? Evaluating multiple marine threats to Procellariiformes**

Stephanie Borrelle[1], Holly Jones[2], Roberto Salguero-Gomez[3], Barbara Bollard-Breen[1], Dave Towns[1]
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More than half (53%) of Procellariiformes (albatrosses, petrels, and shearwaters) are experiencing rapid population declines due to reduced fledgling survival rates and adult mortality. Seabirds are vulnerable to multiple threats on land; introduced predators and habitat loss, and at sea; plastic pollution ingestion, fisheries interactions, prey distribution and environmental shifts due to climate change. For logistical reasons, conservation efforts have been focused on predator eradication at terrestrial breeding grounds. However, despite impressive efforts on land, the impacts of marine threats are inflicting pressures on many seabirds that may be outweighing these efforts. We evaluated the risk of Procellariiformes to multiple marine threats through a review of scientific literature on interactions of birds with plastic pollution, commercial fisheries, and climate change (e.g. prey distributions shifts). The five aims for the review are to: 1) evaluate multiple threats acting in unison; 2) identify regions of increased interaction with marine threats; 3) identify knowledge gaps of urgent scientific, ecological and societal demand, including geographic and taxonomic gaps; 4) identify physiological traits common to species that may correspond to threat risk or resilience and; 5) and provide insight into species that may currently not be at risk, but may become

threatened. Our review synthesizes the current state of knowledge on marine threats to Procellariiformes and aims to inform seabird management actions to achieve long-term seabird conservation goals.

**PS19.8 Predicting the offshore distribution and abundance of marine birds from shipboard surveys, using a community distance sampling model**

Holly Goyert[1], Beth Gardner[1], Rahel Sollmann[1], Richard Veit[2], Andrew Gilbert[3], Kathryn Williams[3]
*[1]North Carolina State University, [2]City University of New York, College of Staten Island, [3]Biodiversity Research Institute*

Marine spatial planning efforts in the United States have recently drawn attention to the proposed development of wind energy areas (WEA) on the Atlantic Outer Continental Shelf. We used a hierarchical Bayesian community distance sampling model to estimate the seasonal abundance of marine birds exposed to WEAs off the coast of Delaware, Maryland, and Virginia. This approach allowed us to (1) accommodate for imperfect detection, (2) account for the diversity of rare and common species, and (3) predict the community response to static and dynamic habitat characteristics. We hypothesized that avian benthivores (bottom-feeders) respond more to seafloor variability and that piscivores (fish-eaters) respond more to surface productivity. Of the 46 marine bird species that we observed during 16 shipboard surveys from April 2012 to April 2014, overwintering Northern Gannets (Morus bassanus) were highly abundant and detectable, compared to the rest of the community. Results from the winter season were most consistent with our hypothesis: dynamic covariates quantifying surface productivity drove the distribution and abundance of piscivorous species, whereas static covariates characterizing the seafloor had stronger effects on benthivores (e.g. scoters, Melanitta spp.). By comparing the ecological drivers of the community's distribution and abundance, within and among species, we were able to evaluate the potential exposure of marine birds to proposed offshore WEAs.

**PS19.9 Spatial variation in seabird traits and their association with demographic parameters: using eggs to monitor the state of coastal marine habitats**

Nina O'Hanlon[1], Ruedi Nager[1]
*[1]University of Glasgow*

Developing suitable ecological indices is important in the marine environment which is otherwise difficult to monitor. As top predators, seabirds have the potential to monitor the state of marine ecosystems. In particular, seabirds are a convenient model to monitor coastal habitats which contain some of the most diverse and productive marine habitats, yet despite their importance, pressure on these habitats has increased markedly over the last several decades. Currently, long-term datasets focused on seabird colony counts are used to identify changes in the marine environment. These datasets provide invaluable information on the temporal variation in seabird numbers; however, detecting even small significant changes in population size can be extremely difficult. In addition, due to the long lifespan of seabirds and their slow reproduction there will be a delay between environmental change and detectable changes in seabird counts. We aim to investigate the effectiveness of seabird traits that can be readily measured in the field to monitor the marine environment with a greater temporal resolution than colony counts. Here we explore spatial variation in egg traits of Herring Gulls Larus argentatus from nine sites across Northern Ireland and south-west Scotland that have experienced contrasting population trends over the last few decades.

We show that there is spatial variation in egg attributes which are associated with the local populations' demographic parameters. The environmental factors driving this spatial variation in egg traits will also be explored, and could help identify potential drivers for the population changes. Outcomes will be used to validate this alternative monitoring tool to provide an effective early warning that a colony is experiencing adverse environmental conditions; enabling management, conservation and policy actions to be considered more immediately.

## S13 Advances in Design and Analysis for Seabird Demographic Studies

### S13.1 Robust inference from seabird demographic studies through a synergy among hypotheses, design, and analytical tools

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The robustness of inference from seabird demographic studies is determined by rigorous a priori hypothesis development, creative study design and marking/detection methods, flexible statistical and population models, and accessible analytical software. There have been great advances in marking methods, statistical models, and software in the last 25 years. Many of these advancements have been motivated by seabird studies, and have involved close collaborations between seabird biologists and statistical ecologists. Because seabirds are generally long-lived and far-ranging, they are often only directly accessible for capture/resighting in large numbers in a limited number of life history stages (e.g., as chicks, breeders). In addition, in many cases individuals that are detected cannot always be reliably assigned to phenotypic state. Demographic inference for seabirds has been advanced by the development of multistate statistical models, including the ability to account for unobservable life history states, and more recently the extension of these models to account for state uncertainty in those detected. Estimation problems due to unobservable states have also been mitigated by technological (e.g., telemetry devices or archival tags that indicate an individual's location when not capture on a breeding colony), and design (e.g., multiple sampling periods within a field season, use of dead recoveries, auxiliary sightings) advances. Access to these advances in methodology has been eased by the development of flexible computer programs such as MARK, ESURGE, WinBugs, and JAGS. The synergy from collaborations between seabird biologists, quantitative ecologists, and technology development has been productive to date, and promises great advances in the future.

### S13.2 Using multi-event models for estimating seabird demographic parameters

Roger Pradel[1]
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The multi-event framework is a way to look at capture-recapture data. Its main idea is that we want to learn about the population dynamics independently of the way we study it. Another important idea is that to achieve our goal, we may resort to information beyond the sole direct observation of the focal individual and that information may be imperfect. I will present and discuss the multi-event main assumptions from both a biological (are they reasonable?) and methodological point of view (how important are they in the model?). I will then develop examples: nest inspection can be used to study reproductive skipping and within-colony nest dispersal, migratory strategies may be identified indirectly from mixture models that incorporate environmental covariates related to the putative

distant migratory sites. I will then discuss how some assumptions (memory extending beyond one occasion, trap-response) can be relaxed within the multi-event framework.

**S13.3 Estimation of demographic parameters of emperor penguin using integrated population modeling**

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A major challenge in seabird demography is to obtain reliable estimates of juvenile survival (i.e., from fledging to first year), as immature individuals stay at sea and remain undetectable for several years. In this work, we proposed a Bayesian integrated population modeling to estimate the juvenile survival of emperor penguin (Aptenodytes forsteri), and other demographic parameters. Using this method, we simultaneously analyzed capture-recapture data of adults, the annual number of breeding pairs, and the number of fledglings of emperor penguin collected at Dumont d'Urville, Antarctica, for the period 1971-1998. We also assessed how climate covariates known to affect the species foraging habitats and prey (southern annular mode, sea-ice concentration) affects juvenile survival. Our findings showed that the mean juvenile survival of emperor penguin was 0.432 (SD =0.124). Our analysis also revealed that there was a significant positive effect of the southern annular mode on juvenile survival (slope = 2.287; 95% CRI = (0.693, 3.550)). The mean adult survival probability and fecundity were estimated at 0.908 (SD = 0.002) and 0.456 (SD = 0.066), respectively. The proposed method appears to be useful in understanding better the population dynamics of emperor penguin. This is the first evidence that early life survival was affected by environmental conditions faced during the period of immaturity in this species, with important consequences for modeling the species response to climate change.

**S13.4 Modelling survival, breeding, and recruitment from long-term data to parameterize a Bayesian Population Viability Analysis for an endangered albatross**

Sarah Converse[1], John Cooper[2], Richard Cuthbert[3], Alexander Bond[3], Steffen Oppel[3], Peter Ryan[2]
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Population viability analyses (PVAs) are powerful tools for assessing the status of small populations. PVAs are most reliable when they thoroughly account for both variability and uncertainty, because variability (environmental and demographic) can have large influences on the trajectory of small populations, and uncertainty masks our ability to understand those trajectories. Bayesian implementations of demographic estimation models allow us to account for environmental variability using hierarchical structures, and also provide full posterior distributions for the parameters of interest, and so are ideal for parameterizing PVAs. We took advantage of these benefits by building a demographic estimation model for endangered Atlantic yellow-nosed albatross (Thalassarche chlororhynchos) on Gough Island based on a 30-year dataset of 1868 ringed individuals. We used the resulting survival and recruitment estimates to build a Bayesian PVA for assessing the viability of the population. The demographic estimation model has a multistate structure designed to account for breeding dispersal and unobservable states. We present estimates of survival, breeding probability, and recruitment from the estimation model, as well as results from the Bayesian PVA, including the growth rate of the population.

**S13.5 Community distance sampling model for estimating seabird population abundance at sea**

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*[1]North Carolina State University, [2]Biodiversity Research Institute, [3]College of Staten Island, CUNY*

Recent interest in wind energy development on the Atlantic Outer Continental Shelf has brought attention to the need for baseline studies identifying the vulnerability of marine species in this region. Understanding environmental factors that shape the abundance and distribution of species and communities is a key step in understanding the potential risks for seabirds related to wind energy development. To address this need, we developed a community distance sampling model that allows species and community abundance to vary with environmental covariates. The model allows each species to have separate parameters, but these parameters come from a common underlying distribution, which is governed by shared hyperparameters. This structure enables us to incorporate species with sparse data sets into the analysis that would be otherwise discarded for having too few observations. We applied the model to seabird data collected during shipboard surveys off the coast of Maryland, Virginia and Delaware from April 2012 to April 2014. There were 16 surveys during this period, which were divided into 8 total seasons. We further included six oceanographic parameters to estimate seabird abundance: distance to shore, primary productivity, salinity, sea surface temperature, sediment grain size, and slope. We detected 46 marine bird species over the course of the study and compared the species-specific responses to these habitat features. Distance to shore and sea surface temperature were the most frequent significant predictors; however there were no strong consistent patterns across seasons or species. Detection also varied by species, Beaufort state, and season. The modeling framework we established allowed for incorporating rarely observed species, making comparisons between species after accounting for detection, and predicting species abundance across unsampled areas. This is a first key step in assessing the potential exposure of marine birds in offshore development areas.

**S13.6 Research priorities for seabird demography**

Morten Frederiksen[1]
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Demographic research on seabirds has made rapid progress in recent decades, and has often been at the forefront of new developments in both research methods and issues addressed. However, important challenges remain, in relation to both seabird conservation and more basic research. Issues that should be prioritized include: 1) Linking individual behavior to demography. Biologging has led to an enormous advance in our understanding of the behavioral choices seabirds make at various stages of their life cycle. But what are the consequences of these choices for fitness or demography? This is largely unknown, and there are severe methodological challenges - including device effects and the fact that for archival tags, information is only available for surviving individuals. 2) We still know very little about the demography of the majority of the world's seabird species. Many species have never been studied, and some are so rare that obtaining sufficient sample size for robust estimation is close to impossible. The way forward may include prediction from related species using phylogenetically constrained meta-analyses, or borrowing information from other species using hierarchical models. 3) There is still much to be learnt about demographic variability. While temporal variability is reasonably well studied, there are still very few studies of

spatial variability, both at small and large scales. In order to achieve greater generality, joint studies of the same species at different sites are needed.

## S14 Restoration of Seabird Nesting Islands

### S14.1 Conditions for engaging science and value judgements within seabird island restoration

David Towns[1]
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Island restoration is a sub-discipline of conservation biology and as such can be influenced by values or value judgements derived from cultural worldviews and practices, politics and religion. In New Zealand, restoration of seabird-driven ecosystems is now underway on more than 100 islands cleared of the invasive mammals. On some islands, almost all native forest cover was removed by earlier attempts at farming. The reconstruction of these island ecosystems presents many ecological challenges. For example, on some islands, previously recorded species are now locally extinct and may need to be reinstated. Other islands are inhabited by relict populations of extremely rare species such as the New Zealand storm petrel. Such species may be compromised by inappropriate restoration activity. Although restoration of a particular site can present species- or site-specific technical problems, the kind of restoration activity regarded as appropriate can only be determined through judgements that are not scientific. We use case studies from islands in New Zealand to demonstrate the range and complexity of decisions involved with restoration of seabird islands. We conclude that as the island restoration projects increase in size and complexity, so too does the range of values and value judgements. Furthermore, the role of human behaviour and the values of local populations will increase as inhabited islands become included in restoration actions. Unless there are transparent systems for dealing with increasingly complex value-judgments, the potential for larger scale restoration may become limited by sector groups with conflicting agendas.

### S14.2 Eradication of invasive vertebrates: more and bigger islands, multiple and novel species to protect seabirds and other insular assets

John Parkes[1]
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Few islands remain pristine with no introduced plants or animals. So, what can be done to protect and restore islands when these introductions are a problem? The answer is a great deal judging by the success in eradicating introduced mammals from hundreds of islands around the world. Rodents have been eradicated from 405 islands, feral cats from 110, foxes from 61 and feral pigs from 42 islands to note a few species that have particular impacts on seabirds. In this talk I will touch on several challenges that are emerging and give examples (the island examples in brackets) relevant to protecting island birds, particularly seabirds. 1. Many islands have multiple pests and removing them all simultaneously or in the right order to avoid unexpected consequences can be important (Santa Cruz, Macquarie, Guadalupe). 2. Non-target impacts of the control methods can be a perceived (Rat) or real (Pinzon) problem. 3. Managing pests on islands with human inhabitants can be difficult for proponents as everyone may not agree with the goals or with the methods (Lord Howe, Great Barrier). 4. Novel species for which we have few precedents for success present problems in convincing funders to take the risk (Angaur macaques, Ile aux Aigrette musk shrews). 5. Even for species with many successful precedents, such as aerial baiting for rodents, new habitats can be a

problem. Rat eradications on tropical islands have a higher failure rate than on temperate islands. The cause is unclear (Lehua). 6. This is a wider issue as apart from rodents we have no technique that will reliably kill 100% in a single application, and the costs to detect and remove survivors constrains the size of islands that can be attempted (North and South islands of New Zealand).

**S14.3 Effects of seabird ecosystem engineering on invertebrate food web structure**

Joshua Thoresen[1], David Towns[1], Sebastian Leuzinger[1]
*[1]AUT University*

Seabirds are the archetypal ecosystem engineer, while nesting on islands they transfer nutrients from the sea and disturb the soil through burrowing. However, seabirds are in decline worldwide and so too are the ecosystems they create. The research on these ecosystems is extensive, but little is known about the effects of seabirds on the ecological networks that make up these ecosystems. Eighteen leaf-litter invertebrate ecological networks were constructed across nine seabird and nine non-seabird islands. Ten environmental variables associated with seabirds and nine network structural metrics were compared against island type (i.e. seabird vs. non-seabird islands). Principal component analyses and multiple linear models were carried out to determine the predominant seabird effect driving the observed changes in network metrics. We found that seabird islands demonstrated significant changes in most environmental variables and all measured network structural metrics, with seabird islands demonstrating significantly greater network complexity and size. The linear models demonstrated that the predominant driving variables of these changes involved nutrient subsidies and habitat area. We concluded that as seabirds return to newly restored islands we can expect the invertebrate ecological networks to become successively larger and more complex over time.

**S14.4 An adaptive decision-making framework for prioritizing active versus passive seabird population restoration**

Rachel Buxton[1], Christopher Jones[2], Philip Lyver[2], David Towns[3], Stephanie Borrelle[3]
*[1]Colorado State University, [2]Landcare Research, [3]Auckland University of Technology*

At seabird breeding colonies, management of population recovery following removal of a threat falls along a spectrum, from passive - where a population is left to recolonize or recover naturally, to active - where recovery is enhanced using methods such as translocation and social attraction. Past restoration efforts have shown that passive recovery is highly variable, relying on seabirds' slow life-history traits and limited dispersal patterns. The role of active restoration is to overcome these impediments, but it can be costly and labour-intensive. Thus, strategies for deciding when and where to implement active restoration are needed to help optimize the allocation of limited conservation resources. We outline a decision-making framework for seabird restoration management, using the recovery of burrow-nesting petrels (order Procellariiformes) in New Zealand as a case study. Based on a conceptual model of petrel recovery dynamics, derived from a comparative analysis of petrel responses to invasive predator eradication, we identify island and species characteristics predicting a low probability of natural recovery. These characteristics are used to create a stepwise decision tree to select between active or passive techniques. We suggest that active restoration should be implemented when metapopulations are declining, on islands with any combination of: no nearby source colony; small remnant colonies; highly altered habitat with shallow soil and slopes, and; with potentially competitive species pairs. We emphasize the

importance of monitoring the outcomes of either restoration approach, in order to update the conceptual model and to support adaptive management of a restoration initiative.

**S14.5 The population growth of seabirds after vertebrate eradication on their nesting islands**

Michael Brooke[1], Rachel Buxton[2]
*[1]University of Cambridge, [2]Colorado State University*

Over 1000 vertebrate eradications have now been successfully carried out on islands, and various benefits to seabirds have been frequently documented, such as reduced predation and enhanced breeding success. However the evidence that these eradications lead to increases in seabird populations is hitherto sparse, partly because monitoring is generally poor, partly because the long life cycle of seabird species means several years or even decades may need to elapse before the benefits of eradication manifest themselves in seabird population increase. We collated population data from over 100 global seabird populations following predator eradication. Where monitoring data existed, over 90% of populations showed an increase, with growth rates typically of 0 - 20 percent per annum ($\lambda$ = 1.0 - 1.2). In extreme cases, $\lambda \approx 3.0$. In the first years immediately following an eradication we predicted that population increase would be largely due to immigration while, once the seabird's age of first breeding was reached, enhanced recruitment and immigration could both contribute to population growth. We found that population growth rates immediately after eradication were not significantly different from those after the lapse of several years, suggesting the importance of immigration. If immigration is a significant factor in seabird colony recovery, this could influence prioritization of future eradications and future active restoration, on the assumption that immigration is more likely when the nearest neighbouring colony is close and large. Our analysis will address this possibility, and whether immigration differs between taxonomic groups.

**S14.6 Bioacoustics techniques for monitoring and restoring insular avifaunas in Mexico**

Yuliana Rocio Bedolla Guzman[1], Eduardo Inigo-Elias[2], Yuri Albores Barajas[3], Julio Hernández Montoya [3], Antonio Ortiz Alcaraz [3], Maria Félix Lizárraga [3], Gregory Budney[2], Alejandra Fabila[3], Angeles Milanéz Salinas [3], Zayra Peña Moreno[3], David Cosio Muriel[3]
*[1]GRUPO DE ECOLOGÍA Y CONSERVACIÓN DE ISLAS, A.C., [2]Cornell University, [3]Grupo de Conservacion de Islas (GECI)*

The use of bioacoustics techniques for monitoring and restoring insular marine and terrestrial avifaunas requires careful planning with clear objectives and steps needed. Is important to know the hardware and software availability, advantages, and limitations; acquiring good recordings for all target species as well as record calls of unknown species that inhabit islands for future identification; the use of both passive and automatic recording units; the implementation of breeding bird calls acquired in nearby seabird colonies for playbacks to attract seabirds to nest in islands where populations may have been extirpated; or to document presence absence or breeding colony activities. We present recent cases were bioacoustics techniques have been used on marine and terrestrial monitoring and restoration of birds in the Baja California Pacific Islands, Guadalupe Island, and Revillagigedo Islands in Mexico.

**S14.7 The use of social attraction and chick translocations for seabird restoration**

Stephen Kress[1]
*[1]National Audubon Society*

The use of social attraction and chick translocation for seabird restoration. Stephen W. Kress, Seabird Restoration Program, National Audubon Society, 159 Sapsucker Woods Road, Ithaca, New York 14850 USA Seabird chick translocation and social attraction (the use of vocalization playbacks and decoys) are now widely used to encourage seabirds to establish new breeding colonies. These methods can help to restore seabird colonies that were diminished from anthropogenic impacts (e.g., hunting, oil spills and invasive species). They are also helpful for establishing multiple breeding locations to reduce risks posed by chance catastrophic events such as predation, disease and extreme weather. These active restoration methods can enhance recolonization success following the removal of invasive mammals with only modest additional cost. This presentation discusses why some projects fail and others succeed. Consideration of life history of the target species and proximity to source colonies will help to determine which methods to use. Likewise, details such as length of the program, number of translocated chicks and decoys, and effectiveness of audio playback equipment can determine if a project succeeds or fails. Long term success may require ongoing investment in management to sustain restored populations, especially near large human populations. Monitoring throughout the project is necessary to demonstrate success and detect new problems that may require changes in management protocols. This paper presents outcomes from 42 years of successful restoration of Atlantic Puffin and Roseate Tern in Maine, USA and compares lessons learned from failed and successful gannet restoration projects in Canada and New Zealand.

## S15 International Agreements and Seabird Conservation

### S15.1 Working with governments and international organisations - experience from the Agreement on the Conservation of Albatrosses and Petrels

Mark Tasker[1], Marco Favero [1], Richard Phillips[1]
*[1]ACAP Advisory Committee*

The objective of ACAP is to achieve and maintain a favourable conservation status for albatrosses and petrels. The Agreement's Advisory Committee and its three Working Groups provide scientific and technical advice to the governments of its Parties (and some key countries that are not Parties) and international organisations. This has led to a substantial amount of work being done by these governments to implement the Agreement, including the adoption and implementation of NPOA-Seabirds, conservation strategies, seabird recovery plans and introduced pest eradication programmes. Much of this work has been supported by international and national NGOs - especially BirdLife International. Two of the greatest pressures facing albatrosses and petrels are from bycatch in fisheries and introduced pests. Different levels of interaction with governments are required for each of these issues. Fisheries are managed by both governments and international bodies such as the Regional Fisheries Management Organisations. The development and implementation of best practice advice to mitigate seabird bycatch, and strategic engagement with RFMOs and other fisheries authorities remain priority areas of ACAP's Work Programme. Pest eradication is not an international action, but is undertaken on national territories by Governments and/or NGOs. ACAP has prioritised sites that need such action and has reviewed best practice for eradication. Biosecurity should not be forgotten either. In order for ACAP to prioritise it is important to have a good understanding on the conservation status of the ACAP species. ACAP has assembled all relevant information on this and summarised into status documents. This exercise has enabled ACAP to prioritise also where further data on status would be most useful, and advise relevant Governments of this. Governments and international bodies can find comprehensive information via the ACAP

web portal and database. These tools have provided the means to efficiently maintain current, accurate and comprehensive information on populations' trends and threats, both at-sea and on land, essential for further developing effective strategies, prioritising actions and assessing the success of the Agreement.

**S15.2 International efforts to reduce bycatch and improve the conservation status of threatened seabirds: The role of the Agreement on the Conservation of Albatrosses and Petrels (ACAP) and other international instruments.**

Anton Wolfaardt[1]
*[1]Agreement on the Conservation of Albatrosses and Petrels (ACAP)*

Incidental mortality of seabirds associated with fishing operations has been of conservation concern, and a growing area of research and management, since the late 1980s. The pioneering efforts of the Working Group on Incidental Mortality Associated with Fishing of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) led to the development, assessment and implementation of a range of bycatch mitigation measures in the CCAMLR Convention Area. The adoption in 2004 of the Agreement on the Conservation of Albatrosses and Petrels (ACAP), was driven largely by concerns regarding the effects of longline fisheries mortality on all species of albatrosses and the larger petrels. The wide-ranging nature of these seabirds requires an international and collaborative approach to mitigating bycatch. ACAP is a multilateral agreement that seeks to coordinate international activity to mitigate known threats to albatrosses and petrels. The Seabird Bycatch Working Group (SBWG) of ACAP, which comprises representatives from ACAP's 13 Parties, and invited experts, serves as a technical forum that routinely reviews relevant research, and provides updated best practice advice on bycatch mitigation measures and strategies. The development of improved or new mitigation measures remains an active field of research. Initially most attention was focussed on industrial longline fisheries. However, bycatch in trawl and gillnet fisheries and artisanal fleets have also been identified as a significant source of mortality for many species. While effective seabird bycatch mitigation options have been developed for industrial longline and trawl fisheries, implementation across these fisheries and development of mitigation strategies for artisanal and small scale fleets remain a challenge. The International Plan of Action for Reducing Incidental Catch of Seabirds in Capture Fisheries, adopted by the Food and Agriculture Organisation of the United Nations (FAO) in 1999, and revised in 2009, sets out detailed guidelines for nations and bi- and multi-lateral organisations, such as Regional Fisheries Management Organisations (RFMOs), to follow in adopting their own Seabird Plans of Actions. In this presentation, we will provide a brief outline of the role of international agreements and conventions in addressing seabird bycatch.

**S15.3 Establishing International collaborative efforts to conserve seabirds: the success of the Circumpolar Seabird Working Group**

Grant Gilchrist[1], Kathy Kuletz[2], David Irons[3]
*[1]Government of Canada, [2]United States Fish and Wildlife Service, [3]United States Federal Government*

Using seabirds as sentinels of the world's oceans will require international cooperation and action. Many bi-lateral and multi-lateral agreements and treaties have been developed to promote seabird conservation and habitat stewardship, as well as initiatives by non-governmental organizations. However, truly effective efforts will require long-term commitments, established and accepted

action plans, and implementation among government and non-governmental entities. The Circumpolar Seabird Group has been a collaborative effort among 8 arctic nations: the United States, Canada, Greenland (Denmark), Iceland, Faroe Islands, Norway, Finland, and Russia. Additionally, France, Sweden, the Netherlands, and the United Kingdom also participate. The Seabird Group (Cbird) is considered an 'expert working group' of the Conservation of Arctic Flora and Fauna, under the Arctic Council. Meeting in person annually and by year-round communication, the group has produced a seabird monitoring plan for the circumpolar region, Conservation Strategies and Action Plans for thick-billed murres, eider ducks, and Ivory Gulls, as well as over 15 reports on specific issues of interest to seabird conservation in the arctic including fisheries by-catch and harvest. The group has also pooled data from member countries to examine circumpolar shifts in the reproductive success of thick-billed murres in relation to large-scale oceanic conditions. The Circumpolar Seabird Group is in a unique position to offer examples, suggestions, and guidance on this issue. We will present examples of how specific efforts at international collaboration can maximize the use of seabirds as indicators of ecosystem conditions.

**S15.4 From marine IBAs to MPAs: gaining effective protection for seabirds at sea in Spain**

Pep Arcos[1], Juan Bécares[1], Beneharo Rodríguez[1], Albert Cama[1], Javier Pantoja[2], Asunción Ruiz[1]
*[1]SEO/BirdLife, [2]Ministry of Agriculture, Food and Environment (MAGRAMA)*

Marine Protected Areas (MPAs) play a key role in preserving marine biodiversity, but have been lagged behind equivalent figures on land. Moreover, they have largely overlooked wide-ranging species such as seabirds. Here we describe the process to achieve a network of MPAs for seabirds in Spain, likely the most ambitious national network of marine protected sites for these organisms, so far. The starting point was the identification of the marine Important Bird Areas (IBAs) by SEO/BirdLife (2004-2009), a pioneering initiative that produced one of the first complete inventories of marine seabird hotspots at country level (44 sites and 56,000 km2), and contributed to develop a methodology to identify similar sites elsewhere, under the umbrella of BirdLife International. The marine IBAs were then adopted by the Spanish Government as the basis to extend the Natura 2000, the network of protected areas under EU legislation, to the marine environment; specifically the Special Protection Areas (SPAs), defined as part of Natura 2000 by the EU Birds Directive. Work conducted in 2009-2014 allowed to refine the characterization of the marine IBAs, including detailed information on the use that seabirds make of these sites, their interaction with human activities, and the potential threats that they face. A round of workshops was also conducted to inform the stakeholders about the incoming designation of the Natura 2000 marine sites and discuss its implications, and meetings between the relevant administrations were also held to reach consensus. Management guidelines for each site were produced from all this work and, ultimately, most of the marine IBAs were designated as SPAs in 2014 (39 sites and 49,000 km2), increasing by 20 fold the marine area under this figure in Spain. Next step will be the consolidation of management plans, due by 2016, which requires the extension of the participative process to guarantee their acceptance by the stakeholders and the general public.

**S15.5 Developing Marine Protected Area networks for seabirds in the EU: marine Natura 2000 progress assessment & gap analysis**

Marguerite Tarzia[1], Ivan Ramirez[1], Irene Lorenzo[1], Bruna Campos[1], Ben Lascelles[1]
*[1]BirdLife International*

Globally, seabirds are the most threatened group of birds. Within the European region there are 82 seabird species; eight species are threatened, four are near-threatened and a further 18 species are showing regional or global population declines. Developing ecologically coherent networks of marine protected areas (MPAs) is a vital part of conservation efforts for top marine predators, such as seabirds. Within the European Union countries are obliged to identify and protect a network of sites (Special Protection Areas- SPAs) for seabirds through the Directive 2009/147/EC (also known as the Birds Directive). In this study, we assessed the European Union's progress towards protecting seabirds, using a spatial analysis of Member State SPA coverage against BirdLife's marine IBA network, and by calculating the proportion of marine area protected. The SPA network was then analysed for the protection offered to a set of the most threatened and declining European seabirds. The analysis combined a spatial analysis of SPA coverage for the target species with the following synthesised data: regional and site specific information on threats (based on BirdLife International threat categories); existing literature; marine IBA monitoring data; and nationally reported information on SPAs (Standard Data Forms); and individual seabird species (Article 12 reporting), to define current gaps in the SPA network for the most vulnerable seabird species. Our results also indicate that some countries have designated SPAs in terrestrial and coastal sites consistent with the marine IBA network, howver only 3% of EU waters are protected for seabirds, with an uneven distribution to specific countries and sub-regions. Our work highlights the need for a more strategic approach to seabird protection at a regional scale, and for prioritising the collection of threat information during the identification of sites and the development of management regimes.

**S15.7 Integrating IBAs into international agreements: an example of an ongoing process in West Africa and the Canary Current Large Marine Ecosystem**

Semelin Julien[1], Justine Dossa[2], Ross Wanless[2]
*[1]MAVA Foundation, [2]BirdLife International*

West Africa has several breeding endemic seabird species, and is a wintering area or passage route for huge numbers of many European and South Atlantic breeding seabirds. It is also one of the most productive marine systems on earth, and is very heavily exploited by artisanal and industrial vessels (including distant water fleets). The threats to seabirds from fishing operations are legion, and many of the species that forage in West Africa have poor conservation status. There is a clear need to understand seabird distribution patterns and to initiate spatial conservation plans. However until recently, seabirds received negligible attention in the region. In 2013, the selection and delimitation of marine Important Bird Areas (IBAs) within the West Africa subregion began through the ongoing Alcyon project. The Alcyon Project is, inter alia, leveraging existing, and generating new, tracking datasets for a dozen seabird species. However IBA delimitation is merely the first step in driving conservation actions. The final year of Alcyon will be devoted to integrating the IBAs that are identified for West Africa into several multilateral initiatives where IBAs can contribute to marine spatial planning; these include the Convention on Biological Diversity (and the EBSA process), the Convention on Migratory Species, the Abidjan Convention on Migratory Species and the Regional Network of Marine Protected Areas in West Africa (RAMPAO). Based on preliminary results coming from the West Africa sub-region, we will explore during this presentation how recommendations issued from the marine IBA process can feed international and national policy processes and then be translated in concrete conservation measures on the ground for improving the conservation status of seabirds.

**S15.8 BirdLife's work with international agreements to advance seabird conservation**

Ben Lascelles[1], Cleo Small[2], Rory Crawford[2], Marguerite Tarzia[1], Ross Wanless[3], Karen Baird[4]
*[1]BirdLife International Marine Programme, [2]RSPB, [3]BirdLife South Africa, [4]Forest and Bird*

International and regional Multilateral Environmental Agreements and industry standards and guidelines inform and shape national policy, legislation and targets for marine conservation. Ensuring the needs of seabirds are included and recognized within these is therefore of vital importance if conservation gains are to be made. Since 1997 BirdLife International has developed new science and analysis to inform decision making and promote management changes in a range of international and regional policy fora. This has proved instrumental in bringing about changes in legislation and management guidelines aimed at reducing the impact of threats and achieving better protection for seabirds. Our work has particularly focused on reducing seabird bycatch and promoting better protection of key sites used by seabirds. For fisheries bycatch, work has focused on highlighting where bycatch is having the biggest impact at meetings of Regional Fisheries Management Organisations, and once this has been recognized lobbying for mitigation techniques to be implemented within fisheries to address the problem. This has been complemented by work with FAO and national institutes to develop robust Plans of Action for tackling the bycatch problem. In areas where the problem has been recognized and steps taken to minimize impacts, bycatch rates have been dramatically reduced. For protected areas, work has focused on developing methods to define sites in need of protection that gain both scientific and political support. We have provided data to global agreements such as the Convention on Biological Diversity, as well as regional bodies such as the European Union birds Directive and the Nairobi Convention. This has led to new MPAs being designed to protect key at sea areas for seabirds. This talk with provide examples from a range of mechanisms BirdLife has engaged with, illustrating the challenges faced and progress achieved to date.

## L3 & L4 Community Based Seabird Conservation Symposium and Workshop

**L3.1 Approaches to stakeholder engagement for lasting conservation of seabird islands**

Erin Hagen[1], Karl Campbell[1], Gloria Salvador[1], Alex Wegmann[1], Brad Keitt[1]
*[1]Island Conservation*

Invasive mammals have been a driving force behind seabird extinctions historically, and continue to be a leading cause of endangerment today. Eradication of invasive mammals is an effective restoration tool on islands where seabirds nest. However, the eradication of invasive mammals from islands inhabited by people remains challenging, even where these invasive species negatively impact human livelihoods and ecosystem services. Through experiences on seabird islands in the Pacific where local communities are connected to the islands' ecosystems, we share approaches that may help to strengthen stakeholder engagement for seabird restoration projects. To achieve lasting conservation benefits for seabirds, the understanding and analysis of social dynamics among island stakeholders can help to identify elements critical to building trust and open communication. Stakeholders have concerns beyond seabird conservation, such as water and food security, that must be addressed to create effective restoration approaches. Restoration timelines should take into account iterative meetings and activities that permit collaborative planning, accountability, and increasing complexity of co-implementation of activities defined by stakeholders. We will discuss tools and lessons learned from our work on multiple islands, and share perspectives that we believe

can contribute to the development of projects that benefit simultaneously seabirds and human welfare and livelihoods.

**L3.2 East Limestone Island: 25 years in the life of a Murrelet colony; 25 years of community participation**

Keith Moore[1], Tony Gaston[1], Vivian Pattison[1]
*[1]Laskeek Bay Conservation Society*

Half of the world's Ancient Murrelets (Synthliboramphus antiquus) nest on 30 small islands in the temperate rainforests of Haida Gwaii, an isolated archipelago off Canada's west coast. Since 1990, the Laskeek Bay Conservation Society (LBCS), has been monitoring and studying these murrelets on East Limestone Island in Haida Gwaii. Our work provides the most complete body of long-term information about this nocturnal seabird and provides insight into 25 years in the life of a burrow-nesting seabird colony. We report changes in the Ancient Murrelet population over this time period due to the impacts of introduced predators, changing ocean conditions and most recently a massive blowdown affecting 44% of the colony. We continue to monitor population changes in the colony, and are involved in recruitment and restoration efforts. In addition to half a million Ancient Murrelets, Haida Gwaii is also home to 4500 human residents, more than half of whom are indigenous Haida people. For 25 years, LBCS has actively included members of all the local communities in the field work of documenting the lives of these seabirds. Our programs have relied on the contributions of over 600 volunteers from Haida Gwaii, other provinces in Canada, and 15 other countries. Our program also involves local schools and has brought 620 students to the colony. Many volunteers and students have gone on to pursue research or careers in biology. The research of LBCS provides important biological information, engages the local community, and attracts participants from across the country and around the world. The Ancient Murrelet, which feeds on the open Pacific and nests within the temperate rainforest, has become a powerful symbol of island life, a conservation icon as we confront offshore oil exploration and tanker traffic, and a notable example of the power of Citizen Science.

**L3.3 Seabird harvest in Iceland**

Aevar Petersen[1]
*[1]n/a*

Seabirds have been harvested in Iceland since settlement over 1100 years ago. First written information is in 12th century law books. Recent archaeological materials have extended knowledge of harvest to the settlement. Harvesting seabirds was a substantial livelihood of early Icelanders. This practice has persisted although now more as hobby. One exception is down-collecting from Common Eiders. Fowling is also important for maintaining long-standing traditions. Seabird use has changed through the ages, as a result of sociological changes and statutory restrictions. At present 23 seabird species breed in Iceland. Of these 19 can be harvested (eggs, young, full-grown birds, down) while one more (Great Auk) is extinct. Four of these are nowadays mainly killed as pests, although eggs are also taken. Atlantic Puffins have long been the main quarry, now only full-grown birds, formerly taking young was more important. On bird cliffs eggs are gathered from the large auks, Black-legged Kittiwake, and Fulmar. Eggs of some ground-nesting birds, gulls and Arctic Tern, are also taken. Pre legal restrictions traditions developed, by individuals and the community, positive for conservation of the birds, incl. not taking all eggs and food-bearers, not harvest certain parts of

bird cliffs. Since 1995 official hunting statistics have been compiled on birds killed, but egg collecting is exempted. These reports give a good indication of trends in seabird harvests. During past decades seabird harvesting (except Eiderdown gathering) has declined in Iceland. Reasons differ depending on species but sociological aspects, e.g. depopulation of rural areas, young people less appreciative of wild birds and eggs, and lowered economic incentives. During past 15 years many seabird species have also declined seriously in numbers, due to shortage of preferred food species, particularly Sandeels, related to climate changes. Hence motivation is less, while authorities have reinforced regulations.

**L3.4 The value of Inuit participation when conserving the common eider duck in Arctic Canada and Greenland**

Grant Gilchrist[1], Flemming Merkel[2], Christian Sonne[2], Scott Gilliland[1], Anders Mosbech[2], Samuel Iverson[1]

*[1]Government of Canada, [2]Aarhus University*

The northern common eider duck nests in the eastern Canadian Arctic and west Greenland, and migrates to winter in Atlantic Canada and southwest Greenland. The eider is harvested for its meat, feather down and eggs and its ongoing conservation is the shared responsibility of Canada, Greenland, Denmark, and northerners. This presentation will review the meaningful involvement and direct participation of Inuit during many aspects of historical and ongoing eider duck conservation efforts. These include studies that examined the sustainability of harvest, the establishment of new harvest regulations, long term monitoring of breeding colonies in remote coastal locations, reporting on emerging disease epidemics, and ongoing field studies which examine the impacts of polar bear predation under changing sea ice conditions. This presentation will review how working relationships were established between Inuit and scientists, training implemented, and how information was gathered rigorously; all efforts which have contributed to the shared priority of northern eider conservation.

**L3.5 Engaging local communities to advance seabird conservation: Lessons from a decade of community-based projects**

Peter Hodum[1], Phil Lyver[3], Valentina Colodro[4], Hannah Nevins[5], Michelle Hester[4], Chris Jones[3], Henrik Moller[6]

*[1]Oikonos / University of Puget Sound , [3]Landcare Research, [4]Oikonos Ecosystem Knowledge, [5]American Bird Conservancy / Oikonos, [6]University of Otago*

Community-based outreach and engagement programs are essential components of long-term conservation strategies in places where humans co-exist with wildlife, especially for long-lived and slowly reproducing species like seabirds. With increasing threats from anthropogenic impacts, there is a great value and willingness amongst some local communities to engage in efforts to conserve seabird populations. In this presentation, we use several of our long-term projects from the last decade in New Zealand, Chile and the USA to emphasize the paramount importance of establishing and maintaining partnerships and a trust relationship amongst the relevant constituencies and contributors, including managers, scientists, Traditional and Local Knowledge holders, conservation practitioners, and local communities. The creation of meaningful opportunities to engage actively in artistic, educational and/or technical training activities leads to ownership of the process by the community and to co-discovery and implementation of system-level solutions at the appropriate

governance and ecological scales. Clearly defined and agreed seabird conservation goals are fundamentally important, but so too is how those goals are achieved. Passionate leadership and regular presence of, and engagement by, conservation scientists and facilitators in local communities build trust and credibility but also require more time than external agencies and individual scientists may realize. Ultimately, effective community engagement requires a trans-disciplinary approach that changes conservation professionals and their science, the local environmental stewards and, ideally, the local community. Creative and genuine engagement builds local capacity and confidence in the community to act and helps change values and build commitment for long-term conservation and restoration efforts.

## S16 From Movement Ecology to Population Dynamics

### S16.1 From early life to old age; how does foraging ecology affect population dynamics of long lived seabirds??

Henri Weimerskirch[1]
*[1]CNRS*

Seabirds are known for their longevity, and during the past decades, there has been accumulating evidence from long term studies that breeding and survival change markedly over the course of an individual's lifetime. Since survival and reproduction depend entirely on the ability of animals to find resources in the marine environment, changes in the foraging pattern of animals are expected to occur through life, with consequences for the fitness of individuals. Here we examine in seabirds the change in life time foraging in seabirds, taking the wandering albatross as an example, based on the combination of long term demographic data and tracking data. During the long period of immaturity, the first months of life after independence from the parents are critical in terms of survival. At this time young naïve juvenile disperse over extensive areas, but several characteristics of their dispersal are species and population specific, probably selected for minimizing mortality. Survival during early life is highly variable through years although the sensitivity of young birds to environmental variability decrease with age. Young individuals progressively settle in zones that will be their wintering zone when adult, but start short visits to their future breeding grounds. From recruitment until old age, demographic as well as foraging parameters during the breeding season change extensively. During non-breeding season or sabbatical year migratory behavior appears to vary extensively among and between populations from sedentary behavior to the longest migratory movements known in seabirds. These variations between individuals and between populations, together with the complex changes with age in foraging ecology have important consequences in terms of life history evolution.

### S16.2 Movements and population dynamics of partial migrants

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A central aim in seabird ecology is to understand how the dynamics of mobile populations will be affected by climate change, including the effects of extreme weather events. It is now clear that partial migration, where populations comprise mixtures of resident and migrant individuals, is widespread in nature. Partial migration may cause radical differences in the environmental experiences and life-histories of resident versus migrant individuals, creating profound demographic heterogeneity that could substantially exceed that of fully resident or fully migratory populations.

Migration strategy could affect survival probability and have carry-over effects on subsequent breeding performance. In addition, dispersal and migration may covary if dispersers are more or less likely to migrate than non-dispersers. Demographic consequences of migration strategy could be particularly substantial if movements are fixed from a young age such that individuals are consistently migrant or resident throughout their lives. However, we currently lack the empirical data to understand the links between migration and population dynamics of partially-migratory species, including responses to extreme weather. This talk will present results from a study of a partially migratory meta-population of European shags Phalacrocorax aristotelis in north-eastern UK that has recently experienced extreme weather events. Since 2009, >12,000 chicks and adults have been colour-ringed at 6 breeding colonies across the meta-population range. Shags have wettable plumage and therefore return to land daily, providing an invaluable opportunity to resight colour-ringed individuals throughout the year. Intensive programmes of field resightings have been undertaken over the last six years, resulting in >30,000 live sightings of >6,000 individuals of all ages and from all breeding colonies. In addition, breeding success of colour-ringed individuals has been recorded. We used this data to quantify the extent to which migration strategy differs among ages, sexes and subpopulations. We also tested whether survival, breeding success and dispersal differed with migration strategy, and whether these relationships varied in the face of extreme weather. This study demonstrates the profound consequences of migration strategy on the population dynamics of a partial migrant in a changing climate.

**S16.3 Tracking Early Life History Demographics And The Ontogeny Of Habitat Use Through Movement Studies of Short-Tailed Albatrosses**

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High resolution, long-term tracking data of long-lived, pelagic animals can be used to quantify early life stage demographics and the development of movement patterns that cannot be obtained from land-based studies alone. We attached 22 g solar Argos GPS satellite transmitters to 62 Short-tailed Albatross chicks (Phoebastria albatrus) prior to fledging from two breeding colonies in Japan over a 5 yr period (10-14 birds yr-1). After leaving the colony, fledglings typically "drifted" (< 5 km/hr over 2-4 hr period) at sea for 9 days on average (range = 2 - 21 days) with only short flights before obtaining sustained flight (ground speeds of > 20 km hr-1 over a 2-4 hr period). Post-fledging survivorship to sustained flight was not significantly different between breeding colonies, however post-fledging mortality prior to sustained flight was strongly female biased and averaged 15% (85% survival for females and 100% for males). The number of days post-fledging to sustained flight increased with physiological indicators of muscle damage (aspartate aminotransferase and creatine kinase) and wing loading, but did not vary by sex. Distribution at sea during the first few years, however, did vary by sex and age. Males traveled more extensively over continental shelf areas, while females stayed more locally in some areas. During the first flight year, birds spent more time over the continental shelf and oceanic regions, which changed markedly in the 2nd flight year, and by the 3rd year, birds occurred most frequently over shelf break and slope regions, with habitat use more similar to adult birds. Our results provide insight into post-fledging mortality and shifts in spatial distribution of short-tailed albatrosses during early life stages with implications for both long-term population demographics and conservation management of late-maturing, long-lived species.

**S16.4 Individual foraging specialisation varies with age in a marine predator**

Stephen Votier[1]
[1]*University of Exeter*

Behaviourally mediated individual foraging specialisations are widespread among natural populations and are particularly prevalent for long-lived iteroparous vertebrates. Nevertheless, the ontogeny of such consistent individual behaviours and how they vary with age is not known. Here we use GPS tracking to compare individual foraging strategies between breeding and immature gannets Morus bassanus - a far-ranging marine predator. Our results show that breeders have highly consistent inter-individual differences in foraging locations and routes, indicating individual specialisation. In contrast, immatures have highly variable foraging locations and low route fidelity, indicating that individual specialisations were absent. Our findings suggest that consistent individual foraging behaviours are learned in long-lived species like seabirds. Moreover we suggest that the development of such behaviours play an important, but previously overlooked role in shaping important life histories tactics such as age of first breeding.

**S16.5 Effects of dispersal strategies on population dynamics: the crucial role of prospecting movements**

Aurore Ponchon[1], Romain Garnier[2], David Grémillet[3], Thierry Boulinier[3]
[1]*ISPA,* [2]*Princeton University,* [3]*Centre d'Ecologie Fonctionelle et Evolutive*

Dispersal consists for an individual to move from a natal or previous breeding area to a new one. As it can have multiple consequences both on individual fitness and population dynamics, it constitutes an essential process in ecology and evolution. Over the last decade, many seabird species have been documented as prospecting, i.e. gathering personal and social information on the local environmental quality of other breeding areas before making dispersal and settlement decisions. However, the demographic consequences of such individual movements have never been quantified, because they imply different spatial and temporal scales. Using a metapopulation dynamics model based on the life cycle of the black-legged kittiwake Rissa tridactyla, a species known for prospecting, we compared the effects of four dispersal strategies on population dynamics, structure and persistence in various environment scenarios. In a heterogeneous and variable environment, informed dispersal, the strategy based on the use of information gathered during prospecting, maintained populations at higher levels than random dispersal or strict philopatry and prevented population extinction on the long-term. Contrasted dynamics also arose: philopatry led to ecological traps, random dispersal led to source-sink dynamics and informed dispersal drove extinction-recolonization processes. Overall, this study highlights the need for the development of more integrative studies to better incorporate the links between individual behaviour and population dynamics. Combining individual-based data with long-term demographic surveys may be a key approach to infer whether and how informed dispersal may contribute to the observed spatial and temporal dynamics of populations. Ultimately, it may help better predict seabird population responses to environmental change.

**S16.6 How coloniality-driven Allee effects constrain penguin metapopulation dynamics**

Heather Lynch[1], Philip McDowall[1]
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The metapopulation dynamics of obligately colonial breeders must account for potential Allee effects deriving from their coloniality. Gentoo (Pygoscelis papua), chinstrap (P. antarctica), and Adélie (P. adeliae) penguins breed sympatrically along the western Antarctic Peninsula and are broadly similar across a suite of life history traits, but differ in their ability to colonize new territories. This difference in colonization ability likely stems from species-specific differences in their needs for colonial breeding, and has significant consequences for their ability to shift their breeding ranges under climate change. We use a metapopulation dynamics model to explore the role that coloniality-driven Allee effects may play in constraining Pygoscelis spp. penguin colonization of available habitat patches, and how this can create artificial gaps or range boundaries that are not a direct reflection of underlying habitat suitability. Coloniality is an extremely common trait among seabirds; understanding its role in shaping patch persistence, and linking that to occupancy at the metapopulation scale, is critical for predicting seabird population responses to climate change.

## S17 Establishing New Seabird Colonies

### S17.1 Seabird attraction and chick translocations in New Zealand: insights from 30 years across multiple species projects

Graeme Taylor[1], Helen Gummer[2], Colin Miskelly[3], Mike Bell[4], Steve Sawyer[5]
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Seabird chick translocations started in New Zealand in the mid-1980s and have accelerated as a tool for species conservation and site restoration over the past decade. This talk will briefly summarise the extent of New Zealand seabird translocation projects (types of species and the range of sites targeted), how the focus of these projects has changed over time, and which techniques have proven successful (chick transfers, passive sound attraction). A number of guiding documents have been developed to pass on knowledge about how to plan and implement these projects. These documents also list the known risks or problems with these different techniques. Of the 22 Procellariiforme seabird chick translocations attempted to date, chicks have so far returned to breed from 13 (59%) of these projects. Whether or not viable long-term colonies will form is still uncertain but second generation birds have started breeding at three sites so far. Passive sound attraction (no chick transfers) has been successful in attracting six species of seabirds to eight sites leading to nine new breeding colonies. Projects based on sound only are more cost effective but successful establishment depends on prospecting birds of the targeted species being lured to the vicinity of the sound system. Key issues that need consideration include: impacts on source colonies from multiple projects, long-term security and appropriate size of the new seabird site, quality of artificial nests, managing heat stress and diet quality/hygiene during chick translocations, selecting high quality chicks that fledge over a short time period and good outcome monitoring. A second series of chick translocations are now being attempted for some sites to bolster small populations.

### S17.2 Establishing and re-establishing seabird colonies in the twenty-first century.

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*[1]Office of Environment & Heritage, [2]Museum of New Zealand Te Papa Tongarewa, [3]Ecoworks NZ Ltd*

In the last decades, the pressures on seabird species have continued to increase, sometimes requiring active programs to provide new breeding locations for the seabirds that will safe-guard their existence, at least through this century. Through both translocation and/or attraction

techniques, species are being relocated to higher ground against sea-level rise, adjacent to more productive waters for better breeding success, into traditional areas to restore ecological function or simply as a way to avoid introduced predators that make their on-going survival in current locations difficult, if not untenable. Practicalities aside, there are a range of additional factors that may influence the decision to perform translocations. These can include the restoration of a 'natural balance' as required by traditional custodians at translocation sites, the need for offsets from potential damage to seabird populations elsewhere from industrial or domestic constructions or the desire of local communities to engage in recovery of regional seabird colonies. This paper explores the short and long-term commitments to establishing new seabird colonies, the myriad of techniques that have been developed to ensure their success and the questions that still needing to be answered to facilitate a sound management basis for seabird restorations.

**S17.3 When to establish a new seabird colony? A Case study of the African Penguin**

Christina Hagen[1], Ross Wanless[1]
*[1]BirdLife South Africa*

Establishing or re-establishing seabird colonies can be a useful conservation tool and has been attempted for various species (mostly Procellariiforms) with varying degrees of success. Reasons for establishing colonies vary. Before establishing a new colony, justification must be provided due to the huge investment of resources (funding, time, and personnel) needed and consideration must be taken of the effects on the source population (either captive or wild) if birds will be translocated. We present the African Penguin Sphensicus demersus as a case study of translocation as a conservation tool. Despite enormous, costly interventions for all known threats, the African Penguin population continues to decrease rapidly. A major recent driver is poor food availability, from shifting forage fish distributions and fishery competition; both may prove impossible to address directly (particularly if climate change is a root cause). The South African population is split into two main centres separated by 600 km; a new colony mid-way between these centres will: - Increase resilience to catastrophic events (e.g. oil spills, disease outbreaks) - Enhance connectivity - Increase the overall population size - Reduce the relative effects of large-scale, multi-year environmental forcing events (e.g. the loss of fish on the west coast) on the entire population Work on Little Penguins in Australia, suggests that the size of the source population must be large enough to provide enough founders for the new colony. As the wild population becomes smaller, the risks in attempting to create a new colony which ultimately fails becomes greater and legal and institutional resistance to interventions for endangered species increases. Problems associated with small populations (e.g. demographic skews, Allee effects) come into effect as individual colonies become smaller.

**S17.4 Ten years without cats: seabird nesting on Ascension Island a decade after the eradication of a mammalian predator**

Eliza Leat[1], Nicola Weber[1], Steffen Oppel[2], Mark Bolton[2], Tara Pelembe[3], Jolene Sim[1], Sam Weber[1]
*[1]Ascension Island Government, [2]Royal Society for the Protection of Birds (RSPB), [3]Joint Nature Conservation Committee*

Ascension Island is a volcanic island in the tropical South Atlantic that supports regionally and globally important populations of 11 seabird species. Prior to human settlement in 1815, the island was likely home to millions of nesting seabirds; however the introduction of cats shortly after human

colonisation resulted in rapid population collapses and the complete displacement of all but one ground-nesting species from the mainland. Seabird nesting on Ascension largely became confined to inaccessible cliff ledges, 14 small offshore stacks and a large islet. In 2001 a programme was initiated to eradicate feral cats and by 2006 the island had been declared cat-free. Seabird re-colonisation of the mainland began almost immediately. The first masked booby nests were recorded in 2002, and subsequent monitoring has documented the rapid growth of their colonies from 2 pairs to more than 1400 pairs in 2015. By 2011, 8 out of the 11 seabird species were breeding on the mainland, but with one notable absence. Despite efforts to attract them back to their former nesting sites, the endemic Ascension frigatebird remained confined to a single, offshore islet. However, in December 2012 two frigatebird nests were located in a remote corner of the Island and each year since has seen a rapid increase in their numbers, from 12 pairs in 2013/2014 to 44 pairs in 2014/2015. Almost a decade after the eradication of feral cats we appear to be on course to restoring one of the tropical Atlantic's great seabird nesting stations, demonstrating that even severe losses can be reversed through effective conservation action. The closely-monitored return of nesting to the mainland has also provided valuable insights into habitat preferences and the mechanisms of colony formation. Yet challenges remain. In particular, the careful management of invasive plants and rodents, increasing following cat eradication, is needed to ensure that legacy of this landmark conservation effort is maintained.

**S17.5 A Comparison of Diets Used During a Colony Translocation of New Zealand Grey-faced Petrel Chicks, Pterodroma macroptera gouldi**

Micah Jensen[1], Brett Gartrell[1], Nick Cave [2], Kerri Morgan[1]
*[1]Wildbase, Massey University, New Zealand, [2]Massey University, New Zealand*

The translocation of burrow nesting petrel colonies is a valuable conservation tool used to conserve rare Procellariiforme seabirds and restore habitats. Seafood based diets selected to feed translocated petrel chicks are heavily influenced by the practical limitations of storage, cost and availability in remote locations. The same diets are often fed across species, irrespective of their different foraging strategies and diverse prey items. In New Zealand a tinned sardine in soya oil based diet has been used to feed over 13 different species of petrel, including the critically endangered Taiko Pterodroma magenta. Feeding this sardine based diet for longer periods has resulted in deaths related to nutritional disease. This raises the concern that birds may be fledging with malnutrition which could impact their survival at sea. This study assess the effects of feeding different artificial diets to petrel chicks by running a dietary trial during a colony translocation of 76 grey-faced petrel chicks, Pterodroma macroptera gouldi from Motuhora Island (37o 52' S, 176o 58' E) to Cape Kidnappers (39o 40' S, 177o 06' E). The chicks were fed either tinned sardines in soya oil, or a powdered Mazuri fish analog© seabird diet, supplemented with fish oil. The results of a dietary trial will be presented; comparing the effects of the diet on growth parameters, fledging rates, and the disease incidence during the translocation. To compare the nutrient content of artificial diets with the wild diet, proventricular samples of freshly fed wild chicks were collected from a control colony of grey-faced petrels in West Auckland (36o 54' S, 174o 27' E0). Blood samples from wild and translocated chicks were also taken to measure erythrocyte phospholipid ratios, illustrating the change in fatty acid deposition that occurs while being fed different oil based diets, over a 3 week period. The results of this study will aid in the diet choices for future seabird translocations.

**S17.6 Seabird sensory-based conservation: in depth investigation of petrel vocalizations for attraction to nest sites**

Megan Friesen[1], Jacqueline Beggs[1], Anne Gaskett[1]
*[1]University of Auckland*

The unique senses of seabirds make them prime candidates for sensory-based conservation efforts. Synthesis of recent seabird management approaches reveals that 'sensory-based conservation' is a developing new field, current efforts primarily aim to attract birds to restored nesting habitat and deter from threats at sea. Results from our review of sensory-based conservation techniques in seabirds indicate that most studies have targeted Charadriiformes (10 species studied), or Procellariiformes (12 species studied). One of the most widely targeted senses for seabird conservation is the auditory sense, with 17 out of 34 published attempts relying on either auditory stimuli alone or auditory stimuli accompanied by other sensory modes (12 studies targeted visual cues alone, and 4 were aimed solely at olfactory cues). Our own experiments indicate that auditory attraction can be optimized by incorporating call behavioural context or synthetic calls. We found that grey-faced petrels (Pterodroma macroptera gouldi), a large subspecies of petrel endemic mainly to New Zealand's North Island, were strongly attracted to conspecific attraction calls, as well as recorded human calls ('war-whoops'), but were less attracted to conspecific aggression calls. Because the human auditory stimulus was also highly effective at attracting seabirds, our results indicate what vocal qualities are important for auditory communication in pterodroma petrels.

## S18 Impacts of Oil Spills

**S18.1 Challenges to assessing oil spill impacts to seabirds in the deep ocean**

J Christopher Haney[1], Rohan Clarke[2], David Evers[3], Britta Hardesty[4], Patrick Jodice[5], William Montevecchi[6]
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Hydrocarbon exposure in the deep ocean sets substantial challenges for evaluating impacts on seabirds at individual, population, and species levels. Difficulties include regulatory regimes conflicted by competing interests, lack of transparency, and limitations imposed by highly dispersed sampling at remote locations, including the fact that significant proportions of seabirds at offshore spills can be long-distance migrants rather than local breeders. Small (Terra Nova) to very large (Montara, Deepwater Horizon) deep ocean spills have occurred so far from land that conventional shoreline assessments for bird mortality and morbidity prove ineffective. Baseline requirements for assessing impacts over the deep ocean include pre-emptive knowledge of species' presence, density estimates, and behavioral attributes that influence exposure probability at or just above the sea surface. By combining models of habitat suitability with such density estimates at regional scales, preparedness for spill events can be enhanced. Satellite imagery of slick area, or numerical calculators that relate known spill volume to slick size based on oil type, viscosity, temperature, and dissipation rate, can help delineate spatial extents of deep ocean spills for use in exposure probability models that estimate mortality. Demographic models for determining bird-years lost from these spills are also necessary under some jurisdictions so as to calculate restoration costs. To measure hydrocarbon exposure in individual seabirds for up-scaling to the population level, minimally invasive tools for hydrocarbon detection are needed, similar to a simple swabbing

technique in which preening oil permits the detection of environmental exposure to common ocean plasticizers in seabirds.

**S18.2 Sex, death, and oil: Conservation implications of individual and geographic variation in Brown Pelican movement patterns**

Juliet Lamb[1], Patrick Jodice[2]
*[1]Clemson University, [2]South Carolina Cooperative Fish and Wildlife Research Unit*

Although Brown Pelicans (Pelecanus occidentalis) are ubiquitous along developed coastlines throughout much of the United States and Central America, very little information exists on their movements and habitat use outside breeding colonies. At the same time, interest in offshore oil development and wind energy is growing throughout the species' range. Variation in foraging and migratory patterns could expose different subsets of the population to differing risk factors and play a substantial role in population dynamics of the species; however, accounting for such variation requires a fuller understanding of individual movements. To address this information gap, we used GPS loggers to track 85 Brown Pelicans breeding across the northern Gulf of Mexico during a two-year period. For all individuals for which we obtained at least one complete annual cycle (n=67), we modeled breeding and nonbreeding movement patterns, migratory strategy, and environmental characteristics of habitat as a function of both individual characteristics and breeding colony locations. We then calculated individual exposure risk as a function of likely proximity to petroleum infrastructure year-round. We found that extensive postbreeding movements and use of offshore habitat resulted in significant increases in exposure risk outside the breeding area. In general, Western and Central Gulf breeders moved the greatest distances, and Central Gulf breeders used offshore habitats more than breeders in other regions throughout the annual cycle. Females undertook longer post-breeding movements and used offshore habitats more than males during the nonbreeding season, increasing their exposure risk relative to males across all regions. We are currently conducting contaminants analysis to test whether individual PAH levels follow the patterns of exposure predicted by spatial risk models.

**S18.3 Post-release survival and productivity of oiled little blue penguins rehabilitated after the C/V Rena oil spill**

Karin Sievwright[1], Phil Battley[1], Kerri Morgan[1], Helen McConnell[2]
*[1]Massey University, [2]Resource and Environmental Management Limited*

There is contentious debate regarding the conservation value of rehabilitating oiled wildlife. One way to evaluate the effectiveness of such rehabilitation is to conduct post-release monitoring of oil-rehabilitated animals to determine whether these animals survive the transition to the wild and thereafter have survival and reproductive rates equivalent to control animals. We monitored the survival and productivity of little blue penguins (Eudyptula minor) oiled and subsequently rehabilitated after the 2011 C/V Rena oil spill in Tauranga, New Zealand. Post-release survival of oil-rehabilitated penguins (that were micro-chipped pre-release) was similar to the survival of control birds (that were not oiled but were micro-chipped during the oil spill response). There was however a reproductive impact. Hatching success (proportion of chicks hatched from eggs laid) in the year after the spill was significantly reduced in breeding pairs containing at least one rehabilitated adult (rehabilitated pairs) compared to pairs containing no rehabilitated adults. Fledging success (proportion of chicks fledged from chicks hatched) and overall egg success (proportion of chicks

fledged from eggs laid) were also reduced but not significantly so. Despite these reductions, hatching, fledging and egg success rates for rehabilitated pairs were higher or within ranges reported for other little blue penguin colonies in Australia and New Zealand. These results suggest that the oil-rehabilitation process was reasonably effective at treating and counteracting most negative effects of oil contamination on the post-release survival and productivity of rehabilitated little blue penguins. These findings support the continued conductance of oiled wildlife rehabilitation in New Zealand and highlight the importance of undertaking post-release monitoring of rehabilitated animals so that the efficacy of the rehabilitation process can continually be assessed and improved over time to maximise success.

**S18.4 Long-term survival and breeding success of de-oiled African penguins and Cape gannets**

Peter Barham[1], Richard Sherley[2], Res Altweg[3], Barbara Barham[1], Robert Crawford[4], Nola Parsons[5], Les Underhill[3], Philip Whittington[6], Anton Wolfaardt[7]
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Since 1968, over 50,000 seabirds have been de-oiled in South Africa. The majority were Cape gannets Morus capensis and African penguins Spheniscus demersus oiled in three catastrophic spills: in 1983, 5,000 gannets were affected; in 1994 and 2000, 10,000 and 19,000 penguins were oiled, respectively. Large percentages (91% 2000) were de-oiled, banded, released and monitored for survival and breeding success. Survival rates of de-oiled gannets were ca. 2% lower than unoiled gannets, a difference similar to that between colonies. Oiling did not affect their probability of breeding. Survival rates of de-oiled and unoiled penguins were similar in non-breeding individuals for at least 10 years after oiling. De-oiled penguins from both spills that attempted breeding suffered costs associated with reproduction. After 1994, the incidence of breeding abstinence was elevated in de-oiled penguins; intermittent breeders suffered higher mortality. An estimated 27% of de-oiled penguins did not breed after 1994. After 2000 those that bred had survival rates 7 to 17% lower than unoiled birds in two years following the spill. Clutch sizes and hatching success were unaffected, but over 11 years the birds de-oiled in 2000 fledged 6% fewer chicks per pair than unoiled birds. After both spills fledging rates, fledging periods and chick growth rates were negatively impacted when prey availability was low. Despite a persisting detrimental effect of oiling on their ability to rear chicks, modelling results suggest that the rehabilitation of oiled penguins has made a substantial contribution to conservation efforts and reduced the impact of oiling.

**S18.5 An Assessment of Oiled Seabird Rehabilitation Success: A Review of California Spills, 1996-2011**

Kyra Mills-Parker[1], Christine Fiorello[1], Michael Ziccardi[1]
*[1]Oiled Wildlife Care Network, University of California, Davis*

Oil spills, both chronic and catastrophic, are a major threat to seabirds worldwide. Where programs and facilities exist, seabirds are frequently captured, cleaned, rehabilitated, and released. This activity, while often strongly championed by the general public, has long been debated within the wildlife profession itself as to its utility and overall worth. Benchmarks for successful rehabilitation

include survival to release, survival post-release, and successful breeding. Improvement of oiled seabird rehabilitation techniques requires regular evaluation of current protocols in reference to seabird survival through release, and the adaptive inclusion of new and improved techniques into current protocols is essential for continual advancement of oiled seabird rehabilitation. Herein we present information on the first benchmark: survival from capture to release. We compiled data from oil spills that have impacted seabirds in California, 1996-2011, and examined key factors related to survival to release: species, delay to capture, time to wash, time in pools, overall time in care, and several biomedical parameters. The purpose of this presentation is to review these advances in rehabilitation and diagnostic techniques of oiled birds in relation to predictors of survival during rehabilitation.

**S18.6 Stress in seabirds while in oil spill rehabilitation - How do we recognise and mitigate the effects?**

Bridey White[1]
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Stress is caused by an environmental condition that is adverse to the well-being of an animal. A stress response is a normal reaction that animals have in relation to changes in their environment. It is acknowledged that the stress response is an important and necessary part of an animal's life as it stimulates alertness to dangers and an ability to respond to threats. The physiological response is the same regardless whether the threat is real or perceived. With this in mind, the difficulty for wildlife care in an oil spill facility is that in helping wildlife, animals may perceive danger which could result in a detrimental effect. Stress response manifests in two main ways: 1) Behavioural responses - these are those that can be seen and measured by those that have experience with that species; 2)Physiological responses - these are a cascade of hormones that influence the mechanisms of homeostasis. Animals have various coping mechanisms including acclimatisation, acclimation and habituation, and some of these can work in your favour in a facility. It is important that we recognise that during an oil spill, animals housed in a facility will be experiencing various levels of stress just from being in captivity. Birds can have a unique response, displaying a preservation reflex, in that, outwardly they look normal, while internally they are not. Mitigating and reducing the effects of stress while birds are in care is paramount for the successful outcomes for these patients. Fortunately there are low tech but important ways to manage this, however sometimes this can be a labour intensive job. Those that work in the husbandry areas should be cognisant that they cannot fully eliminate stress on the animals but can be responsible for managing it thereby reducing some of the impacts.

**S18.7 Oiled Wildlife Response: A review of advances and continuing challenges**

Curt Clumpner[1]
*[1]International Bird Rescue Research Center*

It has long been recognized that oil spills impact wildlife and the efforts to mitigate that impact go back to early in the last century. However in the past 20 years, the efforts to evaluate and improve the systems and science-based techniques used in have increased greatly around the world. International Conventions, national legislation and both national and regional regulations as well as public perceptions have led to increased expectations and focus on preparedness to both prevent and respond to oiled wildlife incidents. The documentation of wildlife impacts of other chemical

releases into waterways the resulting response to some these incidents have led increased awareness and preparedness. Increasingly effective communication and cooperation in both response and research among formal and informal networks of oiled wildlife response organizations has increased knowledge, efficiency, capacity and professionalism in the this still developing field. This presentation will review the advances in oiled wildlife response over the 26 years post Exxon Valdez as well as discuss some the still remaining challenges to effective mitigation the effects of spills on birds and other wildlife.

**S18.8 Magnetic cleansing of oiled wildlife: three year implementation plan**

Peter Dann[1], Stephen Bigger[2], John Orbell[2]
*[1]Phillip Island Nature Parks, [2]Victoria University*

Researchers at Victoria University and the Phillip Island Nature Parks, Australia, have been working on advancing the rehabilitation of oiled wildlife using oil-sequestering magnetic particles for the removal of contaminants from plumage and fur. This treatment has some advantages over conventional detergent-based methods, including not requiring water, requiring significantly less recovery time post-treatment, being useful on site, due to its portability and being faster and cheaper. We know it removes oil from feathers, mammalian fur and rock and are confident that it will work on turtles and reptiles - but we need to evaluate the method on oiled wildlife under field conditions. Over the next three years we hope to achieve this in a three stage process: optimisation of the technology for use in the field, develop partnerships with key stakeholders and evaluate the technology using oiled wildlife - when the opportunity arises. It is our intention to develop several elements of this technology further in including the use of heated particles/pre-conditioning agents, the optimization of the magnetic field strength, the evaluation of new particle types and the further development of pre-conditioners. Concurrently, we hope to develop a global network of partners that we can work with to test the efficacy of this technology for cleansing oiled wildlife. Thermography has been shown to have a potential role in the testing of cleansing techniques and the post-cleaning recovery of normal thermoregulation and will be used here. Protocols have been also developed that take into account health and safety aspects for both the practitioner and the wildlife. Testing has been carried out on the short-term navigation and breeding productivity of breeding Little Penguins, Eudyptula minor, exposed to levels of magnetism that are equivalent to those for a moderate cleansing process. A particularly useful potential application is the provision of a quick clean upon first encounter.

## PS20 Demography 2 – Extreme Events and Population Services

**PS20.1 Sooty tern migrations and the hurricanes they encounter**

Ryan Huang[1], Stuart Pimm[1], Oron Bass Jr.[2]
*[1]Duke University, [2]US National Park Service*

Determining sources of mortality and locations of migratory and feeding routes is difficult for seabirds due to their expansive ranges over oceans. Here, we will present data on the sooty tern (Onychoprion fuscatus), a common seabird that breeds at the Dry Tortugas National Park, USA. We use data from a mixture of data from satellite transmitters that follow their migrations and a capture-recapture data set that span 50 years with over 300,000 individuals. We locate potential sources of mortality by mapping the terns' migratory route and developing a model of survivorship. Results show that individuals currently nest in the park from January to June and spend the rest of

the year over open water traveling south off the continental shelf of South America to offshore of the mouth of the Amazon before returning north in mid-December. This path leaves individuals susceptible to hurricanes, a trend supported by historical data. Hurricanes that are both early and high intensity cause spikes in sooty tern mortality. These data are important for determining the impact that future disturbances, such as increased hurricane frequency from climate change, may have on seabird populations.

**PS20.2 Contrasting effects of tropical cyclones on the annual survival of a pelagic seabird in the Indian Ocean**

Malcolm Nicoll[1], Marie Nevoux[2], Carl Jones[3], Norman Ratcliffe[4], Vikash Tatayah[5], Ken Norris[1]
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Tropical cyclones are an important feature of marine and coastal tropical ecosystems and known for their destructive nature. Over the last 40 years their intensity, frequency and tracks have changed and future predictions indicate that these trends are likely to continue with potential consequences for human populations and biodiversity. However, our understanding of how tropical cyclones currently affect marine biodiversity, and pelagic species in particular, is limited. For seabirds the impacts of cyclones are known to be detrimental at breeding colonies, but impacts on the annual survival of pelagic adults and juveniles remain largely unexplored and no study has simultaneously explored the direct impacts of cyclones on different life history stages during the seasonal life cycle. We combined a 20 year data set on tropical cyclones in the Indian Ocean with tracking data from 120 Round Island petrels and long-term capture-mark-recapture data to explore the impacts of tropical cyclones on the survival of adult and juvenile (first year) petrels during both the breeding and migration seasons. The tracking data showed that juvenile and adult Round Island petrels frequented the three cyclone regions of the Indian Ocean (southern hemisphere, Arabian Sea and Bay of Bengal) and were therefore potentially exposed to cyclones for a substantial part of their annual cycle. However, only juvenile petrel survival was affected by cyclone activity; negatively by strong cyclones in the vicinity of the breeding colony and positively by increasing cyclone activity in the northern Indian Ocean where they spend the majority of their first year at sea. We suggest that these positive benefits of cyclones may arise through improved foraging opportunities. These contrasting effects raise the intriguing prospect that projected changes in cyclone metrics, under current climate change scenarios, may have positive as well as the more commonly perceived negative impacts on seabird demography.

**PS20.3 A Wreck Is A Wreck Is A Wreck? Elucidating the Pattern of Massive Mortality Events**

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Seabird wrecks, or massive fallouts of beach-cast carcasses, have been reported worldwide and are commonly attributed to severe weather, pollution events, fisheries bycatch, or spatio-temporal shortages in prey base, although the ultimate causes of most events remain unknown. More common in the winter, wrecks suggest both individual and ecosystem stress, and are typified by starvation as the proximate cause of death. As the incidence of massive mortality events appears to be on the rise, examination of the regional to local scale pattern(s) of wrecks may help to elucidate

causality, as well as allow for predictive modeling of when, where, and in what taxonomic space wrecks are most likely to occur. In winter of 2014, the Pacific Northwest experienced a significant wreck of Cassin's Auklets (Ptychoramphus aleuticus) stretching from northern California north to Haida Gwaii. Within the Coastal Observation and Seabird Survey Team (COASST) program, more than 3,500 carcasses were documented between September and January, with beach-specific encounter rates up to three orders of magnitude higher than long-term regional averages. COASST used this event, together with previous significant wrecks in the Pacific Northwest, to model the characteristics of wrecks, including aspects of the intensity, duration, and timing of encounter rate anomalies; carcass location on the beach; species diversity and demographics; and measures of carcass freshness, including intactness, foot pliability, and eye state.

**PS20.4 Spatial mismatch between winter mortality events and subsequent breeding population declines in the partially migratory European shag Phalacrocorax aristotelis.**

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Quantifying the effects of extreme weather is a key question in seabird ecology since models predict increased climate variability in many regions. Extreme weather events are particularly important outside the breeding season since this is typically when most adult mortality occurs, and the population dynamics of seabirds are generally most sensitive to changes in adult survival. At the meta-population scale, weather-induced mortality in one location may cause downstream impacts elsewhere, especially in partially migratory species. Such effects could substantially reshape meta-population range and structure. One species that is vulnerable to extreme weather is the European shag Phalacrocorax aristotelis. The UK east coast meta-population experiences periodic winter wrecks and is partially migratory. It is therefore a useful system to quantify spatial links between weather-induced winter mortality and subsequent changes in breeding population size. We focus on two winter wrecks in 2012/13 and 2013/14. In total, 716 corpses were found in the first winter and 255 in the second. Juveniles were more likely to be found earlier each winter, suggesting a greater susceptibility to extreme weather. Males were more likely to die earlier each winter than females, although there was no overall difference in numbers found dead in the two sexes. Crucially, we found a spatial mismatch between locations of mortality and subsequent breeding population declines. The majority of corpses were found in the central part of the range in 2012/13, while population declines were only recorded in southern colonies in 2013. In contrast, corpses were concentrated in northern locations in 2013/14, with declines only apparent in the central part of the range in 2014. These spatial mismatches between locations of mortality and breeding population declines demonstrate that extreme weather may have complex downstream consequences on meta-population structure and range in partial migrants.

**PS20.5 Large-scale oceanographic fluctuations and local weather conditions drive Antarctic petrel demography and breeding phenology**

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Polar regions are experiencing environmental changes at unprecedented rates with cascading effects on top predators such as seabirds. Fluctuations in factors that directly affect seabird populations are difficult to measure in situ as seabirds generally use very large areas. However, those conditions can often be well approximated by variations in global climatic indices. Using a long-term dataset on survival and reproduction of Antarctic petrel Thalassoica antarctica from the largest known breeding colony (Svarthamaren, Dronning Maud Land), we showed that most of the variation in reproductive success and survival of Antarctic petrels can be accurately modeled using the two modes of large-scale climate variability in Antarctica, the Antarctic Oscillation and El Niño Southern Oscillation. Moreover, local conditions at the colony, and more specifically weather extremes in the form of snow storms also play a significant role in driving Antarctic petrel reproductive success. This stresses out the importance of considering changes in environmental conditions at both the breeding site and the foraging areas to understand the dynamics of free-living seabird populations.

**PS20.6 Sympatric kittiwake species exhbit similar demography despite disparate foraging ecology and winter range**

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Demographic data for colonial seabirds are typically collected on the breeding grounds, where most species are central place foragers and easy to study in a single location. However, seabirds spend non-breeding seasons (⅔ to ¾ of their life history) at sea in locations that may be distant from their breeding colonies. Many analyses of environmental drivers of demography have necessarily focused on oceanographic conditions during the breeding season because spatial overlap of seabirds with oceanographic and other habitat parameters during the non-breeding season has not been possible without identification of seabird movements away from the breeding colony. The red-legged kittiwake (Rissa brevirostris) and black-legged kittiwake (R. tridactyla) are sympatric species breeding on the Pribilof Islands, SE Bering Sea, where they have been studied for nearly four decades. On the breeding grounds, the two species nest together but forage differently, with red-legged kittiwakes relying heavily on lanternfish (Myctophidae)from the Bering Sea shelf break, while black-legged kittiwake prey on a more diverse suite of species from the shelf itself, including a larger percentage of invertebrates. The wintering ecology of both species has remained largely unknown until a recent geolocator study provided the first information on non-breeding distribution. Red-legged kittiwakes remained largely in the Bering Sea, whereas black-legged kittiwakes migrated to the subarctic North Pacific south of the Aleutian Islands. Despite these differences, we found strong positive correlations between species for multiple demographic parameters (population trend, reproductive success, timing of breeding and annual survival). We evaluate relationships among overwinter survival and potential climatic drivers in both the breeding and non-breeding foraging ranges.

**PS20.8 Connectivity of managed and un-managed Caspian Tern breeding colonies in the Pacific Coast Region of North America**

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Management of Caspian Terns (Hydroprogne caspia) has been implemented at several breeding colonies in the Pacific Coast Region of North America to reduce the impact of tern predation on survival of juvenile salmonids (Oncorhynchus spp.) listed under the U.S. Endangered Species Act. Management is designed to disperse terns to sites where impacts on fish stocks of conservation concern would be minimal. Using multi-state models, we evaluated inter-colony movements of Caspian Terns based on 10 years (2005-2014) of band-resighting at four colonies; (1) a very large colony where tern nesting habitat has been reduced since 2008, (2) a colony where tern nesting habitat was reduced in 2014, (3) colonies on artificial islands built as compensation for management elsewhere, and (4) a colony not subjected to management. Terns from the very large managed colony quickly responded to construction of alternative nesting islands as distant as 550km, with movement rates up to 6%, while movement rates to other colonies were low (<1%) in most years. Movement rate from the colony where management was implemented in 2014 to an un-managed colony just 100km away was 18%, similar to the rate when the managed colony failed due to avian and mammalian predation several years prior to management. When colonies at alternative islands experienced severe drought, however, movement rates away from the islands increased to 22%, resulting in net movement from those islands to managed and un-managed colonies. Our study revealed a high degree of connectivity among managed and un-managed Caspian Tern colonies, with movement rates influenced by highly variable nesting conditions and habitat. Even greater movements among breeding colonies and emigration to sites outside the study area are expected in future years due to the high vagility of the species and further reductions in tern nesting habitat planned for the region.

## PS21 Island Restoration

### PS21.1 Globally Threatened Seabirds and Island Conservation Opportunities

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While seabirds play important functional roles in marine and terrestrial ecosystems, 29% of species are at risk of extinction. Significant threats to seabirds occur on islands where they breed, but in many cases, effective island conservation can mitigate these threats. To guide island-based seabird conservation actions, we identified, for the first time, all past and current breeding islands for the 98 threatened seabird species as recognized on the International Union for Conservation of Nature Red List, and quantified the presence of threatening invasive species, protected areas, and human populations. We matched these results with island attributes to highlight feasible island conservation opportunities. We identified 1,362 threatened breeding seabird populations on 968 islands. On 803 (83%) of these islands, we identified threatening invasive species (20%), incomplete protected area coverage (23%), or both (40%). Most islands with threatened seabirds are amenable to island-wide conservation action because they are small (57% were <1km2), uninhabited (74%), and occur in high or middle income countries (96%). Collectively these attributes make islands with threatened seabirds a rare opportunity for effective conservation at scale.

### PS21.2 How have invasive mammal eradication projects benefited native island fauna? A systematic review.

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Miskelly[10], Andrew Burbidge[11], Dave Towns[12], Alfonso Aguirre[13], Araceli Samaniego[13], Steve Ebbert[14], Mark Rauzon[15], Franck Courchamp[16], Elsa Bonnaud[16], Gérard Rocamura[1], Sally Poncet[17], Steffen Oppel[18], Richard Cuthbert[19]
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The number of invasive alien mammal eradications has grown substantially over the last few decades, with the primary goal of biodiversity protection including protecting threatened native species. Eradication techniques, successes, and failures have been reviewed globally but the benefits to native island species have not yet been systematically collated at the global scale. We first aimed to collate data on potential beneficiaries of invasive mammal eradication globally by quantifying Critically Endangered or Endangered mammals, birds, reptiles, and amphibians breeding on invasive mammal-eradicated islands in the past 10 years from an existing database. We found 270 populations of 117 highly threatened species potentially benefitted from invasive mammal eradication on 159 islands across the globe. This represents 17% of highly threatened island-breeding species globally, leaving conservation opportunities for more threatened species benefits with further invasive mammal eradication efforts. Next we did an in-depth systematic review of realized beneficiaries, in which we identified species that 1) increased in population size or reproductive success, 2) naturally recolonized an island after being extirpated, or colonized an island for the first time (unassisted colonization or recolonization) and/or 3) had a population translocated (conservation introduction or reintroduction) following invasive mammal eradication. We assessed realized species benefits for Australia, Ecuador, France, Mexico, New Zealand, the Seychelles, the United Kingdom, and United States of America, where >80% of eradications have taken place globally. We used established databases, a literature review, and expert interviews to procure the relevant information to compile this list. At least 448 populations of 199 species benefitted, including 60 populations of 26 globally threatened species, from 250 invasive species eradications across 133 islands.

**PS21.3 Fauna and habitat recovery after mammal eradication on Socorro island**

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Socorro Island is well known for its high number of endemic species of flora and fauna. However, these species are being threatened by the presence of exotic species: sheep, cats and mouse. Therefore, as a conservation measure, the eradication of feral sheep was conducted between 2008 and 2012. In order to document the recovery of vegetation, since 2009 a total of 20 quadrants have been monitored, where richness and abundance of plant species are recorded. Results to date demonstrate an increase in vegetation cover in areas previously inhabited by sheep, shifting from an initial value of less than 30% to more than 80% for most of the sites. On the other hand, the eradication of cats will thus contribute to protect the island's fauna. A program to control feral cats started, from 2011 to 2014, more than 360 cats were captured. Detection dogs will be used to find the last individuals, which tend to be the ones in the most remote areas. Thanks to this habitat

recovery and the greater availability of food, both native and endemic fauna is also improving. Endemic birds are becoming more abundant as vegetation cover increases on what used to be barren landscapes. The eradication of sheep has encouraged the recovery of the habitat. Furthermore, the ongoing eradication of feral cats is diminishing the pressure over the fauna, like Socorro blue lizard and landbirds, which will eventually allow the reintroduction of the Socorro Dove, extinct in the wild.

**PS21.4 Cooperative Planning Efforts to Eradicate and Control Introduced Mammals on Seabird Breeding Islands in Japan and The Republic of Korea**

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In 2014, the Pacific Seabird Group and Japan Seabird Group convened two meetings in Tokyo on eradication and control of introduced mammals on seabird islands in Japan and the Republic of Korea: (1) a roundtable discussion (RTD) at the International Ornithological Congress; and (2) a working group meeting at the Japan Wildlife Research Center. More than 67 people participated, including scientists (Japan, Republic of Korea, New Zealand, United States, and Canada), naturalists, and members of the Japan Ministry of the Environment. In Japan, most (70%; n = 60) known seabird breeding island groups are protected within designations such as national monuments or wildlife protection areas. However, introduced mammals (mainly rats and cats) have been reported as: (1) present on 20 groups; (2) suspected on 7 groups; (3) not present on 8 groups; and (4) status unknown on 25 groups. Recent eradications in the Ogasawara Islands, Japan, and over the past few decades in New Zealand and western North America, have encouraged region-wide planning in Japan and the Republic of Korea. Much work is needed in both Japan and the Republic of Korea to: (1) build a database of seabird islands that includes information on introduced mammal and breeding seabirds; (2) conduct impact studies to demonstrate the effect of introduced mammals on breeding seabirds; (3) conduct appropriate baseline and follow-up monitoring to demonstrate the benefits of eradication and control to seabirds and island biodiversity; (4) create conservation bait matrices that are legal in both countries; and (5) determine methods to prevent future introductions of non-native mammals to seabird islands. Given the declining status of many seabirds in Japan and the Republic of Korea, eradication and control of introduced mammals are important steps for restoring seabird populations and island biodiversity.

**PS21.5 Island Conservation and Prioritisation in the Western Indian Ocean**

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Seabirds critically depend on islands for their breeding life-stages, where terrestrial global change impacts of biological invasions and climate change are severely threatening. The Western Indian Ocean includes 28 islands groups comprising nearly 2,000 islands. Non-native mammals have been introduced to these islands both historically (East Africa) and contemporarily (Mascarene archipelago). We document the distribution of introduced mammals in the Western Indian Ocean

and report on the success rate of eradication programmes to eliminate the threat of invasive mammals, and the subsequent recoveries by sea and land bird populations. Mammal eradications have been recorded for 45 islands, mainly in the Seychelles and Mauritius. Twenty-four species have benefited from pest eradication or control, including 8 species down-listed in the IUCN red-list. For island groups with mostly complete mammal inventories we estimate percentage island area invaded and vulnerability to projected climate change. Sea level rise and coastal inundation is expected to significantly impact 85% of islands in the region, although these only make up 0.1% of total island area. Introduced cats and rats are ubiquitous on Western Indian Ocean Islands, and so we finally report on a prioritisation list of islands for cat and rat eradication in the Mascarene archipelago to benefit seabird recovery and recolonization. This list demonstrates the importance of scaling mammal eradication efforts to much larger islands (>300 ha) which are robust to predicted climate change impacts. Madagascar and the Maldives are identified as high priorities for island inventories.

**PS21.6 Seabird restoration project on Mexican Pacific islands: experiences and inputs for a wide regional strategy**

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Invasive species has caused 17 vertebrates extinctions in Mexican islands. To prevent more extinctions, 56 populations of 12 mammals were eradicated from 36 islands. 147 endemic taxa and 227 bird breeding colonies have been protected. Now these islands are a safe habitat for birds to return. An ongoing seabird restoration project in the Mexican Pacific island takes place on: Coronado Archipelago (39, 11 and 112 ha), Todos Santos Archipelago (30 and 87 ha), San Martín (256 ha), San Jerónimo (48 ha), Natividad (728 ha), San Roque (37) and Asunción (43). Techniques like social attraction systems comprising Double-crested, Brandt's and Pelagic cormorants, Elegant Tern and Heermann's Gull decoys and mirrors; artificial burrows for Cassin's Auklets, all of them with colony vocalizations and playbacks powered by solar panels, and monitoring of seabirds and land birds. Results to date are positive and encouraging; a Double-crested Cormorant successful nest was recorded on the decoy colony, Heermann's Gull are breeding since the project started with highest nest number of 36 nests per season and the recolonization of Cassin's Auklet and Brown Pelicans have been confirmed on Asuncion and San Roque islands, previously extirpated. As part of the project, an environmental education program was implemented on the islands and communities, impacting more than 1, 300 persons in 2014. This project benefits seabird populations distributed along the wide US-México international region. The project involves collaboration between US and Mexican government agencies, donors and local fishermen communities.

**PS21.7 Past, Present, and Future of Invasive Species Eradication on Islands in Alaska, USA**

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*[1]Alaska Maritime National Wildlife Refuge*

Alaska Maritime National Wildlife Refuge is a 1.4 million hectare dedicated conservation unit spread across much of coastal Alaska, including most of the Aleutian Islands. Widely regarded a premier seabird conservation unit, Alaska Maritime National Wildlife Refuge provides breeding habitat for roughly 40 million nesting seabirds as well as important habitat for marine mammals, island endemics, and other species. Refuge employees have a 50 year history of restoring seabird habitat

through eradicating invasive vertebrates. Historically, most of the work was to eradicate introduced arctic fox (Vulpes lagopus) and red fox (Vulpes vulpes), though the refuge has also eradicated reindeer (Rangifer tarandus), cattle (Bos Taurus), hoary marmot (Marmota caligata), brown rats (Rattus norvegicus), and European rabbits (Oryctolagus cuniculus) from refuge islands where they had previously been introduced by humans. Refuge employees are in the midst of a planning effort to determine the fate of abandoned cattle on two additional refuge islands, Chirikof and Wosnesenski Islands, both south of the Alaska Peninsula in the North Pacific. Future island restoration opportunities on the refuge may involve projects with heightened complexity due to technical or social challenges. I will discuss various internal and external challenges to implementing important seabird conservation actions through invasive species management from the perspective of a government land manager.

## PS22 Population Structure, Parasites and Pollution

### PS22.1 Signature of natural selection on the mitochondrial genome of penguins

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Most studies have not considered the role of selection on mitochondrial genome. We sequenced the complete mitochondrial DNA genome using Next Generation Sequencing from 12 individuals of six penguin species, and compared with four other penguin species comprising a total of 16 genomes and ten species from the equator to Antarctica. We characterized the genomes, genetic diversity and evaluated the signature of selection on 13 mitochondrial protein-coding genes by comparing among species within and between genera (Spheniscus, Pygoscelis, Eudyptula, Eudyptes and Aptenodytes). We also obtain chlorophyll and temperature data from remote sensing along each species distribution. Pairwise species Ka/Ks ratios and analyses of selection at codon sites (FEL) suggest that there has been directional selection on ND3 and ATP8 genes in all of the penguin species evaluated. In contrast, COX1 has a signature of purifying selection with a near zero Ka/Ks ratio for overall comparison within and between genera. Species from the most extreme polar and tropical/temperate environments (Aptenodytes forsteri and Spheniscus) had the highest signatures of selection in ND3 and the lowest values with ATP8 across all pairwise comparisons among genera. In contrast, comparisons among genera of ND3 genes patterns revealed evidence of positive selection with Pygoscelis species and negative selection with Spheniscus. These results suggest that genetic patterns of mtDNA, particulary ND3 and ATP8, may reflect signatures of selection. However, between species of Spheniscus and Pygoscelis, the GLM showed high significance ($P<0.05$ and AIC) between Ka/Ks ratios and environmental variables for ND4, ND4L, ND5, ND2 and COX1. These results are the first step in understanding the genes involved in adaptation in penguins, which is crucial to developing predictive models of how these penguin species will respond to the impacts of local and global environmental and climatic changes.

### PS22.2 Relationships of New Zealand's recently extinct Procellariiformes

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Two species of Procellariiformes are known to have become extinct since human settlement of New Zealand. We use genetic techniques to clarify the relationships of Scarlett's shearwater Puffinus spelaeus Holdaway & Worthy, 1994, and an undescribed Chatham Island gadfly petrel (Pterodroma sp.). The sister taxon of Scarlett's shearwater is the fluttering shearwater (P. gavia) and, with Hutton's shearwater (P. huttoni), these species form a distinctive New Zealand clade within Puffinus. The Chatham Island gadfly petrel is well-differentiated from other taxa genetically but belongs within a clade that includes soft-plumaged petrel (Pt. mollis), Bermuda petrel (Pt. cahow), black-capped petrel (Pt. hasitata), Fea's petrel (Pt. feae), Madeira petrel (Pt. madeira), Magenta petrel (Pt. magentae), Atlantic petrel (Pt. incerta), white-headed petrel (Pt. lessonii) and great-winged petrel (Pt. macroptera).

**PS22.3 Population structure and migration in the emperor penguin revealed using genomics**

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A reduction in Antarctic sea ice, which is predicted to occur by the end of the century, is a major threat to emperor penguins (Aptenodytes forsteri). Understanding the mechanisms that govern emperor penguin population dynamics is vital to be able to make accurate predictions about their ability to cope with such reductions in sea ice. Using genome-wide single nucleotide polymorphisms (SNPs) identified by RAD-sequencing, we genotyped 115 emperor penguins from eight colonies around Antarctica. We present the first accurate assessment of population structure and migration in Emperor penguins. We confirm the existence of a Ross Sea population that is genetically differentiated from other nearby colonies, but we also find complex patterns of genetic differentiation around East Antarctica and in the Weddell Sea. The results suggest that emperor penguins may migrate more frequently than previously thought and that populations may need to be considered through the lens of metapopulation dynamics. The results presented here, along with studies of the movement of entire colonies from satellite and aerial photographs (LaRue et al. 2014), suggests that emigration may play a much larger role in emperor penguin population dynamics than previously considered, and as such, predictions of their ability to cope with reductions in sea ice need to be updated.

**PS22.4 Lice infesting breeding terns of the Arabian Peninsula? seas.**

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For long period of time the study of lice/terns interaction was neglected. Through this work six species of migratory breeding terns of Arabian Peninsula were examined for head chewing lice of genus Saemundssonia at four different islands around the coasts of Saudi Arabia on Red Sea and the Arabian Gulf. Four species of this genus were recorded for the first time from birds on the region and two new host/lice association were reported for White cheeked Tern and Sanunders's Tern. Also, host switching phenomenon for Saemundssonia laticaudata (Rudow) on White cheeked Tern was observed from Karan Island population. The gene bank data for COI gene for seven species of Saemundssonia that infest some marine birds were used to induce evolutionary tree using two

different statistical methods Maximum Parsimony (MP) and Neighbor-Joining (NJ). The tree indicates the relations between terns' lice and other marine birds especially gull lice. ANOVA test was also conducted to test the parasitic loud mean for each tern species under study and the result indicate that there is a relation between lice loud and colonization behavior of the host. The data of specimens examined, photos of chewing lice and their hosts and evolutionary trees are given through this paper.

**PS22.5 Linking parasitism and life-history: novel questions with a novel energetic approach**

Olivia Hicks[1], Sarah Burthe[2], Francis Daunt[2], Jonathan Green[1]
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Quantifying energy expenditure is crucial for addressing questions on a diverse range of fields from fisheries modelling to understanding the effects of environmental change on life-history decisions. However, measuring energy expenditure in free-ranging animals has proved challenging. Until recently, studies of field energetics have been dominated by the use of heart rate and doubly labelled water methods. Here, we used accelerometers to accurately derive time-activity budgets and calculate Overall Dynamic Body Acceleration (ODBA) a relatively new, but rapidly growing approach to estimating energy-expenditure. ODBA is as effective as the established approaches in the laboratory and over extended periods in the wild, but its suitability as a robust proxy for energy expenditure across all natural behaviours in free-ranging seabirds is untested, and there have been specific questions over its validity during diving. By deploying bio-loggers on 12 breeding individuals that simultaneously monitored heart rate and acceleration over 35 day periods we undertook the first comparison of heart rate and ODBA-derived energy expenditure across all behaviours in a free-ranging animal. Analyses indicated the crucial importance of temporal scale in the application of ODBA, with excellent correlations over long temporal intervals, but counter-intuitive negative relationships across dive behaviour at fine temporal scales. Validating the effectiveness of the ODBA method allows us to ask fundamental questions about individual life-history decisions. In our study we combined estimates of energy expenditure with endoparasite load to explore the energetic costs of parasitism on individuals. This is the first time that this promising technique has been validated at a fine scale in a field setting and given its relative ease of deployment and cost we consider that this is a powerful method for elucidating seabird life-history decisions under environmental variability.

**PS22.6 Regurgitation of the koilin layer in chinstrap penguins (Pygoscelis antarcticus): a potential countermeasure against the parasitic load**

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Koilin membrane, formed by the secretions of the ventricular and pyloric glands, functions as a protective layer in the gizzards of most bird species. However, the ecological functions of koilin have been rarely studied in free-ranging populations of wild birds, especially in penguins. During the two austral summers from 2012 to 2014, we observed the koilin regurgitating behaviour of chinstrap penguins (Pygoscelis antarcticus), and detected significant difference in the daily regurgitation rate between the pre-hatching and post-hatching periods in the chinstrap penguin's rookery. However, few regurgitated koilins were found at the pathway of gentoo penguins (P. papua) while those were common in the pathway of chinstrap penguins, suggesting specific difference in the koilin

replacement strategy. We also found 233 gastrointestinal parasites, Stegophorus macronectes (Nematoda, Acuariidae) from 26 out of 45 freshly regurgitated koilins of chinstrap penguins. Based on the results, we suggest that adult chinstrap penguins may gain benefits from the regurgitation of koilins by reducing associated parasitic loads during their fasting periods for incubation and may also help decrease the risk of parasite transmission to their chicks. The detailed strategy and functions of koilin replacements across penguins remain for further studies, but our results present the first observation of koilin regurgitating behaviour in breeding chinstrap penguins, which is a potential countermeasure against parasite loads.

**PS22.7 Prevalence and potential sources of elevated strontium in waterfowl eggs in interior Alaska**

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Studies have implicated strontium (Sr) as a contaminant of concern in avian population declines. Previous work on contaminants in eggs of waterfowl breeding in Interior Alaska found an inverse relationship between egg Sr concentrations and eggshell thickness and measurable levels of radioactive Sr in egg contents and shell. Strontium is a naturally occurring alkaline earth metal with no known biological function in birds. It is chemically similar to calcium, which can lead to substitution for calcium in tissues, affecting physiological processes and mechanical characteristics. We measured Sr concentrations in the eggs of five species of waterfowl in Interior Alaska at three locations. To determine potential sources, we compared eggshell chemistry with food and water chemistry at breeding sites. We also examined eggshell d13C and d15N to assess if trophic level and/or nutrient allocation strategy affected eggshell Sr concentrations. Preliminary data suggests eggshell Sr varied by species, site, and year and was related to local water chemistry and the nutritional strategy of the hen during egg production.

## S19 Researcher Disturbance on Nesting Seabirds

**S19.1 What have we done? Effects of researcher disturbance on nesting seabirds**

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Seabirds are being studied by humans since centuries. Highly mobile and very visible they are perfectly suited as indicators of environmental change. Since the first global assessment of the conservation status of birds in 1988 seabirds have been identified as the group deteriorating fastest. Today 28% of seabird species are classified as threatened by the IUCN and about 50% are known or suspected to experience population decline. Ongoing monitoring and research is vital for species conservation and to improve our understanding of the marine systems they (and we all) rely on. Given many seabird species' precarious conservation status it is essential to minimise any negative effects associated with research. Whereas effects of tourist disturbance receives increasing scientific attention to improve visitor management guidelines, the potential effects of researcher disturbance is often neglected when reporting results of research or monitoring efforts. However, even monitoring regimes that are considered low-impact such as single nest counts have the potential to cause nest abandonment and failure. It is imperative to quantify and ultimately minimise human disturbance related effects not only to reduce potential impact on productivity but also to gather

reliable and representative long-term monitoring data. Here we summarise our current knowledge about the effects of researcher disturbance on nesting seabirds and suggest methods to quantify disturbance related effects during future research and monitoring efforts. We encourage case-by-case re-assessment of best practice protocols in order to minimise research related disturbance effects.

**S19.2 Breeding success in a cliff-nesting seabird derived from time-lapse photography**

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The development of new efficient methodologies for obtaining baseline data on difficult-to-access locations or easily disturbed species is an important challenge. A cost-effective option for obtaining such data is to use automated time-lapse photography. We describe a method that can generate measurements of annual breeding success in cliff-nesting seabirds or otherwise gregarious breeding birds, which require only a single, short visit in the colony every second or third year. The method is based on a relatively simple image analysis, which makes it easy to differentiate between breeding and non-breeding birds and to determine when breeding attempts have failed. The method represents a realistic long-term monitoring technique, as it reduces an overwhelming number of photos to a manageable number. In addition, the method minimizes the need for time-consuming and potentially disturbing ground-truth studies, as the time-lapse photo technique is directly comparable with the conventional method of measuring breeding success (direct observations). We present results from two locations in Greenland using thick-billed murre (Uria lomvia) as the study species.

**S19.3 Quantifying seabird disturbance in the wild: physiological and behavioral measures in breeding king penguin**

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Quantifying recreational and research-related disturbance on seabirds is essential from a conservation stance, and for scientists to account for potential biases when drawing conclusions from their data. A major complication in assessing the effects of human activities on seabird disturbance is that those effects are not always directly visible. Behaviourally calm seabirds might nonetheless experience profound physiological changes in response to disturbance. Behavioural/physiological responses to human activities may also be disturbance-specific, or depend on intrinsic (e.g. individual's life-history stage or temperament) and extrinsic (e.g. the presence of conspecifics, climate) factors. Assessing human disturbance on seabirds' biology thus requires a dual approach, encompassing both behaviour and physiology. Here, we present data on physiological and behavioural responses of king penguins (Aptenodytes patagonicus) breeding ashore to human disturbance. We consider the heart rate stress responses of birds to 3 experimental stressors (a distant approach, a capture, and a loud sound) that differ in intensity and mimic tourist and researcher-related activities. We also consider behavioural data on alert- and flight-initiation distances of breeding birds to standardized human approaches. Our results suggest that penguins living in area of frequent human disturbance have adjusted to certain, but not all, types of stressors.

In these areas, stress responses to low-intensity stressors (distant approaches and sounds) are attenuated, but this is not the case for captures. Bird alert and flight-initiation distances appear to be affected by breeding stage and changes in colonial density. We discuss those results in the context of research-related activities, and suggest some guidelines to minimize disturbance of breeding birds.

**S19.4 Aerial Seabird Counts with Drones**

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Remotely controlled, unmanned aerial vehicles (UAVs) are being used for different ecological applications since they become available for civil use in the last few years. In this study, we used UAV quadcopter drones equipped with HD cameras to assess the number of active nests of colonial guanay cormorants (Phalacrocorax bougainvillii) and Peruvian boobies (Sula variegata) at three sites off Peru in November 2014. We further compare our counts with those obtained by the traditional method of sketching the distribution of Peruvian guano birds on maps. Nesting status, nest density, number of nests or individuals, occupancy area and distribution of the birds on the islands could be successfully assessed with the drones. No disturbance to the birds was detected at altitudes above 30-m from the ground. Direct counting of > 30,000 nests from the aerial digital photos were time-consuming, but automatic counting with a multi-platform photo manipulation software considerably reduced the time of work with an error of < 5% in comparison to the direct counts. Likewise, count bias was reduced to 10 - 75% when compared to the sketching method. This study demonstrates that aerial photography with drones is an inexpensive, reliable, fast and accurate method to count colonial guano birds in Peru. We further explore the utility of drones in other colonial seabird species and discuss the extent and limitations of their use.

**S19.5 Can't touch this: the impact of regular handling on the growth and stress physiology of nutritionally compromised mottled petrel chicks**

Rachael Sagar[1], Brendon Dunphy[1], Denise Fastier[2], Catherine Mitchell[2], Margaret Stanley[1], Matt Rayner[3]
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Few studies of procellariiform chick development control for and report on the potential stress induced effect of regular handling on growth and fledging condition. Effects of handling stress on chicks may be further exacerbated by the nutritional status of the chick, with chicks in poor condition predicted to be more susceptible to the effects of stress. Given the ever-increasing threat of climate change, which is known to compromise chick-rearing and growth in many seabird species, it is0likely that chicks in poor condition will be handled regularly during current and future studies exploring the impact of climate change at the individual and population level. We tested a hypothesis of handling induced stress in a cohort of mottled petrel chicks (Pterodroma inexpectata), known to be naturally nutritionally compromised, under three handling regimes. Nutritionally compromised mottled petrel chicks handled daily achieved significantly lower peak weight, lower fledging weight, slower wing chord growth and shorter wing chord length than chicks handled every two to three days or chicks handled a maximum of three times during the entire study period. Physiological evidence supported these findings, with chicks handled daily exhibiting attenuated

stress responses compared to chicks handled every two to three days, and chicks handled minimally. Our results highlight the importance of controls in any seabird research that aims to report data representative of natural chick development/ biology. Moreover these findings provide guidance for acceptable levels of handling that allow 'natural' growth data to be reported for future studies of procellariiform species. These findings have significant implications for future stress physiology research in seabirds, particularly in light of the potential impacts of future climate change.

**S19.6 Ruggedized remotely deployed Gigapan panoramic camera systems for studies of wildlife and fisheries**

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Remote sensing, exploits technologies at scales ranging from global-regional coverage by satellites to locally placed camera traps. We ruggerdized and tested via remote deployment a commercially available Gigapan panoramic camera system. By stitching together multiple overlapping megapixel digital photos, which the Gigapan robotic camera mount allows a telephoto-lens equipped DSLR to take, a high resolution (Giga) panoramic (pan) image is created. We enhanced the 'off the shelf' mount and camera with development of a weather proof housing and self-contained hardware and software control solutions, which allows for programming of long-term deployments with minimal power consumption. Our improved system collects data across a range of spatial and temporal scales that are of interest to wildlife and fisheries biologists. We have now trialled across applications which include: several studies of shy albatross breeding biology, human disturbance to fur seal haul-out colonies, fishing effort at an offshore artificial reef and patterns of human use within urban aquatic reserves. For each application we found that we needed to tailor the set up (i.e. lens size, rate of sampling, field of view), study design and analysis strategy. Our system has proved to be generally useful for collecting data for questions scoped at scales of 20m - 3km and 30 minutes to 6 months. This places the platform into the spatial scale of aerial surveys but with the temporal persistence of standard camera traps.

# Friday October 30 2015

## PS23 Climate Change

**PS23.1 135 year time-series of Atlantic Puffin harvest is negatively correlated to sea surface temperature: A function of population control by temperature dependent metabolic rate of sandeel prey?**

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The complete pole netting harvest record (1880-2014) of Atlantic Puffins In the Westman Islands, Iceland, is negatively correlated to seasonal sea surface temperatures (SST). Ringing recoveries show that pole netting is age selective with ~80% of the harvest being immatures. Variation in harvest reflects past production until age of maturity & colony attendance of immature birds, both reflecting availability of the key prey, the Lesser Sandeel. The relationship between Puffin harvest & SST is hypothetically explained by sandeel population control by temperature dependent metabolic rate.

Sandeel life history is composed of summer growth period in May-July, and dormant winter period in August-April spent buried in sand. In winter, increased SST accelerates the sandeel's metabolism & their rate of reserve depletion, but reduces energy allocation to growth & reserves during summer. A critical sandeel length threshold Lth was calculated annually for the sandeel dormancy period, which the 0-group sandeels need to attain to "survive" the SST profile of the following winter [1]. Mean annual summer temperature was also calculated. The 3 variables were prewhitened & split into regimes by a sequential t-test [2]. The regime timing & level of change of the three variables was compared. Three main production crashes were identified in 1890, 1932 and 2005, and three regimes of growth <1880, 1968 and 1990. The combination of three warm winter regimes with Lth > 7.5 cm & two warm summer regimes correspond to the observed production (harvest) regime pattern. This analysis supports the metabolic hypothesis & advocates a further analysis. 1. Mikael van Deurs, Martin Hartvig, & John Fleng Steffensen (2011). Critical threshold size for overwintering sandeels (Ammodytes marinus). Marine Biology 158: 2755-2764 2. Sergei N Rodionov (2004). A sequential algorithm for testing climate regime shifts. Geophysical Research Letters 31: L09204

**PS23.2 Climate change, food webs and seabird productivity: impacts of oceanographic change on UK kittiwake breeding success**

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The black-legged kittiwake (Rissa tridactyla) is one of the UK's most abundant seabirds but the population has declined by 60% since the 1980s. Declines have been linked to rising sea surface temperatures (SSTs) that are believed to affect recruitment and growth of the lesser sandeel (Ammodytes marinus), a key kittiwake prey species, in turn causing reduced breeding success. However, these relationships have often been derived from a small number of intensively-studied colonies from a geographically limited area, and analyses have primarily considered SST within arbitrarily-defined areas surrounding breeding colonies. Consequently, important national-scale drivers may not have been detected and oceanographic indices may not accurately reflect the conditions experienced. We have attempted to address these issues by using tracking data to estimate colony-specific foraging areas for eleven colonies. Estimates of SST, stratification strength, and stratification onset date from these areas were linked to colony productivity. Higher productivity was associated with lower SSTs and weaker early-year stratification. Climate change projections indicated that rising SSTs could drive substantial kittiwake productivity declines by the late 21st Century. Finally, food web components linking physical conditions to kittiwake productivity were explored using Continuous Plankton Recorder data. Higher productivity was associated with higher sandeel abundance, which in turn was associated with higher calanoid copepod abundance. Higher Calanus finmarchicus abundance was associated with later stratification and weaker early-year stratification, whilst higher Calanus helgolandicus abundance was associated with stronger stratification throughout the year. Hence, our analyses show how changing oceanographic conditions can influence kittiwake food webs, in turn influencing breeding success; further examination of such links should improve understanding of the threats posed by climate change.

**PS23.3 Complex foodweb dynamics of marine bird communities of the high and low arctic**

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Arctic marine bird communities are integral components that maintain biological teleconnections between the mid- and northern latitudes. We report on studies done in 2010 - 2014 in Northwest Greenland focused on the nearshore dynamics related to climate change of marine bird communities. Our preliminary results indicate that the community-wide spatial and temporal dynamics of marine bird ecosystems are far greater in our study period than was evident in past decades. We also find that the magnitude of change is greater here in the high Arctic (e.g, 78°N) compared to low Arctic coastal marine ecosystems (e.g., western Aleutian Islands 53°N). In particular, we show that the ecological patterns observed within such widespread arctic species as Dovekie (Alle alle), Northern Fulmar (Fulmarus glacialis), and Black-legged Kittiwake (Rissa tridactyla) indicate diets are strongly perturbed on small geographic and temporal scales of km and years. Moreover, we find that the variance in environmental and ecological parameters is increasing rapidly over time. We hypothesize that these fine-scale changes are related to oceanographic and trophic-level responses to increased freshwater injection by increased glacial melt and run-off into coastal waters, in addition to larger-scale perturbations possibly related to a cascade of climate-related factors.

**PS23.4 Non-linear relationships between diet and demography signals environmental change in the North Sea**

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Seabirds have long been proposed as suitable biological indicators of change in the marine environment. However, growing numbers of anthropogenic pressures on marine ecosystems, makes evaluating the effectiveness of seabird indicators increasingly urgent. Although seabirds have been used as effective indicators of environmental change, current approaches have gained limited understanding of the processes underpinning such responses. Insights may be gained by quantifying the links between parameters (e.g. breeding success and diet) as candidate indicators, aiding a mechanistic understanding of processes involved. This is because changes in the shape of these relationships over time can signal specific ecosystem changes, thereby providing more informative marine indicators. The North Sea is one of the most rapidly warming marine ecosystems on the planet, resulting in profound changes in the distribution and abundance of species, including the Lesser Sandeel Ammodytes marinus, the principle food source of most seabirds in the region. Here, we investigate patterns of change in diet and demography, and the relationship between them, in European shags Phalacrocorax aristotelis breeding on the Isle of May, Scotland using data spanning three decades. We found that reductions in sandeel size and associated dietary increases in alternative prey are linked to breeding performance and survival, with strong temporal patterns in these relationships. Crucially, our results show that changes in the relationship between dietary composition and demography indicate specific changes in the availability and profitability of alternative prey. Our findings confirm the value of using the links between parameters to deliver more informative indicators of environmental change.

**PS23.5 Marine distribution of seabirds in the Eastern Canadian Arctic: then and now**

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Climate change is causing rapid changes in Arctic marine ecosystems and the decline in sea ice will open waterways to increased vessel traffic and development. The waters of the Canadian Arctic support millions of seabirds, and studying the patterns and processes of their at-sea distribution and abundance can identify critical habitats, provide a better understanding of marine ecosystem functioning and help to monitor the impacts of climatic and anthropogenic changes. Using vessel-based survey data spanning six decades (1965-1992 and 2006-2013) we examined changes in the summer distribution and abundance of seabirds in the eastern Canadian Arctic (sub-arctic waters around Newfoundland north to Barrow Strait, Nunavut). Over six decades, Lancaster Sound, Baffin Bay, Davis Strait and the waters off Labrador and Newfoundland have consistently supported high densities of seabirds such as northern fulmar (Fulmarus glacialis), black-legged kittiwake (Rissa tridactyla), and thick-billed murre (Uria lomvia) in the summer. Davis Strait and Baffin Bay were important marine areas for dovekie (Alle alle) both currently and in the past. Recent surveys found high densities of kittiwakes and murres in Lancaster Sound in July but past surveys show higher densities there in August. At a broad-scale, marine distribution of Arctic seabirds has remained similar during this time period, although some changes in range extent and temporal variability of important marine areas are evident. Linking decadal changes of seabird distribution to changes in ice thickness and extent may provide some indication of future important areas previously unavailable due to year-round ice coverage.

**PS23.6 Influence of climate change and fisheries bycatch on shy albatross in southern Australia**

Robin Thomson[1], Rachael Alderman[2], Geoffrey Tuck[1], Alistair Hobday[1]
*[1]CSIRO, [2]Department of Primary Industries, Parks, Water and Environment*

The impacts of climate change on marine species are often compounded by other stressors that make direct attribution and prediction difficult. Shy albatross (Thalassarche cauta) breeding on Albatross Island, Tasmania, show an unusually restricted foraging range, allowing easier discrimination between the influence of non-climate stressors (fisheries bycatch) and environmental variation. Local environmental conditions (rainfall, air temperature, and sea-surface height, an indicator of upwelling) during the vulnerable chick-rearing stage, have been correlated with breeding success of shy albatross. We use an age-, stage- and sex-structured population model to explore potential relationships between local environmental factors and albatross breeding success while accounting for fisheries bycatch by trawl and longline fisheries. The model uses time-series of observed breeding population counts, breeding success, adult and juvenile survival rates and a bycatch mortality observation for trawl fishing to estimate fisheries catchability, environmental influence, natural mortality rate, density dependence, and productivity. Observed at-sea distributions for adult and juvenile birds were coupled with reported fishing effort to estimate vulnerability to incidental bycatch. The inclusion of rainfall, temperature and sea-surface height as explanatory variables for annual chick mortality rate was statistically significant. Global climate models predict little change in future local average rainfall, however, increases are forecast in both temperatures and upwelling, which are predicted to have detrimental and beneficial effects, respectively, on breeding success. The model shows that mitigation of at least 50% of present

bycatch is required to offset losses due to future temperature changes, even if upwelling increases substantially. Our results highlight the benefits of using an integrated modeling approach, which uses available demographic as well as environmental data within

**PS23.7 Endotherms under climate change: effects of temperature on thermoregulatory behaviour and evaporative water loss in four sympatric seabird species**

Timothée Cook[1], Richard Sherley[2], Jennifer Roberts[3], Philna Botha[3], Rowan Martin[3], Peter Ryan[3], Emilee Sparks[3], Corlia Meyer[3], Leslie Underhill[4], Greg Campbell[5]
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Direct physiological impacts of rising global temperatures are rarely reported for endothermic species such as seabirds, limiting our understanding of the threats they may face from climate change. We predicted that seabirds will be challenged by increasing temperatures due to the direct linkages between climate and breeding sites. Indeed, seabirds must balance conflicting adaptations for dealing with cold environments when foraging and hot environments when nesting. Some seabird species gular flutter to thermoregulate, a behaviour that effectively dissipates heat but increases evaporative water loss. We examined gular fluttering behaviour in four southern African cormorant species: Crowned (Microcarbo coronatus), Cape (Phalacrocorax capensis), Bank (P. neglectus), and White-breasted (P. carbo lucidus) Cormorants. Gular fluttering was influenced by ambient temperature, body position and body size, with larger species spending a greater proportion of time gular fluttering for a given temperature. Threshold temperatures for initiating gular fluttering were lower for large than for small cormorant species. Proportions of time spent gular fluttering were higher when birds were sitting than when crouching over the nest. Water loss shows the same pattern as gular fluttering, with the larger species estimated to lose as much as 40% of their daily ingested water after eight hours of gular fluttering. These results suggest climate change will likely have serious direct impacts on some nesting seabird species. In southern African cormorants, gular fluttering is predicted to increase by 25% and water loss by 10% by 2100 under conservative projected global temperature increases, which do not include increases in local extreme events, like heat waves. Some species may show phenological plasticity to compensate, but if life-history events are timed to coincide with peaks in their prey, this may result in poorer diets or increased heterospecific competition.

**PS23.8 Differential migratory responses of closely-related dietary generalist and specialist marine predators to long-term climate change**

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Climate change has resulted in widespread and rapid shifts in the distribution of many marine species, and ocean warming is causing poleward redistributions of cold-water zooplankton. If marine predators reliant on copepods are to adapt to these changes, they will need to modify both foraging behaviour and migration strategies. However the capacity to do so may differ between species that

are dietary generalists, and those that are specialists. Small petrels are major consumers of zooplankton in the Southern Ocean, and species differ in bill morphologies depending on the degree of specialisation on oceanic copepods. In this study we focus on two small congeneric petrels; the Antarctic prion Pachyptila desolata, a dietary generalist, and the broad-billed prion P. vittata, a specialist that feeds predominantly on large copepods. To examine the responses of these two species to long-term climate change, we first investigated historical trends in carbon and nitrogen isotope ratios using museum specimens dating back to 1926. Controlling temporally for the Suess effect, δ13C of Antarctic prions but not broad-billed prions declined significantly, suggesting Antarctic prions may have shifted their non-breeding distribution southward over the last century. Both species exhibited significant declines in δ15N during the same period, indicative of long-term decreases in oceanic productivity, or changes in the trophic structure of prey communities. Broad-billed prions fitted with combined geolocation-immersion loggers migrated ~ 1000 km east of the breeding colony to where the Louisville seamount chain bisects the subtropical front; an area typified by cooler water temperatures and high productivity. Topographically driven upwellings are stable and predictable features that may be crucial in bringing plankton to the surface. Targeting seamounts could therefore mitigate the impact of climate-induced prey shifts by providing refugia for this planktivorous species.

## PS24 Diving Ecology

### PS24.1 Fly or dive? Timing of breeding and evolutionary trade-offs in two sympatric auk species

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The two sympatric auk species, Common Murre (Uria aalge) and Razorbill (Alca torda) has seemingly almost identical life-history strategies, morphological characteristics, and foraging and behavioural ecology. For a flying bird, the Common Murre has evolved extreme diving abilities and it has the lowest wing area/body mass ratio of all birds. The Razorbill has 30% larger wing area, but is still a competent diver. Both species breed on the Swedish island of Stora Karlsö in the largest colonies of both species (>10,000 pairs respectively) in the Baltic Sea. This is significant parts of the region's populations of both species. They both feed their chick with European Sprat (Sprattus sprattus) and both populations have at least doubled in numbers during the last 10-15 years. The Razorbills breed on average two to three weeks later than the Common Murres, but both breed synchronously within their respective species. We have studied the spatial distribution of the two species while foraging at sea during the breeding season, by systematic visual observations from vessel and simultaneous monitoring of fish stock abundance using hydro acoustics. We found a significant difference in the distribution at sea of the two species. The Common Murres were evenly distributed in relation to the density of prey fish, whereas Razorbills were concentrated to shallow areas with good access to fish. We conclude that constraints in diving ability in the Razorbill delay onset of breeding, whereas the Common Murre with its superiors diving skills, can utilize less accessible food earlier in the season and thefore breed earlier. The advatage of a better flying ability in the Razorbill will be discussed, but is not obvious given the ecological context of this study.

### PS24.2 Going deep: 3-D foraging strategies of diving seabirds

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Diving seabirds respond to complex environmental heterogeneity at multiple scales to maximize overlap with prey, making decisions about where and when to search for resources. The circumstances in which seabirds capture of prey underwater are largely unknown, as are the search strategies used in successful and efficient foraging events. Accelerometer tags in combination with high resolution GPS tags provided accurate data on the 3-D underwater movements of razorbills (Alca torda) and common guillemots (Uria aalge) for the first time. The use of unsupervised clustering expectation maximisation (EM) algorithms allowed discrimination of the space used, when, where and at which spatial scale the two species search for prey. The clustering analysis highlighted readily-interpretable behavioural modes at both large scales (flying, sitting on land, floating and diving) and small scales (behaviours within dives such as searching, prey chasing/capture, descending, and ascending). Number of dives performed (more frequents in razorbills than common guillemots), diving depths and durations (shallower and shorter in razorbills than guillemots), and use of the water column obtained from the clustering analysis, clearly differed between the two species highlighting the strategies used to search and locate prey underwater. The combination of new tag data and the application of novel modelling methods shows the fundamental importance of considering and connecting all the phases of activity that characterise seabird foraging behaviour. Here we highlight the variability and flexibility in the foraging strategies used by two species, underlining the importance of considering all dimensions of seabird foraging strategies when quantifying foraging movement. By doing so it is possible to develop accurately parameterised foraging models which are able to predict behavioural responses to environmental heterogeneity and habitat changes such as the development of offshore tidal power.

**PS24.3 Combined use of GPS and accelerometry reveals fine scale three-dimensional foraging behaviour in the short-tailed shearwater**

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Determining the foraging behaviour of free-ranging marine animals is fundamental for assessing their habitat use and how they may respond to changes in the environment. However, despite recent advances in bio-logging technology, collecting information on both at-sea movement patterns and activity budgets still remains difficult in smaller pelagic seabirds species due to the constraints of instrument size. The short-tailed shearwater, the most abundant seabird species in Australia (ca 23 million individuals), is a highly pelagic procellariiform. Despite its ecological importance to the region, almost nothing is known about its at-sea behaviour, in particular its diving behaviour. Using a combination of GPS and tri-axial accelerometer data-loggers, the fine scale three-dimensional foraging behaviour of 10 breeding individuals from two breeding colonies was investigated. Five at-sea behaviours were identified: (1) resting on water; (2) flapping flight; (3) gliding; (4) foraging (i.e. surface foraging and diving events); and (5) taking-off. There were substantial intra- and inter-individual variations in activity patterns, with individuals spending on average 45.8% (range: 17.1-70.0%) of time at sea resting on water and 18.2% (range: 2.3-49.6%) foraging. Individuals made 76.4 ± 65.3 dives per foraging trip, with a mean dive duration of 9.0 ± 1.0 s and with no dives being recorded at night. With the continued miniaturisation of recording devices, the use of combined data-loggers could provide us with further information on the foraging behaviour of small

procellariiforms, helping to understand better their interaction with their prey. Keys words: Habitat use, GPS tracking, movement, tri-axial accelerometer, procellariiforms, short-tailed shearwaters.

**PS24.4 Inter-annual comparison of diving depth of Gentoo penguins on King George Island, Antarctica**

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Penguins are one of top predators feeding krill and fish in Antarctic marine ecosystems. Based on the two year data (2009/2010 and 2013/2014) of diving depth of breeding gentoo penguin (Pygoscelis papua) on King George Island, Antarctica, we analyzed the diving parameters and statistically tested 1) if there were differences in diving depth and efficiency between day dives and night dives, and 2) if there are inter-annual variations in diving characteristics between the two years. Gentoo penguins dived frequently at shallow water (<20 m). Maximum dive depths varied among individuals but it did not exceed 180 m depth. When we compared day dives and night dives, dive depth was lower and dive efficiency was higher at night. Inter-annual variation was observed in both day and night dives. At daytime, dive depth was similar in both years, but dive efficiency was different: The maximum dive efficiency occurred at 25-30 m depth, but the value in 2009/2010 was higher than that in 2013/2014. At nighttime, dive depth and efficiency were different: dive depth in 2013/2014 was more concentrated at shallow depth (< 20 m), compared to 2009/2010. Accordingly, the dive efficiency at shallow depth was higher in 2013/2014 and it became lower in deeper water. Taken altogether, we discuss that the shallow dive at night would be related with the diel vertical migration of krill and it also could be affected by light conditions. The inter-annual variation in dive depth at night implies that gentoo penguins were more likely to be affected at night dives possibly by vertical distribution of krill. Also, despite the similar pattern of dive efficiency between the two years, the different maximum dive efficiency at daytime may be due to the different prey abundance or density in our study site between years.

**PS24.5 Seabird diving behaviour reveals the functional significance of shelf sea fronts as foraging hotspots**

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Oceanic fronts are key habitats for a diverse range of marine predators. Increased productivity and biomass entrainment have been predicted to attract higher trophic level consumers but direct tests of this are lacking. Here, we examine the diving behaviour of a medium-ranging marine predator, the Northern gannet Morus bassanus, in relation to shelf sea fronts identified via composite front mapping. Two dive strategies used by gannets were identified from time depth recorder (TDR) tags. V-shaped dives were those with little active swim phase, relying mainly on momentum from the plunge dive and were generally short and shallow. In contrast, U-shaped dives contained a substantial swim phase, where gannets used wing beats to pursue prey underwater. These dives tended to be longer and reach greater depths. We found the prevalence of U-shaped dives was reduced by half around frontal features. In contrast, V-shaped dives were more prevalent and of shorter duration when in proximity to fronts. We suggest this behavioural response results from a change in the availability and type of prey concentrated at fronts, and that these prey are most successfully exploited through the use of short shallow dives at higher speeds, which are more

energetically efficient. As such, fronts appear to constitute enhanced foraging habitat and this should be considered in spatial management and the mitigation of the effects of anthropogenic activities including fisheries and marine renewable developments.

**PS24.6 An In-Depth Exploration of Cassin?s Auklet Diving Behavior in the Variable California Current**

Nina Karnovsky[1], Pete Warzybok[2], Russell Bradley[2], Meredith Elliott[3], Zachary Brown[4], Jaime Jahncke[3]

*[1]Pomona College, [2]Point Blue , [3]Point Blue, [4]Inian Islands Institute*

We studied the seasonal and inter-annual variation in diving behavior of Cassin's auklets (Ptychoramphus aleuticus) breeding on Southeast Farallon Island, which is located off the coast of California, USA. We affixed Time Depth Recorders to 73 provisioning adults from 2008 - 2013. Each bird carried the TDRs for approximately three days. TDRs recorded time, temperature, and pressure every 5 seconds and when the bird dove below 5 meters, every .5 seconds. In addition, we collected diet samples and monitored reproductive success. We made oceanographic measurements of physics and krill biomass during research cruises carried out in the vicinity of the island. Oceanographic conditions, diets, diving behavior, and reproductive success varied greatly amongst years. We examined the relationship between diving parameters such as dive depth, dive duration, post dive interval, and proportion of dives spent at depth (bottom time). We hypothesized that in years with warmer water, the birds would make more frequent deep dives, would spend longer under water and their dives would have higher bottom time and they have lower reproductive success. We predicted that these parameters would be an indication that their zooplankton prey (primarily the euphausiids Thysanoessa spinifera and Euphausia pacifica which are associated with cold water) would be less available and the birds would have to work harder to find food for their chicks. We found significant interannual variation in water temperature and diving behavior. Bottom time, dive depth, and dive duration increased with temperature. However, contrary to our hypothesis, in 2010, the year when the birds made frequent deep dives, they had high reproductive success and water temperatures were warm and zooplankton biomass in the diving range of the Cassin's auklets (upper 30m) was highest. Our results emphasize that the density and horizontal distribution of zooplankton prey are important in interpreting diving behavior.

**PS24.7 Strong differences in individual specialisations in spatial use and dive behaviour over time in a benthic seabird, the Kerguelen shag, and their implications for foraging success**

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Individual specialisation, which occurs when individuals use a small subset of the population's resource base, has received a growing attention in the past decade. However, quantitative measures of it are lacking for most species and its implications are poorly known. In the present study, Kerguelen shags (Phalacrocorax verrucosus) were used to investigate the relationships between foraging specialisations, foraging success and body condition. A total of 21 nesting pairs were fitted with GPS loggers, 6 of which were also instrumented with a dive behaviour data logger. The loggers recorded between 3-18 successive trips for each bird, with 10 individuals being instrumented in incubation and again a month later when rearing chicks. A total of 233 trips were obtained. Adults and their chicks were weighed before and after deployment to estimate foraging success. Species in

the blue-eyed shag complex have been suggested to display foraging area fidelity and fidelity to one or more specific depth ranges. Here we show that some individuals not only visited the same foraging grounds on consecutive trips but did so repeatedly over a one-month interval. Maximum distance to the colony (range: 0.2km-26.6km), trip duration (range: 0.7h-18.1h) varied greatly between individuals. Individual mean and maximum dive depths also differed markedly, ranging from 2.3 to 58.3 m and 6.1 to 85.4 m, respectively. A remarkable consistency in individual dive depth was exhibited in most individuals. As benthic foragers, Kerguelen shags appear to exhibit strong individual differences in specialisation. The implications for foraging success and whether specialists pair with other specialists, as well as the effect of age on specialisation, were investigated.

**PS24.8 Revisiting the organization of foraging behaviour in little penguins from colonies with contrasted bathymetry through the lens of fractal analysis**

Xavier Meyer[1], Andrew MacIntosh[2], Akiko Kato[1], Andre Chiaradia[3], Thomas Mattern[4], Cédric Sueur[1], Yan Ropert-Coudert[1]

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Animal behaviour (e.g. movement, foraging) exhibits fractal structure, complex patterns that repeat across a range of measurement scales and exhibit a degree of determinism characterized by self-similarity, self-affinity and/or long-range dependence. Theory predicts the production of complex, fractal foraging patterns as an optimal strategy particularly under heterogeneous environmental conditions. Studies also show that in the presence of stressors, the organizational structure of behaviour sequences becomes less complex, i.e. more stereotypical, further suggesting that complexity is biologically adaptive. Few studies have empirically linked fractal complexity in foraging sequences to environmental conditions, and even fewer if any to reproductive success. To address this, we used a published data set collected on little penguins (Eudyptula minor) from four colonies which showed that bathymetry was the key factor explaining changes in diving effort and breeding success. These data show that penguins foraging in shallower waters displayed a lower diving effort but greater fledging success than penguins foraging in deeper waters. Here we re-analysed these data using fractal time series analysis to test whether environmental conditions (i.e. variations in bathymetry) affect complexity in foraging sequences. Preliminary investigations suggest that dive sequence complexity is significantly greater in penguins foraging in deeper waters. Considering the published data, complexity thus appears to be associated with increased diving effort and decreased breeding success across colonies, strongly suggesting that maintaining necessary levels of complexity in foraging sequences for prevailing environmental conditions is an energy intensive process. Our analytical approach can thus provide novel information about the influence of the environment on behavioural processes in diving animals like seabirds which are often used as environmental indicators.

## PS25 Population Monitoring

**PS25.1 Vocal Activity as a Low Cost and Scalable Index of Seabird Colony Size**

Abe Borker[1], Matthew McKown[2], Joshua Ackerman[3], Collin Eagles-Smith[3], Donald Croll[1], Bernie Tershy[1]

*[1]University of California - Santa Cruz, [2]Conservation Metrics , [3]U.S. Geological Survey, Western Ecological Research Center*

Although seabird conservation actions have increased globally in number and complexity, the lack of scalable, cost-effective monitoring methods limits adaptive management and the evaluation of conservation efficacy. Automated sensors and computer-aided analyses provide a scalable and increasingly cost-effective tool for seabird monitoring. A key assumption of automated acoustic monitoring of birds is that measures of acoustic activity at colony sites are correlated with the relative abundance of nesting birds. We tested this assumption for nesting Forster's terns (Sterna forsteri) in San Francisco Bay for 2 breeding seasons. Sensors recorded ambient sound at 7 colonies that had 15-111 nests in 2009 and 2010. Colonies were spaced at least 250 m apart and ranged from 36 to 2,571 m². We used spectrogram cross-correlation to automate the detection of tern calls from recordings. We calculated mean seasonal call rate and compared it with mean active nest count at each colony. Acoustic activity explained 71% of the variation in nest abundance between breeding sites and 88% of the change in colony size between years. These results validate a primary assumption of acoustic indices; that is, for terns, acoustic activity is correlated to relative abundance, a fundamental step toward designing rigorous and scalable acoustic monitoring programs to measure the effectiveness of conservation actions for colonial birds and other acoustically active wildlife. We discuss extensions of these findings to additional species and other acoustic approaches, as well as important limitations for the design of acoustic monitoring programs.

**PS25.2 Passive acoustic monitoring of breeding wedge-tailed shearwaters and black noddies on North West Island, Australia, a viable method for monitoring long term trends**

Matthew McKown[1], Andrew McDougall[2], Abram Fleishman[1], Graham Hemson[2]
*[1]Conservation Metrics, [2]Queensland Parks and Wildlife Service*

The Great Barrier Reef Marine Park (GBRMP) hosts breeding populations of 22 seabird species potentially breeding on over 900 islands. A review of seabird monitoring data from the Great Barrier Reef Marine Park concluded that existing survey data were insufficient to meet a monitoring goal of detecting a 10% change in seabird populations over a 20-year period. Given the scale of the GBRMP, the review concluded that managers should adopt new monitoring technologies to help meet these goals. We compared data from passive acoustic surveys to traditional seabird surveys (2 nest counts/season) for wedge-tailed shearwaters (Ardenna pacifica) and black noddies (Anous minutus) on North West Island in the Capricornia Cays National Park, Queensland, Australia, to evaluate the utility of automated acoustic surveys for long term monitoring of these species. While traditional surveys provide a snapshot of nesting activity at a given point in the season, acoustic surveys have the potential to provide information on phenology, daily activity patterns, relative abundance, as well as a statistically robust index to compare through time. Wedge-tailed Shearwater call rates were significantly correlated with burrow density in 2012/2013 and 2013/2014 ($r^2 = 0.69$, $p < 0.05$ and $r^2 = 0.84$, $p < 0.05$ respectively). Black Noddy call rates are also correlated with nest densities in the 2 weeks before and after each nest count ($r^2 = 0.6$, $p < 0.05$). Acoustic activity showed consistent seasonal patterns across breeding sites for both species. Our results indicate that acoustic monitoring can be an effective tool for monitoring seabirds at the scale required for the GBRMP.

**PS25.3 How to monitor endangered seabirds in remote and treacherous locations without plummeting to your doom**

Andre Raine[1]
*[1]Kauai Endangered Seabird Recovery Project*

Kaua'i holds approximately 90% of the World population of the Newell's Shearwater Puffinus newelli, along with internationally important numbers of Hawaiian Petrel Pterodroma sandwichensis. Monitoring these species is particularly challenging as they are nocturnal, rare, patchily distributed, breed in remote, upper montane habitats and nest on steep, often heavily vegetated cliffs. Monitoring therefore requires the use of a range of technologies and techniques to allow for a colony wide approach. Management for both species is currently on-going at four different colonies in the north-west of the island, with the main management tool being invasive predator control (both species are targeted by cats, pigs, rats and Barn owl). The Kaua'i Endangered Seabird Recovery Project monitors all of these areas to assess the effectiveness of management. Active seabird burrows are located through a combination of auditory surveys and cold searching in areas with high activity rates and suitable breeding habitat. All burrows located are individually marked and visited on an annual basis throughout the breeding season to calculate annual Fledging Success Rates. Remote cameras are placed on a sub-set of individual burrows to track burrow attendance, along with visitations by introduced predators and predation events. At the colony level, song meters (acoustic recording devices) are deployed at ten fixed locations in each management area and set to record during peak vocal periods each night from May to August. These units allow monitoring to occur over dangerous and inaccessible areas, as well as being used to track changes in call rates over each successive year, allowing for an assessment of the change in overall colony activity rates. Results of monitoring efforts in the 2013 and 2014 breeding seasons are discussed in the context of overall seabird management and the merits of each monitoring technique.

**PS25.4 Radar survey of Cory's shearwater population in Corvo Island, Azores**

Pedro Geraldes[1], Ricardo Tomé[2], Martin Poot[3], Nadine Pires[2], Alexandre Leitão[2], Filipe Canário[2], Nuno Oliveira[1], Sandra Hervias[1], Inês Rosário[2], Paulo Cardoso[2]
*[1]SPEA, [2]STRIX, [3]Bureau Waardenburg*

Radar survey of Cory's shearwater population in Corvo Island, Azores Pedro L. Geraldes(1), R. Tomé (2), M. Poot (Bureau Waardenburg), N. Pires (2), A. Leitão (2), F. Canário (2), N. Oliveira (1), S. Hervias (1), I. Rosário (2), P. Cardoso (2) 1 - SPEA; 2 - STRIX Nocturnal burrowing seabird populations are traditionally difficult to survey due to their habits, specially in islands of difficult access and geography such as Corvo. Corys' shearwater population in Corvo is one of the largest in Azores. In this study an exploratory approach to the study of these populations was made with the use of RADAR technology within the Scope of the Life Project "Safe Islands for Seabirds". This was the first time that a radar was used in Portugal to study seabirds, although this technology has been used before elsewhere to study seabird movements at sea and to monitor breeding procellariform populations. The equipment used was a mobile radar, band X, with 25 Kw of power and 9410 MHz, used both in horizontal and vertical sweeping mode with 1,5 km of range. The images obtained were continuously recorded for 4 nights, totalling more than 28h. Testes were conducted from points in land and from a boat travelling along the cliffs to determine: number of birds/h, mean highness of flight, population estimates per surveyed area, period of maximum activity, patters of flight, etc.. The data was later analysed with the program BirdMonitor and visually checked to eliminate errors and to confirm positive identification of targets. The highest density of birds recorded was 721 birds/ km2/h, and the mean highness of flight was 131,14 m. The population within the surveyed area of the coast was estimated in 2000-2400 birds, which is supported by the large rafts counted in the vicinity of the areas surveyed. Radar technology was concluded to be very useful to study these birds in otherwise inaccessible areas and to identify breeding areas and estimate breeding populations.

**PS25.5 Accounting for non-detection in Antarctic seabird breeding distributions derived from rapid site visits**

Michael Schrimpf[1], Heather Lynch[1]
*[1]Stony Brook University*

Research on Antarctic breeding birds has traditionally been concentrated at a few sites near research stations, or on species that can be monitored by remote sensing technologies. Brief site visits allow for broader mapping of species distributions and provide a more complete characterization of habitat use, however, such methods often entail logistical constraints which limit the detectability of breeding occurrence. We use rapid surveys from vessels of opportunity combined with published census data to map breeding distributions of all seabird species in the Antarctic Peninsula region. By using Bayesian site-occupancy models to estimate non-detection and accounting for the spatial pattern of observed breeding locations, we project estimated breeding range maps for the entire avian community. Our results assign probabilities of occurrence on areas in which breeding has not been observed for each species, providing predictions that can be tested with future site visits. We suspect that some of the distributional patterns we observe may emerge from interspecific interactions at and near breeding colonies.

**PS25.6 An ode to the Pacific Ocean Biological Survey Program and its biologists, 1963-1969**

Autumn-Lynn Harrison[1]
*[1]Smithsonian Conservation Biology Institute*

From a grant agreement made with the U.S. Department of Defense in 1962, the Smithsonian Institution initiated the Pacific Ocean Biological Survey Program (POBSP). From 1963 to 1969 over 40 biologists conducted surveys in the Pacific Ocean in the area bounded by latitude 30 degrees north to 10 degrees south, and longitude 148 degrees to 180 degrees west. Banding efforts and observations of migration, distribution, and reproduction of pelagic birds were a major priority; over 1,800,000 birds of 56 species were banded and approximately 150,000 at-sea observations of seabirds were made. The Smithsonian Institution recently catalogued the full collection of historical papers and field notebooks related to the POBSP. This talk will revisit the program, synthesizing and presenting data, information, and personal perspectives found within historical reports, correspondence, interviews, maps, photographs, and field notebooks of the participating biologists. Links between historical information and contemporary understanding of Pacific Ocean seabirds will be made.

**PS25.7 Sooty and Pink-footed shearwaters declining off Valparaiso, central Chile: seasonal trends and possible causes**

Alejandro Simeone[1], Luis Cabezas[2]
*[1]Universidad Andres Bello, [2]Birdlife International Chile*

Seabird conservation has deteriorated faster in the last decades compared to other bird groups and Procellariiformes are the most threatened seabirds. Long-term monitoring has been pointed as a crucial tool to detect population trends in endangered species and thus improve their management and conservation. In 2006 we started a seabird monitoring programme at the Valparaiso Bay in central Chile (33°S), a key commuting and stopover area for boreal and austral migrants and a relevant foraging zone for Australasian seabirds. At-sea abundance of seabirds was monthly

determined by counting animals from a boat along a linear transect. In this study we present information for Sooty (Ardenna grisea, SOSH) and Pink-footed (A. creatopus, PISH) shearwaters, two endangered seabirds with key ecological roles in the Humboldt Current. To estimate seabird density, we used the program DISTANCE 6.0. Monthly records were grouped into seasons and to estimate inter annual trends, we calculated seasonal anomalies of shearwater densities. SOSH presented a constant presence in the area (97% frequency) while PISH occurred mostly during spring-summer (60% frequency). Density anomalies for SOSH showed no significant tendencies in most seasons ($p>0.5$), except for autumn in which a negative trend was evident (permutation test, simple linear regression, $p= 0.015$). This time of the year coincides with SOSH northward migration to wintering areas. PISH showed no significant trends for most seasons ($p> 0.8$), except for spring which exhibited a significant negative trend ($p= 0.04$), coinciding with their southward migration back to their breeding areas. For each species, the reasons for density decrease appear to be located in different geographical areas but both are presumably related to fishery interactions: south-central Chile for SOSH and southern Peru for PISH. Financial support was provided by research grants from the Vicerrectoria de Investigacion y Doctorados, Universidad Andres Bello to AS.

**PS25.8 Are there more yelkouan shearwaters than we thought?**

Dilek Sahin[1]
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Yelkouan shearwater (Puffinus yelkouan) is one of the least known endemic species in the Mediterranean Basin. Its breeding behaviour hinders to make precise population estimation from breeding colonies. Land based count data from the Bosphorus reveal that remarkable numbers of yelkouan shearwaters are passing along the site just before the egg-laying period. Ninety thousand birds counted in four hours and this total is well corresponding the global population estimates. Continuous passage after four hours draws attention to reconsider the estimates derived from breeding colonies and gives rise to a discussion on how accurate these estimates are and are there any possibility to make more precise estimates with land-based counts. The aim of this paper is to emphasize the value of the Bosphorus in monitoring Yelkouan shearwaters and call for standardised land-based counts during the February passage of the species in order to support global population estimates.

## L5 & L6 Outcome Based Conservation Symposium and Workshop

**L5.1 Investing in full life cycle seabird conservation: measuring outcomes and tracking success**

Scott Hall[1], Anthony Chatwin[1], Ian Davidson[1], Claude Gaston[1], Daniel Petit[1]
*[1]National Fish and Wildlife Foundation*

Seabirds represent a diverse group whose life histories are intricately linked to marine and coastal resources: globally, 97 of 346 seabird species are threatened. In this context, the National Fish and Wildlife Foundation initiated the Seabird Keystone Initiative in 2009. Investment strategies and expected conservation outcomes were outlined in a 10-year business plan. In 2011, an updated 5-year business plan was developed for the conservation of Pacific seabirds. The Pacific seabird business plan is focused on improving the survival, reproduction and knowledge of ten seabird species; the plan identifies five principle conservation strategies for improving species status across four major geographic regions. Species selection, threat identification, potential conservation

actions/projects, theory of change "results chains", tracking metrics and species outcomes were developed through ranking exercises, expert solicitation and partner input. The resulting material allowed the Foundation to construct a portfolio of investments and timelines targeting threat reduction across the full life cycle of priority species. Project specific and portfolio level metrics and outcomes were developed for evaluating progress. In 2014, a program audit was conducted by an external review team to assess program architecture, progress and impact - the resulting analysis provided guidance for refining investments and future planning efforts.

**L5.2 The Eradication Calculation: Why One Donor Invests in Island Restoration**

Curt Riffle[1]
*[1]David and Lucile Packard Foundation*

The David and Lucile Packard Foundation's (Foundation) Marine Birds subprogram began working with grantees in 2006 to identify islands where eradications could most cost effectively contribute to seabird conservation. These islands were selected based on several criteria including: a) relatively high confidence that the eradications could succeed; b) the impact on seabird populations would be significant in relation to the cost of eradication; and c) the island would have a low likelihood of re-invasion. The Foundation hired the Redstone Strategy Group in 2008 and again in 2013 to analyze over 1,000 islands around the world where the 98 threatened seabird species bred (or recently bred). The objective was to identify those island where projects to eradicate invasive species would offer the greatest return-on-investment (ROI) in the campaign to protect and restore seabirds. The analysis revealed that removing invasive species on 178 islands in almost every part of the world would offer important benefits to these threatened seabirds. Redstone's ROI estimates for island eradications considered the potential benefit to threatened seabirds, the likelihood of success, and the associated cost. ? Potential benefits were calculated for each seabird-island pair and represented the effective reduction in overall threats to a seabird population that would result from eradicating invasive species on a given island. ? The likelihood of success was discounted from 100% by the percentage of the invasive threat that could not be expelled. ? Cost estimates reflected the total expense of the eradication projects including planning and implementation for each category of invasive species targeted. Costs also varied by the size of the island and the distance from a major port. Overall progress during the 2006 to 2012 time period exceeded expectations. At least 22 threatened species and seven near-threatened seabird species have or will benefit from completed or on-going eradications on 67 island groups with seven threatened species likely to dramatically increase their populations. This means at least 29 seabird species will less likely become extinct. During this period the Foundation did not insist that grantees work only on the most important breeding islands for threatened or near-threatened seabirds based on Redstone's analysis. Only 32% of the island eradications funded by the Foundation occurred on islands that were threatened seabird breeding sites, and of these, only 63% of the invasive species were deemed harmful to a threatened seabird species on the island. However, this flexibility allowed organizations to develop and mature, attract support from other funders, and increase their technical capacity. The ability to measure the potential increase in reproductive success requires a longer time-scale to verify and is dependent on the length of the seabird lifecycle. Other factors including bycatch and sea-level rise may also impact the recovery rate of a species (no projects were supported on islands with a maximum elevation lower than 10 meters to avoid investing in islands where breeding habitat will be lost to sea level rise.) Grantmaking strategies may shift to provide more support for biosecurity of

cleared islands and social attraction and translocation techniques to increase the benefits of eradications.

**L5.3 Tackling the big jobs: eradication of invasive species on high priority, challenging feasibility islands.**

Nick Holmes[1], E Hagen[1], A Wegmann[1], K Campbell[1], G Howald[1], B Keitt[1]
*[1]Island Conservation*

Invasive species are recognized as a primary cause of insular extinctions and a key threat to today's threatened island species. Eradication of invasive species from islands is a feasible restoration activity for many islands. Over 1100 successful eradications of invasive vertebrates have been undertaken worldwide, many providing demonstrable results in biodiversity protection and recovery of threatened species. The field of invasive vertebrate eradications is in a phase of increased replication, and many projects previously perceived as intractable are now being tackled, redefining what is achievable while uncovering new challenges and knowledge gaps. These projects are often on islands with disproportionately higher biodiversity benefits, including highly threatened seabird species, species impacted by climate change, plus socio-economic benefit for human residents. Challenges to the feasibility of these projects include limitations of the tools available, real and perceived risk influencing project acceptance by human residents, increasing project complexity in biodiversity rich tropical environments, risk to non-target species from implementation methods and adequate funding. Here we report new developments to tackle these challenges for island restoration, and global trends in project implementation. We use case-studies from the Juan Fernandez, Galapagos and Hawaiian Archipelagos to highlight approaches being used to advance planned island restoration, including application of social science methods and conflict resolution for working with stakeholders, recommendations for best practice for tropical rodent eradications, multi-lateral funding strategies, and combining eradication of invasive vertebrates with other restoration techniques.

**L5.4 Building a framework to prioritise conservation actions: the work of ACAP in facing land-based and at-sea threats to albatrosses and petrels**

Marco Favero[1], Mark Tasker[1], Rosemary Gales[1], Richard Phillips[1], Anton Wolfaardt[1], Wieslawa Misiak[1], Warren Papworth[1]
*[1]Agreement on the Conservation of Albatross and Petrels*

The Agreement on the Conservation of Albatrosses and Petrels is a multilateral agreement created with the objective of improving the conservation status of the listed species. Recognising the existence of a large asymmetry between the magnitude of conservation challenges, and limited human and financial resources, the Agreement developed a framework for prioritising conservation actions. The main purpose of this tool was to assist Parties and ACAP as a whole in implementing the Agreement's Action Plan more effectively and efficiently, by prioritising actions that are most likely to reduce adverse impacts on populations. The approach followed a semi-quantitative assessment, using a combination of expert judgement and available data, to determine priorities, with scores assigned to variables relating to the vulnerability of a particular seabird population, the severity of the threat and the likelihood of success of management action. Management actions that would address multiple threats are then grouped together, and ranked accordingly. Land-based and at-sea conservation priorities were scored separately, although using a similar approach. The framework

was originally developed, and subsequently refined and updated by an ad-hoc working group on priorities, with assistance and review from the Advisory Committee Working Groups and the Agreement's Secretariat. During the most recent 2014 review, the highest five land-based priority actions were the removal of cats and reindeer from Grande Terre (Kerguelen), house mouse from Gough Island, and cats from Formentera and Menorca, and to address the problem of avian cholera at Ile Amsterdam. Priority conservation actions for at-sea threats included 28 seabird populations and 27 fisheries (pelagic and demersal longline, and trawl). The primary purpose of the framework is to provide a tool for Parties, the Advisory Committee and Working Groups to effectively prioritise limited resources for implementing, or advocating for conservation actions. This framework was developed to provide a robust guide for decision-making, to be used in conjunction with expert opinion. In addition, the framework guides the allocation of the Agreement's funds in terms of defining research and capacity-building priorities, refining implementation reporting requirements for Parties and developing performance indicators. The framework is meant to be a living tool given the lack or partial data in many fields, both at breeding sites and at sea. For example, the current framework for at-sea threats identifies priorities in high seas fisheries at a coarse RFMO scale. Now that this framework is established, the work of the Agreement is to determine who can best progress the priority actions, e.g. Parties, ACAP's advisory committee and its working groups, or others. Where possible, desired actions are given a time-frame for completion.

**L5.5 Penguins: Main threats and priority conservation actions**

Pablo Garcia-Borboroglu[1], Dee Boersma[2], Phil Trathan[3], Charles-Andre Bost[4], Robert Crawford[5], Glenn Crossin[6], Peter Dann[7], Lloyd Spencer Davis[8], Santiago De La Puente[9], Ursula Ellenberg[0], Heather Lynch[11], Thomas Mattern[8], Klemens Putz[12], Phillip Seddon[8],
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Penguins are one of the most threatened groups of seabirds. Eleven of the 18 species are listed as threatened by IUCN, and 14 species have been upgraded to a more severe conservation status in the past twenty years. The Global Penguin Society used expert opinion and literature review to determine the most important threats to penguins and suggest priority conservation actions to address them. The assessment included 49 scientists from 12 countries. For each threat, we determined the risk, severity and impact. We categorized these threats into general themes: harvesting of adults for oil, skin, and feathers and as bait for crab and rock lobster fisheries; harvesting of eggs ; terrestrial habitat degradation; marine pollution; fisheries bycatch and resource competition; environmental variability and climate change; and toxic algal poisoning and disease. Habitat loss and degradation, pollution, and fishing, all factors humans can readily mitigate, remain the primary threats for penguin species. Around 80% of the threatened species occur on islands, increasing their vulnerability to threats such as introduced predators. Varying prey availability affected by climate variation is one of the most commonly suggested causes of population decline. Penguins depend on forage fish which include krill and squid. Since most species are predators constrained in distribution or foraging range, spatially explicit fisheries management plans that accounts for predator demands and consideration of climate change are imperative. We suggest protection of breeding habitat, linked to the designation of appropriately scaled marine reserves will be critical. However, large-scale conservation zones are not always practical or politically feasible. Other ecosystem based management methods that include spatial zoning, bycatch mitigation, and

robust harvest control must be developed to maintain marine biodiversity and ensure healthy ecosystem functioning across a variety of scales. Larger scale ecosystem-based conservation planning, with more focused local efforts are needed for the successful conservation of many penguin species.

**L5.6 Gadfly petrels: status, threats and priority actions**

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After the species covered by the Agreement for the Conservation of Albatross and Petrels, the next most threatened group of seabirds are the gadfly petrels (Pterodroma and Pseudobulweria). Of the 39 species the IUCN red List shows that 1 is Extinct, 6 are Critically Endangered, 8 Endangered, 12 Vulnerable, 4 Near Threatened and just 8 of Least Concern. They make up a complex, cryptic group found in tropical and temperate regions. Many are single island endemic breeders, often found in remote areas. Many are wide ranging when at sea, with some being highly migratory. The IUCN Red List assessment was used to assess severity and nature of threats and conservation actions required. Threats were shown to be introduced predators, habitat loss/alteration, light pollution and vulnerability due to limited numbers of known nesting sites as some of the common threats on land. Threats at sea, if any, are generally poorly known. Conservation actions required were heavily weighted towards invasive/problematic species control, with re-introduction, site protection and management, improved legislation, development of recovery plans and increased awareness and communication all scoring for smaller numbers of species. In addition, we undertook a gap analysis of relevant data held within the Global Seabird Tracking Database (www.sebairdtracking.org) to identify future tracking priorities for key species and sites. The Gadfly Petrel Conservation Group was established in 2008 by the BirdLife International Marine Programme with the aim of improving knowledge and conservation status of one of the most threatened and least known groups of seabirds. The Conservation group now has 110 members with expertise covering all species. This initial assessment of threats and actions will be circulated for expert review and addition via the members of the Gadfly Group. This will include an assessment of feasibility of conservation actions, though many are likely to be largely site dependent.

**L5.7 An overview of outcomes-based funding in relation to seabird conservation.**

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Outcomes-based approaches are increasingly widespread in education, medicine, development and social services, but not in conservation. This is unfortunate because outcomes-based approaches facilitate better projects and increased public support via: 1) agreed upon, transparent and measureable goals; 2) ability to compare effectiveness of different techniques and practitioners; and, 3) iterative improvements in quality and cost of projects. Outcomes-based funding is predicted to decrease US medical costs by 10% and has decreased the costs of protecting ground-nesting birds by 30% in Australian experiments. Common objections to outcome-based approaches are that outcomes are difficult to define, measure, and contract for, and that there are huge cultural barriers to change. In conservation, outcomes-based funding will require increased investment in third-party

monitoring and evaluation (ideally using standardized measures and randomized controls), changes to financial and operational models for both funders and practitioners, and a willingness to let go of poorly performing ideas and practitioners. Seabirds are an excellent group with which to advance outcomes-based funding within the conservation sector because their threatened status is well-documented, and most threatened species breed in known colonies where they are relatively easy to count and can be protected using proven approaches. However, because seabirds are long lived, changes to demographic rates may give more immediate information outcomes than waiting for population size responses.

## S20 Impacts of Marine Debris

### S20.1 A global assessment of plastic ingestion risk for seabird species

Chris Wilcox[1], Denise Hardesty[1], Erik van Sebille[2]
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Marine debris is a global pollution problem, and thought to be a major threat to biodiversity. Seabirds appear to be among the most heavily impacted taxa, with evidence for reduced body condition, fecundity, and direct mortality from both ingestion and entanglement in debris. We developed the first global risk assessment for marine debris impacts on seabirds. We use a global scale particle tracking model to predict the distribution of debris in the ocean, considering both the sources of the debris and the likely pathways of movement. We overlay this with the distribution of all the major seabird taxa to evaluate the exposure of each species to debris based on spatial overlap. We compare these estimates of exposure to the results of a major review of seabird diet studies to evaluate whether exposure is a reliable predictor of debris ingestion. Based on a statistical analysis of differences between exposure and observed ingestion, we evaluated which ecological characteristics are likely to bias seabirds towards significantly higher or lower rates of debris ingestion. Our results speak directly to management actions to address debris impacts on seabirds, as we provide a list of the relative exposure to debris and predictions for which species are likely to be heavily impacted based on their ecological characteristics along with a global map of expected impacts. Our analysis points a way forward to predicting the risk to marine species from this pervasive and growing threat.

### S20.2 Developing an Ecosystem Metric for Plastic Ingestion with Wedge-tailed Shearwaters (Puffinus pacificus)

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Wedge-tailed Shearwaters (Puffinus pacificus) were salvaged from O'ahu, Hawai'i to investigate the relationship of diet and condition to plastic ingestion. Necropsies were performed on 143 chicks; 70 from 2009 and 73 from 2010. Morphometric measurements, plumage characteristics, condition, and health were determined for nestlings. Principal Components Analysis was utilized to determine the relationship of nine individual characteristics. The first two axes explained 98.9% of the variation; percent down (indicative of age) had the strongest loading on PC1 whereas condition (amount of fat) and weight were the most important variables on PC2. Correlations were found between the PC axes and plastic and squid occurrence. On a subset of birds (25 per year), detailed analyses of proventiculus and gizzard contents were performed. 78% of shearwater nestlings contained plastic.

All six types of plastic were documented; fragments constituted the largest proportion of incidence, followed by line and sheet. There was no correlation between plastic amount and year for 2009 and 2010; however nestlings had more plastic in the proventriculus (average of 4.1 fragments, mean weight 0.106g) than in the gizzard (average of 2.9 fragments, mean weight 0.033g). The proventriculus of one bird contained 42 fragments. All birds contained squid beaks, and their abundance varied significantly by year ($p < 0.001$) with higher numbers in 2009. More recent analyses of adult shearwaters (2010-2014) have also revealed high plastic incidence, with an increase from historical samples collected 30 years ago in O'ahu: plastic incidence was 60% in 1984 (20 birds captured live) and 71% in 2014 (28 salvaged birds killed by predators). Together, these results underscore the value of Wedge-tailed Shearwaters as bio-indicators of plastic pollution.

**S20.3 Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics**

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We analyzed polybrominated diphenyl ethers (PBDEs), one of the major flame retardant applied to plastics, in the tissue of oceanic birds (short-tailed shearwaters, Puffinus tenuirostris). Toxicological effects of PBDEs on wild animals and human, especially disruption of thyroid hormone system, are of concern. The short-tailed shearwaters were collected in northern North Pacific Ocean. In 4 of 33 short-tailed shearwaters, we detected higher-brominated congeners (i.e., BDE209 and BDE183), which are not present in the natural prey (pelagic fish) of the birds. The same compounds were present in plastic found in the stomachs of the birds. Sporadic occurrence of higher-brominated congeners is ascribed to that the flame retardants are added to specific plastics products. The 4 birds showed higher concentration of PBDEs in the tissue (max: 186ng/g-lipid weight in fat, 65ng/g-lipid weight in liver) than the others (mean: 3.8 ng/g-lipid weight in fat and 0.8 ng/g-lipid weight in liver). We also observed sporadic accumulation of high concentration of PBDEs dominated by BDE209 in tissue of 3 individuals (up to 178ng/g-lipid weight) among 20 northern fulmar, Fulmarus glacialis collected in North Sea (mean: 23.3 ng/g-lipid weight). These data suggest transfer of additive-derived BDEs from ingested plastics to the internal tissue of seabirds and worldwide pollution of seabirds by ingesting plastics. Samples of seabirds from the southern hemisphere will be analyzed and the results will be included into the presentation on the conference.

**S20.4 The impacts of plastic on Western Aleutian Islands seabirds: detection of phthalates in muscle and embryonic tissues**

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We are investigating phthalate concentrations in seabirds inhabiting the far western Aleutian Islands, including auklets (Aethia spp.), murres (Uria spp.), puffins (Fratercula spp.), cormorants (Phalacrocorax spp.), and gulls (Larus glaucescens). Little is known about seabird exposure to contaminants in this remote region of the Aleutian Island archipelago, and this is the first study quantifying phthalates - the plasticizing chemicals that coat plastic objects - in any seabird species globally. These islands have no point sources of contamination, but are influenced by ocean currents

carrying contaminants and debris from other regions of the Pacific. Inorganic materials have been identified in stomach contents of 42 of 227 individuals. We have detected DMP (Dimethyl phthalate), DEP (Diethyl phthalate), BBP (Benzyl butyl phthalate), DBP (Dibutyl phthalate), and DEHP (Diethyl hexyl phthalate) in muscle tissues from individuals with and without inorganic matter in their stomachs. Differences in contaminants in species foraging at different trophic levels may indicate biomagnification of phthalates through the food chain. We found evidence of of phthalates within embryos from a tufted puffin, ancient murrelet, and a common murre, which indicates that these compounds are metabolically active and labile within the adult bird. Furthermore, this evidence raises the question of whether or not embryonic exposure to phthalates impacts chick development.

**S20.6 Assessing the utility of seabird wrecks for plastic debris monitoring**

Heidi Acampora[1], Rick Officer[1], Roisin Nash[1], Ian O'Connor[1]
*[1]Galway-Mayo Institute of Technology*

Bird wrecks commonly occur during and after rough weather events. However, the reasons for these mortalities are not always certain. This research aims to investigate the use of seabird stranding events as a tool for monitoring marine debris. Whilst fulmars (Fulmarus glacialis) are routinely used internationally following protocols established by the OSPAR Commission and Europe's Marine Strategy Framework Directive to monitor marine litter at sea, assessment of the utility of alternative seabird species is required in areas where fulmars are not abundant and hence, monitoring might be inconsistent. We investigated seabirds washed ashore along the east coast of Ireland during the winter of 2013/2014, including: 15 guillemots (Uria aalge); 14 razorbills (Alca torda); 4 gulls (Larus argentatus & L. ridibundus); 1 gannet (Morus bassana); 1 kittiwake (Rissa tridactyla); and 1 fulmar. Necropsies assessed health parameters, such as fat layer depth, presence/absence of parasites, ulcers, condition of internal organs, and stomach content analysis. Stomach analyses considered the proventriculus and gizzard separately. Each was washed through a 1mm sieve and all solid contents were analysed under a 10x/20 Leica EZ4 microscope. Changes in weather patterns and currents can alter food availability, weakening birds and their ability to withstand strong winds. Wrecked birds were found to have died from starvation. Ingestion of debris appears to be species-specific and related to the feeding mode of different species. These results highlight that not all seabirds are prone to ingestion of plastic debris, and therefore several species cannot be used for monitoring of marine litter.

**S20.7 A biochemical approach for identifying plastics exposure in live wildlife**

Britta Denise Hardesty[1], Chris Wilcox[1], Andy Revill[1], Daniel Holdsworth[1]
*[1]CSIRO*

Plastic pollution is a long-standing ubiquitous issue. Global use of plastics is continuing to rise and there is increasing interest in understanding the prevalence and risk associated with exposure of wildlife to plastics, particularly in the marine environment. To facilitate assessing the ubiquity of ingestion of plastics in seabird populations we developed a minimally invasive tool that allows for detection of exposure to plastics. Using a simple swabbing technique in which the waxy preen oil is expressed from the uropygial gland of birds, we successfully tested for the presence of three common plasticizers; dimethyl, dibutyl and diethylhexyl phthalate (DMP, DBP and DEHP respectively). These plasticizers are prevalent in the manufacturing of plastic end-user items which

often end up in the marine environment. Using gas chromatography-mass spectrometry and protocols to reduce background contamination, we can confidently detect targeted plasticizers at low levels. We present results from >250 birds of a dozen species using this new method. Applying this simple, minimally invasive approach is particularly appealing for detecting plastics exposure at individual, population and species levels. Using this approach we can begin to quantify plasticizer loads and, importantly, the method has no observed detrimental impacts to wildlife.

**S20.10 Elevated levels of plastic ingestion in a high-Arctic seabird**

Alice Trevail[1], Geir Gabrielsen[1], Susanne Kühn[2], Jan Van Franeker[2]
*[1]Norwegian Polar Institute, [2]IMARES*

Plastic pollution is of worldwide concern, however increases in international commercial activity in the Arctic are occurring without knowledge of the existing threat posted to the local marine environment by plastic litter. Here, we quantify plastic ingestion by northern fulmars, Fulmarus glacialis, from Svalbard, at the gateway to future shipping routes in the high Arctic. Plastic ingestion by Svalbard fulmars does not follow the established decreasing trend away from human marine impact. Of 40 sampled individuals, 35 (87.5%) had plastic in their stomachs, averaging at 0.08g or 15.3 pieces per individual. Critically, plastic ingestion levels on Svalbard exceed the ecological quality objective defined by OSPAR for European seas. Furthermore we present analytical results that suggest a tissue chemical burden that results from plastic ingestion. Such chemicals may cause disruption to the endocrine and immune system of birds, and thus the potential for population-scale effects are evident. This highlights an urgent need for mitigation of plastic pollution in the Arctic as well as international regulation of future commercial activity. The picture attached shows an example of the stomach plastic content from one fulmar on Svalbard. Scale bar is 1cm.

**S20.11 Seabirds and plastic interactions on Canada's three coastlines**

Jennifer Provencher[1], Alex Bond[2], Mark Mallory[3]
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Marine plastic ingestion by seabirds was first documented in the 1960s, but over 50 years later our understanding about the prevalence, intensity and subsequent effect of plastic pollution in the oceans is still developing. In Canada, systematic assessments using recognized standard protocols began only in the mid-2000s. With marine plastic pollution identified by the United Nations Environmental Program (UNEP) as one of the most critical challenges for the environment, a greater understanding of how plastics affect marine birds in Canada, along with a national strategy is timely and necessary. In order to better understand which and how many marine birds are affected by marine debris we reviewed reports of plastic ingestion and nest incorporation in Canada. Of the 91 marine bird species found in Canadian waters, detailed plastic ingestion data from multiple years and locations are available for only six species. Another 33 species have incidental reports, and we lack any data on dozens more. Future monitoring efforts should focus on characterizing the risk of plastic ingestion among understudied species, and on continued monitoring of species that are known indicators of plastic pollution internationally and found in multiple regions of Canada to facilitate comparisons at the national and international levels.

**S20.12 Plastic ingestion by tern island seabirds: a community-wide perspective**

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Michelle Hester[3], D. Michael Fry[1]
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We used standardized necropsies to assess the current status of plastic ingestion (incidence and loads) by seabirds breeding at French Frigate Shoals (FFS), Northwestern Hawaiian Islands (NWHI), and to investigate impacts of this pollution on focal species with high incidence rates. Between 2006 and 2013, we opportunistically sampled 350 specimens of 16 species: 233 specimens (66.6%) and 11 species (68.7%) had ingested plastic. While only one species represented a new record of plastic ingestion (the Brown Booby Sula leucogaster), we also documented this pollution in 10 other species, where plastic ingestion had been previously documented previously (1980s - 1990s). These species were very diverse, belonging to 7 families and 4 orders, and representing 5 distinct feeding guilds: albatrosses, tuna birds, nocturnal petrels, plunge divers and frigatebirds. Plastic ingestion also varied greatly within species, when individuals of different age classes were compared. In particular, chicks had significantly higher incidence rates and loads of ingested plastic, than conspecific adults. The highest incidence rate (100 %) was observed in 60 Tristram's Storm-petrel (Oceanodroma tristrami) chicks and 5 Bonin Petrel (Pterodroma hypoleuca) chicks. Laysan (Phoebastria immutabilis) and Black-footed (Phoebastria nigripes) Albatross also had high incidence rates (> 50% in adults, > 90% in chicks). Together, these data confirm that plastic ingestion is pervasive and affects a wide range of species breeding in Tern Island. Nevertheless, field-based observations of chicks of two focal species with high levels of ingestion (Tristram Storm-petrel, Laysan Albatross) did not reveal significant correlations between their body condition and growth rates and their plastic loads sampled via necropsy.

## S21 Ecosystem Services provided by Arctic Seabirds

### S21.1 Ecosystem services provided by seabirds: what projections can we make from waterbirds in general?

Johan Elmberg[1]
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To facilitate conservation efforts and wise-use decisions about marine resource use there is an urgent need to further the understanding of what ecosystem services are provided by true seabirds, and to establish methodologies for quantifying the values of these services. Recent reviews address ecosystem services for birds in general (Wenny et al 2011) and for waterbirds (Green & Elmberg 2014), but such analyses are still much needed for the true seabirds. I will use insights from previous general reviews to outline research needs, shortcuts, generalities, projections, and pitfalls in the study of ecosystem services in true seabirds. In doing so, I will contrast previous knowledge and current knowledge gaps with characteristics unique for many seabirds, e.g. small population size, highly localized (vulnerable) breeding sites, extreme mobility, K-selected life histories, bycatch mortality and methodological problems associated with studying them. Johan Elmberg, Kristianstad University, Sweden

### S21.2 The influence of seabird-derived nutrients on island food webs

Adam Cross[1], Ruedi Nager[1], Richard Luxmoore[2], Bob Furness[1]
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The input of nutrients onto island systems from seabirds can play an important role in driving terrestrial community dynamics. Arctic systems are often nutrient-limited and it is probable that seabirds can cause significant effects on land at these high latitudes. The nutrient cycling of seabirds is an important ecosystem service, which can potentially support terrestrial systems by, for example, improving primary production and the provision of nutrients to livestock. This study, based upon Scottish islands which are also nutrient-limited, looks at the effect of seabirds upon vegetation and the indirect flow of nutrients into mammalian herbivores. In particular this study focusses on the surface and burrow nesting species of the great skua (Stercorarius skua) and the Atlantic puffin (Fratercula arctica), respectively. From analysis of nitrogen isotopes over multiple years the influence of seabirds, as described by an enriched 15N signature, can be detected within vegetation influenced by seabirds, relative to control areas for both species. The enriched vegetation within seabird colonies also corresponds to an enriched 15N signature of mammalian hair, relative to control samples. This study thus shows a novel example of how nutrients deposited seasonally by seabirds not only permeate into vegetation but also into mammalian herbivores. This temporal subsidy, often reported with increased vegetative quality and growth, suggests that seabirds could benefit herbivores in a nutrient-limited environment.

**S21.3 Ecosystem services of seabirds on the Pribilofs: a community-based study**

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The ecosystem services of local subsistence resources, including seabirds, may change over time because of changes in social perception, economic need, and cultural patterns of use. Seabirds may strengthen ties to older ways of life and also have potential for future economic opportunities. However, modernization may direct interest away from seabirds as a cultural and economic resource. We look at the two villages on the Bering Sea's Pribilof Islands and investigate the current and historical ecosystem services as reported by the local communities. We conducted a survey and interviews of residents of the two communities, St. Paul and St. George, to assess opinions toward seabirds, and their subsistence use and cultural role. Seabirds provided cultural services and were generally regarded as important both to individuals and the wider community. Despite a long history of use, current levels of subsistence harvest (thus nutritional services) are low, and few people continue to actively harvest or visit seabird colonies. Respondents expressed desire for greater knowledge about seabirds and also concerns about the current economy of the islands and a lack of future development prospects. Despite the challenging economic conditions, the villages retain a strong sense of community and place value on their environment and on seabirds. Surveys indicated an interest in developing eco-tourism based around local resources, including seabirds, as a way to improve the economy.

**S21.4 The little auk population at the North Water Polynya. How palaeohistory, archaeology and anthropology adds new dimensions to the ecology of a high arctic seabird**

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The little auk is the most numerous seabird in the north Atlantic and it has its most important breeding area on the eastern shores of the high arctic North Water Polynya in Northwest Greenland.

Here an estimated population of 30 mill. pairs breeds in huge colonies. The little auk is a high arctic specialist feeding its chicks with large lipid-rich high arctic copepods. With warming of the sea the copepod species assemblage is expected to change to smaller less fatty copepod species with energetic and potentially population consequences for little auks. This presentation takes a broad interdisciplinary approach to the analysis of little auk ecology in times of change. Recent and on-going little auk studies at the North Water Polynya have shown the high densities of little auks(about 2 pairs/m2) breeding under the stones in the vast scree slopes, the highly specialized chick diet (80 % Calanus hyperboreus), the foraging ranges (75 km, GPS tracking) the local foraging behaviour (TDR), and yearly migration pattern (gls) where little auks disperse over the north-eastern Atlantic during winter. An interdisciplinary approach has added new dimensions to population history and human harvest. Lakes with runoff from the huge colonies are hypertrophic and clear signatures can be found in cores from the lake sediment telling the colony history since the last glaciation. A history where large climatic variations but also changes caused by the historic whaling, which nearly removed the plankton-feeding Bowhead whale population, took place. Anthropological research reveals how, though small in size, little auk is a significant resource for the Inuit with important cultural values attached and adding resilience to human populations in times where the dominant marine mammal prey is inaccessible due to seasonal or yearly variations in ice conditions. Archaeological remnants show that little auk has been a resource for successive eskimo cultures inhabiting the area.

**S21.5 Cultural ecosystem services from seabirds - signs of change and synergies?**

Martina Kadin[1], Tycho Anker-Nilssen[2]
*[1]Stockholm University, [2]Norwegian Institute for Nature Research*

Ecosystem services are co-produced by people and nature, resulting in strong links between societal changes and use or status of ecosystem services. New cultural services, most notably tourism, have emerged along with modern societies, while others have grown in numbers, for example books inspired by species and ecosystems. Accelerating pressures such as pollution, climate change and overuse of individual ecosystem services, threaten the continued delivery of a range of ecosystem services. Seabirds, on their own and as highly visible components of marine systems, are integral to cultural services in coastal regions. They are increasingly recognized for their contribution to scientific knowledge and as environmental indicators, aspects that are here considered ecosystem services when facilitating management and use of natural resources. Drawing upon two case studies, from the Baltic Sea and the Norwegian Sea, as well as additional examples, we explore how cultural services provided by seabirds can gain increasing importance and how synergies between services develop. Both case studies represent a history of changing use of ecosystem services, where mainly hunting and egging have stepwise been replaced by tourism and research-related services. Results from local research programs communicate marine environmental issues and inspire works of culture. The attractiveness of local tourism is enhanced by participatory seabird research, in turn providing inspiration for arts and literature, and increase the communicative value of the focal species. We find that the increasing spread of cultural products and the advent of new media, help build links between different cultural ecosystem services and create feedbacks into people's perceptions of seabirds and marine environmental issues. There is substantial potential in employing these synergy mechanisms to strategically highlight emerging environmental issues in marine systems.

**S21.6 Integrating ecology and economics to facilitate effective seabird restoration: Hawaii case study**

Julia Rowe[1], Creighton Litton[1], Chris Lepczyk[2], Kirsten Oleson[1]
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Seabird densities and ranges have decreased dramatically in Hawaii over the last 1,400 years since the arrival of humans. Prior to human arrival, Hawaii hosted >20 seabird species, but currently only six still breed in the main Hawaiian Islands, including two that federally listed. To understand the ecology and economics of seabird conservation and restoration in Hawaii, we addressed two important questions: (1) what are the costs and benefits of seabird conservation and restoration actions across Hawaii today, and (2) considering that nutrient transport from marine to terrestrial ecosystems is a major ecosystem service of seabirds, do seabirds in the currently low population densities in montane ecosystems in Hawaii still add a significant amount of marine-derived nutrients to these ecosystems? The costs and benefits of restoration actions were determined using a rubric specifically designed for this project. Because many costs and benefits naturally occur in bundles, these groupings were assessed and presented in a matrix. In regards to nutrient delivery, we quantified available inorganic soil nutrients (including nitrogen and phosphorous) in seabird and non-seabird plots, and used d15N in soil and the leaves of two common native plant species to determine the contribution of marine sourced nutrients from seabirds to these systems. Plant community composition was also quantified to determine if seabird nutrient subsidies alter vegetation composition. Compared to non-seabird areas, soil NH4+ was significantly higher and foliar d15N was higher in the dominant tree in the seabird plots. While significant amounts of N are still deposited by seabirds, plant community composition did not vary between seabird and non-seabird areas. Our findings indicate that seabirds are playing a key role in ecosystem service provisioning to the Hawaiian Islands and that integrating ecology economics will facilitate the most effective conservation of these important species.

**S21.7 Patterns and trade-offs among multiple ecosystem services from marine bird species**

Martina Kadin[1], Johan Elmberg[2]
*[1]Stockholm University, [2]Kristianstad University*

Ecosystem services (ES) are increasingly incorporated into management of marine and coastal resources. Local investigations of generation and utilization of ES are desirable but may be costly, highlighting a need to develop general tools helping to predict the ES associated with a particular resource or site. Functional guilds or trait-based approaches have been suggested as one way to predict the capacity to deliver desired ES. We assess the ES provided by six species, from pairs of two ecologically similar species in each of the families Anatidae, Alcidae and Phalacrocoracidae, and selected to show the applicability and limitations of such approaches applied to marine birds. The set of ES, interactions between them and differences between populations, are examined for each species. This helps to reveal when the characteristics of ES can be predicted based on knowledge from elsewhere or similar species, or when the local context needs to be analyzed. Our findings suggest that services more closely linked to ecological processes, which include many regulating and supporting services, are often similar within functional guilds. We also find that including breeding habits when defining guilds increases the general applicability of the concept. Cultural services, and services linked to local and scientific knowledge, depend to large extents on local context, on the

other hand. This complicates the process of generalizing results regarding interactions and trade-offs between ES for species or populations that make significant contributions to substantially different kinds of services.

## S22 Seabird Population Health

### S22.1 Declining Seabird Populations in the Salish Sea: Understanding the complex roles of disease, the ecosystem, and anthropogenic stressors

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The Salish Sea is a 17,000 km2 inland sea shared by the United States (Washington State) and Canada (British Columbia). Of the 172 bird species that depend on this marine ecosystem, 32% (n=55) are listed by the US or Canadian Federal government, the Province of British Columbia or the State of Washington as endangered, threatened or are candidates for listing. Numerous factors have been listed as causes for declines in Salish Sea bird populations including disease, forage fish availability, by-catch, derelict fishing gear, oil spills and harmful algal blooms. Unfortunately, understanding the significance of each of these stressors is fraught with challenges. Insufficient data on causes of mortality, disparate monitoring that prevents comparison of population trends on two sides of a bi-national ecosystem, and a lack of understanding regarding the interactive effects of stressors are just a few examples that obstruct understanding of bird declines, thus consequently inhibiting restoration efforts. We combined US (line transect) and Canadian (point count) data from both sides of the international ecosystem and showed that decadal declines in winter counts were most prevalent among pursuit divers (odds ratio 11.07, 95% CI 4.6-33.2, P<0.001) such as alcids (Alcidae) and grebes (Podicipedidae) dependent upon forage fish (odds ratio 7.66, 95% CI 3.9-15.8, P<0.001). Wide-ranging species without local breeding colonies also were more prone to declines (odds ratio 0.33, 95% CI 0.15-0.69, P=0.003). These findings do not discount the likely synergistic impacts of other stressors like disease (e.g. avian influenza), oil spills, and fishing by-catch. However, the relationship between prey and marine bird declines are sufficient for policy makers and managers to address forage fish recovery now, while continuing to investigate and better understand the role of other factors such as disease on marine bird population declines in the Salish Sea.

### S22.2 Diseases of endangered seabirds on Amsterdam island: tracking etiologic agents and introduction of biosecurity measures

Audrey Jaeger[1], Camille Lebarbenchon[1], Jean-Baptiste Thiebot[2], Karine Delord[2], Cédric Marteau[3], Koussay Dellagi[1], Christophe Barbraud[2], Thierry Boulinier[4], Pablo Tortosa[1], Henri Weimerskirch[2]
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Infectious diseases have the potential to cause rapid declines and extinction of endangered vertebrate species. Animals in Antarctica and the surrounding islands have evolved in relative isolation and are likely to be particularly sensitive to introduced diseases. Increased exposition to humans and exotic species has generated opportunities for the introduction of pathogens to native and endemic species. A dramatic example is the recurrent chick mortality occurring in seabird populations of Amsterdam Island, where breeds the endangered and endemic Amsterdam albatross. On this island, the impact and extent of epizootics have increased during the last ten years and

stress the urgent need for (1) the identification of the etiologic agents involved in these epizootics and (2) the investigation of the epidemiology of these pathogens in order to design relevant mitigation and prevention methods. Based on molecular analyses, we provide evidence for the presence of two potentially pathogenic bacteria species, Pasteurella multocida and Erysipelothrix rhusiopathiae, in the five seabird species breeding on Amsterdam. Demographic parameters and count surveys conducted on these bird species suggest that epizootics might affect only three of them, i.e. the sooty and yellow-nosed albatrosses and northern rockhopper penguins. P. multocida was isolated in pure culture from tissues sampled from the two former species, which strongly suggests that this bacteria is indeed the etiological agent. Genetic characterization of the isolates reveals very low diversity, suggestive of a recent introduction that may have been linked to poultry rearing. Although there is no evidence of epizootics in the Amsterdam albatross, recurrent chick mortalities on this species would have dramatic consequences. Strict biosecurity measures have been designed and implemented in order to limit the risk of pathogen transmission among the different populations, in particular during bird monitoring by scientists.

**S22.3 A fishermen-led program for reducing impacts of derelict fishing gear on seabirds**

Kirsten Gilardi[1], Jennifer Renzullo[1]
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Marine debris impacts coastal marine environments and marine wildlife worldwide. Morbidity and mortality in marine wildlife due to debris ingestion or entanglement is significant, in some places contributing to populations declines and recovery failure. In California, fishing gear entanglement is a significant cause of injury in seabirds and other marine wildlife presenting to wildlife rehabilitation centers. For 10 years the California Lost Fishing Gear Recovery Project has worked with commercial fishermen to recover hundreds of lost and abandoned commercial fishing gear from the ocean in order to reduce the entanglement hazard that derelict gear poses to seabirds and other marine wildlife. The Project has documented the presence of hundreds of marine organisms, including seabirds, in recovered gear. Most recently, the Project has worked closely with Dungeness crab fishermen to establish a financially self-sustaining gear removal program that is well-positioned to continue under the leadership of commercial fishermen alone. This presentation will review known impacts of marine debris, including fishing gear, on seabirds, and present a model program for mitigating impacts of marine debris on seabirds and other marine wildlife.

**S22.4 Demographic impact and potential constraints on population recovery following a highly virulent disease epidemic**

Grant Gilchrist[1]
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We investigated the impact of a recently emerged disease, avian cholera, on the survival, productivity and population growth rate of northern common eider ducks in the eastern Canadian Arctic. Mark-resight and nest monitoring models were used to estimate patterns of annual variation in vital rates at a long-term study site monitored before, during, and after a highly virulent multi-year epidemic. The appearance of avian cholera resulted in a precipitous decline in the apparent survival rates of both male and female eiders, the rate of which was predicted well by directly observed mortality events involving nesting females. The frequency of polar bear incursions onto the colony (which is increasing in associate with advancing sea-ice melt caused by climate change), and

harvest rates during the non-breeding season (which are declining due to changes in hunting management policy), had interactive effects with avian cholera prevalence, suggesting additive mortality. Avian cholera did not have an appreciable influence on nest success, which was determined primarily by clutch initiation phenology the frequency of predator incursions, and local weather conditions. The arrival of avian cholera coincided with a marked decline in breeding pair abundance in a previously growing population, which to date has not been offset by a compensatory demographic response.

**S22.5 Contributions to seabird health and wellbeing: best practices for preventing disease introductions to seabird colonies and enhancing seabird health knowledge by collecting samples from bycaught seabirds.**

Marcela Uhart[1], Flavio Quintana[2], Luciana Gallo[2], Esteban Frere[3], Kirsten Gilardi[1]
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Infectious diseases have the potential to cause rapid declines and extinction in vulnerable seabird populations. Human presence can inadvertently contribute to pathogen introduction and spread in otherwise secluded seabird strongholds. Dramatic evidence of this are the recurrent mortalities and reproductive failure from disease presently affecting three albatross species from Amsterdam Island, including the critically endangered and endemic Amsterdam albatross. Biological monitoring of populations requires periodic visitation to breeding sites, and some colonies are increasingly subject to (oftentimes-unregulated) public visitation. Yet very few sites have implemented biosecurity protocols and best practices guidelines for use by researchers and visitors to minimize the risk of disease introduction and transmission. Furthermore, lack of information prevents a thorough and accurate evaluation of the current and potential impact of diseases on seabird populations. Access to specimens for health evaluation is generally restricted, expensive and logistically challenging. For some species however, efforts to monitor the impact of fisheries through on-board observers is common practice. Nevertheless, seabird by-catch carcasses recovered from fisheries are currently under-utilized. With proper protocols and training, evaluation of carcasses from by-catch events could not only provide valuable information on population-level demographics, distribution patterns, genetics, and food habits, but also on overall health condition, pollution loads, and disease exposure. This will allow for the establishment of baseline health data for many species, and the early identification of pathological processes. This presentation will expand on a series of recommendations and technologies for improvement of seabird health knowledge and wellbeing, based on models being developed for albatrosses and large petrels.

## S23 Ecological/Evolutionary Rescue for Threatened Seabirds

**S23.1 Projected continent-wide declines of the emperor penguin under climate change: is there any demographic rescue?**

Stephanie Jenouvrier[1], Jimmy Garnier[2], Henri Weimerskirch[3], Christophe Barbraud[3], Hal Caswell[4]
*[1]WHOI - CEBC- CNRS, [2]Université de Savoie, [3]CEBC- CNRS, [4]WHOI*

Population endangered by climate change may avoid extinction if they can adapt and recover locally (i.e. evolutionary rescue) and/or if additional immigration sustains the local population (i.e. demographic rescue). The emperor penguin life cycle depends on sea ice, which is projected to decline by coupled climate models assessed in the Intergovernmental Panel on Climate Chang (IPCC)

effort. The population dynamics of all 45 known emperor penguin colonies was projected at each colony by forcing a sea-ice-dependent demographic model with local, colony-specific, sea ice conditions projected through 2100. Dynamics differ among colonies, but by 2100 all populations are projected to be declining. At least two-thirds are projected to have declined by>50% from their current size. We investigate if dispersal behaviors could rescue some local populations from extinction, helping to lessen the projected a decline of the global population. For most of the case examined dispersion have a little impact on the global population size dynamics and emperor penguin are critically endangered by future climate change.

**S23.2 The collapse of South Africa's penguin population: is there scope for ecological or evolutionary rescue?**

Richard Sherley[1], Fitsum Abadi[2], Res Altwegg[3], Barbara Barham[4], Peter Barham[4], Allan Clark[3], Robert Crawford[5], Katrin Ludynia[3], Nola Parsons[6], Les Underhill[3], Lauren Waller[7], Florian Weller[3]
*[1]University of Exeter, [2]University of the Witwatersrand, [3]University of Cape Town, [4]University of Bristol, [5]Department of Environmental Affairs, [6]SANCCOB, [7]CapeNature*

In the Benguela Ecosystem, environmental change and fishing pressure concentrated off South Africa's west coast have led to population decreases in seabirds. The African penguin, Spheniscus demersus, population declined by 90% at west coast colonies from 2004 to 2014 and by 65% overall. Annual survival estimates from multistate capture-mark recapture analysis averaged 0.81 (± 0.08) prior to 2002 and 0.61 (± 0.12) after this. In addition, first-year survival was below the level needed to maintain population equilibrium in recent years. Telemetry data at the meta-population level suggest little plasticity in initial post-fledging dispersal, with west coast fledglings tending to move into the ecologically degraded northern Benguela. However, surviving individuals may recruit into source populations elsewhere. A density-dependent response in breeding success may have allowed productivity to increase recently, but this has been insufficient to offset the population decline. The effect may have been weakened by local fishing pressure and prolonged effects from oil pollution. In addition, chicks grew more slowly and fledged in poorer condition. In some instances, chicks were abandoned en-masse prior to fledging as adults entered moult with them still in the nest. Adults show strong mate and colony fidelity, so have little flexibility to move to new breeding localities. Hence the west coast islands may now represent ecological traps. Meta-population persistence may depend on plasticity in natal dispersal. Efforts are underway to understand how this trait responds to density-dependence and environmental conditions in the hope that future conservation translocations could create demographically stable colonies in favourable environments.

**S23.3 Does bridling offer an insight into how North Atlantic common guillemots might cope with climate change?**

Tone Reiertsen[1], Kjell Einar Erikstad[1], Mike Harris[2], Rob Barrett[3], Sarah Wanless[2]
*[1]Norwegian Institute for Nature Research, [2]Centre for Ecology and Hydrology, [3]Tromsø University Museum*

Responses that enable species or populations to cope with environmental change include shifts in distribution and range, phenotypic plasticity, and micro-evolutionary processes (i.e. changes in populations' genetic composition). Here we show how colour polymorphism can be used to study micro-evolutionary processes in seabird populations and the potential for ecological and/or evolutionary rescue. In the North Atlantic the common guillemot Uria aalge has two genetically

distinct colour morphs, the bridled form with a white ring around the eye and the unbridled form. The frequency of bridling follows a north-south gradient, with frequency increasing with latitude. Although it has long been known that mating between the two morphs is random, to date no marked ecological differences between bridled and unbridled birds have been identified. Here we use long-term data on adult survival and breeding success from two populations of common guillemots with contrasting morph frequencies, the Isle of May, UK ( 56ºN, 4% bridled) and Hornøya, Norway (70ºN 30% bridled). Climate trends and projections also differ between the two colonies allowing us to test whether the morphs show different demographic responses to climate and if there are climate-related interactions. We also used geolocators to compare distributions of bridled and unbridled birds from the two colonies outside the breeding season. We discuss our findings in relation to potential mechanisms, whether selection is occurring during the breeding- or non-breeding season, if there is currently any evidence of evolutionary adaptations to global warming, and if so how these will be manifest

**S23.4 Early breeding gives best production: responses to climate change may explain different population trends of two sympatric gull species, Risto Juvaste**

Risto Juvaste[1]
*[1]University of Turku*

Many studies have shown that birds have different responses to climate change through their seasonal migration and breeding timetables. In this study, different variables were used to measure the timing responses to migration in two sympatric gull species, a long-distance migrant nominate Lesser Back-backed Gull (LBBG, Larus f. fuscus) and a short-distance migrant Herring Gull (HG, Larus argentatus). In Europe, the Finnish population trends of LBBG and HG contrast with the West European trends, where breeding is not restricted by ice cover. LBBG is a red-listed species in Finland due to population decrease of more than 50 % from the 1960s. Extensive colour-ringing data (over 30,000 gulls read-ringed in Finland during 1995-2014) was used to estimate breeding success and detailed migration timing of different sub-groups of the species. The analysis was mostly based on over 200,000 sightings (ring-reads) at Joensuu and Tampere dumps in Finland. In comparison with LBBGs, it was found that HG profited more from the global warming, because it's breeding has advanced more rapidly and early breeding gives better production. HGs profited also from the warm winters by foraging at refuse dumps. LBBGs as long distance migrants could advance their breeding only within colonies near dumps. Moreover, these two sympatric gull species often breed in mixed colonies and LBBG chicks are commonly predated by early breeding HGs.

**S23.5 Demography of the critically endangered Balearic shearwater: impact of fisheries, time to extinction and potential for rescue**

Ana Payo-Payo[1], Daniel Oro[2], David Alvarez[2], José Manuel Arcos[3], Miguel Mcminn[4], Rhiannon Meier[5], Russell Wynn[5], Tim Guilford[2], Meritxell Genovart[2]
*[1]IMEDEA-CSIC, [2]IMEDEA (CSIC-UIB), [3]SEO/BIRDLIFE, [4]SKUA, [5]National Oceanography Centre*

The Balearic shearwater Puffinus mauretanicus is the most endangered European seabird, due to a severe declining trend combined with its small breeding population (restricted to the Balearic islands), that led (a decade ago) to an estimated time to extinction of only ca. 40 years. Recent estimates suggest a larger population size, but the available information, despite subject to uncertainty, still points to a sharp population decline, which seems mostly due to fishing bycatch.

We updated the conservation diagnosis and assessed the impact of fisheries using data collected from 1985 to 2014. Two main fishing impacts were considered: bycatch (negative) and discard consumption (as an extra food supply, i.e. positive). We estimated several demographic parameters (including the probability of dying in fishing longlines) using multi-event capture-recapture modelling. We incorporated these parameters in a stochastic population model to assess population viability and forecast time to extinction under different management scenarios involving fishing policies. Breeding success was positively correlated with the availability of trawling discards, while adult survival, estimated at a colony free of alien predators, was much lower than the expected value for other Puffinus species, confirming the overall negative impact of fisheries. Population projections suggested short times to extinction despite the larger population size estimated in recent years. The buffering capacity of a higher breeding success resulting from exploiting fishery discards is limited because the low sensitivity of this parameter on population growth rate, but the incoming EU fishing policies banning discards may further accelerate the declining trend. This study shows that urgent mitigation measures are needed to stop or at least reduce the impact caused by additive mortality in fisheries. The potential of resilient mechanisms (ecological, evolutionary) in this endangered species will also be discussed.

**S23.6 Three species, three population crashes, one demographic model to contrast causes and consequences**

Deborah Pardo[1], Jaume Forcada[1], Andy Wood[1], Geoff Tuck[2], Louise Ireland[1], Roger Pradel[3], Richard Phillips[1]

*[1]British Antarctic Survey, [2]CSIRO, [3]CEFE*

Capture-Mark-Recapture models are a great tool for disentangling relationships between the demographic characteristics of wild populations and their changing environment. The current prognosis for many populations of albatrosses is particularly alarming, given their extremely slow life-cycles, high levels of incidental mortality in marine fisheries and the increased rate of environmental changes in Polar Regions. The wandering, grey-headed and black-browed albatross populations of Bird Island, South Georgia have decreased by 40-60% in the last three decades. This sympatric species framework offers a great opportunity to unravel the main causes of population change as they exhibit contrasted life-histories (e.g. breeding frequency, wingspan, sexual dimorphism). We constructed a multi-event model that allows the investigation of more than 30 years of variations in key demographic rates (survival, return, breeding, and success probabilities) including immature and non-breeding life-stages as well as sexes. Specific climatic (local and global), fisheries (demersal and pelagic longlines and trawling efforts in the whole Southern Ocean) and population (density-dependence) covariates were collated for the foraging zones used during breeding and non-breeding by each species. We addressed 5 main questions: What are the most influential climatic drivers in each species? Is there a significant impact (positive or negative) of fisheries? Can we notice density-dependence effects? Are there remarkable sex and age distinctions? How do species differ in their responses and what can we expect for the future?

## W3 Advancing Gadfly Petrel Conservation

**W3.1 Current wintering habitat and predicted changes induced by global warming of an endemic seabird of Reunion Island : The Barau's Petrel (Pterodroma baraui)**

Brice Legrand[1], Aurore Benneveau[1], Audrey Jaeger[1], Patrick Pinet[1], Matthieu Le Corre[1]

*[1]Université de la Réunion*

Climate changes negatively impact terrestrial and marine ecosystems all over the world. Because of their restricted distribution, endemic organisms are particularly fragile and sensitive to climate changes. We investigated the wintering marine habitats used by the Barau's Petrel (Pterodroma baraui), an endemic endangered seabird of Réunion Island (western Indian Ocean). We tracked adult Barau's Petrels using geolocators during three different years (2008, 2009 and 2012). We built habitat suitability models to determine the environmental drivers that influence the selection of the marine habitats of the species during its wintering. Suitability models were then used to predict changes in the location and size of wintering habitats in 2100 according to different IPCC scenario of climate changes. After breeding, Barau's petrels consistently migrate eastward to a large oceanic area located in the central and eastern Indian Ocean, on both side of the 90th ridge. The three main factors that best predicted the presence of wintering Barau's Petrels were surface wind speed, sea-surface temperature and chlorophyll-a concentration. We identified three distinct sub-areas highly suitable for the species, within this large wintering zone. These areas may change in location and size in the future according to IPCC scenario RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. The current wintering area will be 350 km further east and the total suitable habitat for wintering Barau's Petrels may be reduced by 42%. We speculate that this reduction may lead to an increased intra-specific competition during the wintering period and thus to a reduced body condition of adults when returning to Réunion Island for breeding. The capacity of the species to adapt to climate changes and modify their migration patterns requires further investigations.

**W3.2 Use of an ornithological radar to investigate the breeding ecology and population size of nocturnal seabirds at Reunion Island (tropical Indian Ocean): implications for conservation.**

Benoit Gineste[1], Matthieu Le Corre[1], Mathieu Souquet[2]
*[1]University of La Réunion, [2]BIOTOPE Consulting agency*

Four species of petrels and shearwaters breed in Reunion Island, among them, two are endemic and endangered: the Mascarene Black Petrel (Pseudobulweria aterrima, CR) and the Barau's Petrel (Pterodroma baraui, EN). They breed on unreachable cliffs and mountains, which make them very difficult to study and monitor. They are heavily impacted by introduced predators at breeding colonies and by urban light attraction. We used an ornithological marine radar to quantify the flow of birds that commute from the sea to the colonies at night, at different spatial and temporal scales. The radar was positioned throughout the year, at low elevation, at the mouths of canyons and valleys used by seabirds as corridors. For each bird detected, we recorded altitude and time of flight (date and hours). The two most abundant species (Barau's petrel and tropical shearwater Puffinus bailloni) where detected in high numbers and showed distinct detection patterns: Barau's Petrels were detected in summer only, flew towards the colonies earlier at the end of the afternoon and went back to sea until sunrise. They tended to fly high in altitude, particularly when they returned to the sea. Tropical shearwaters were detected throughout the year, flew towards the colonies very synchronously, 45 mn after sunset (e.g. at complete darkness) and they flew at low altitude. Unlike petrels, they went back to sea before sunrise. We identified four major flight corridors, heavily used by large number of birds every night. For both species, radar counts show that thousands of birds flew inland each night, suggesting that their population sizes may be underestimated. This study shows that ornithological radars are indispensable tools to monitor nocturnal elusive endangered seabird species, especially at locations where most breeding places are unknown or unreachable. It brings good recommendations for urban development plans, particularly useful in a small mountainous island context.

**W3.3 State of knowledge, threats and conservation actions of the endangered Mascarene Black Petrel, endemic of the urbanized Reunion island.**

Francois-Xavier Couzi[1], Fabien Jan[2], Martin Riethmuller[2], Damien Fouillot[2], Eric Buffard[3], Marc Salamolard[4], Matthieu Le Corre[5], Patrick Pinet[4], Sébastien Jacquemet[5], Benoit Lequette[4]
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The critically endangered Mascarene Black Petrel, Pseudobulweria aterrima, is one of the rarest seabirds of the world, and its current population is in need of extreme urgent conservation. Since recently, this specie benefits of a National action plan (2012-2016), which identified major threats and management priorities. A recent LIFE European project (2014-2020) is now in progress. It will attempts to increase long-term conservation actions by implementing demonstrative and innovative large-scale management strategies and appropriate conservation tools. In this talk we will present the current knowledge of the species, based on a wide diversity of investigations conducted by our group since 1995: at-sea observations, nocturnal search of breeding places and recording of display calls, field prospections, rescue campaigns of birds attracted by artificial lights, stable isotope analysis for the study of the at-sea ecology and VHF radio tracking. We will provide an update of the current knowledge of nesting areas, breeding phenology and conservation actions undertaken to reduce the two main local threats: predation by introduced mammals (cats and rats) and additive mortality of fledglings and adults induced by urban lights. Future conservation management strategies for the next 5 years will be also discussed.

**W3.4 Nesting patterns and impact of introduced species for the nearly-threatened tahiti petrel *pseudobulweria rostrata* at Raiatea Island, French Polynesia**

Lucie Faulquier[1], Hélène De Méringo[2], Frederic Jacq[3], Eric Vidal[4]
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The Tahiti Petrel Pseudobulweria rostrata is a Near Threatened gadfly petrel known to breed in at least 5 localities of the Pacific Ocean. However, the breeding biology, the distribution and the conservation status of the species is poorly known. Raiatea Island is a small volcanic island located in the Society archipelago, French Polynesia. The presence of petrel burrows was reported for the first time in 2009 at the Temehani rahi plateau, Raiatea Island. To improve knowledge about the habitat and distribution of the species and identify potential threats, 8 field surveys were conducted at this site from 2010 to 2014. Information about burrows location and evidence of potential predators for this species were collected for the first time in French Polynesia. Additionally, camera-traps were installed, and feral cat control was performed during the 2 last years of the study. 80 burrows of Tahiti petrels were found, described and mapped, and their contents were recorded. Nests were very scattered; burrows occupancy and density were low (25% and 0,38 nests per hectare, respectively). The presence of six predator species was recorded on the site: black rats (Rattus rattus), Pacific rats (Rattus exulans), feral cats (Felis catus), domestic dogs (Canis lapus), wild pigs (Sus scrofa) and swamp harriers (Circus approximans). 90 cat scats, 10 dog scats and 8 harrier pellets were collected and their analyses revealed high levels of predation on Tahiti petrel. Bird remains were found in 15% of cat scats and in 100% of both dog scats and harrier pellets. One camera-trap showed evidence of one cat and two dogs damaging a petrel burrow. One cat was trapped in June

2014. These results strongly suggest the need of implementing further conservation actions in order to control alien mammals populations, and the review of the IUCN species status, which should be classified as vulnerable.

**W3.5 Foraging ecology of the theatened Gould's Petrel: implications for conservation**

Yuna Kim[1], David Priddel[2], Nicholas Carlile[3], John Merrick[1], Alana Grech[1], Robert Harcourt[1]
*[1]Macquarie University , [2]Macquarie University, [3]Office of Environment & Heritage*

Gould's Petrel, Pterodroma leucoptera leucoptera (Threatened), is the rarest Australian seabird and breeds at only four locations. Foraging ecology was investigated over the 2010-2011 and 2011-2012 breeding seasons by quantifying foraging movements and associated behaviours in relation to reproduction. Kernel density models derived from geolocator data showed an extensive foraging range off south-eastern and southern Australia and differences in foraging locations by season and between sexes. Core foraging areas were characterised by low concentration values of chlorophyll a, warm sea-surface temperature and deep water. Monitoring of nest attendance revealed 24-37 % of all trips were 1-2 days in duration, and 11-14% of trips were 3-5 days. Meal size of the provisioned chick increased with increasing trip duration, but did not differ between parents. It appears that individuals' behaviour might be changed by food availability as the environment changes. Variation in diet suggests that they forage opportunistically and flexibly, which is advantageous in dynamic marine environments. Changes in behaviour of the parents may consequently affect the growth of chicks. Although chicks seem to fledge successfully even when in poorer condition, their long term survival might below. Further study on chick survival in relation to chick provisioning will be needed to support future conservation management of this threatened species. Currently, there is no at sea protection as the core foraging area mapped for Gould's Petrel is not covered by marine reserves either with International Union for Conservation of Nature designations, nor Australian marine protected areas. The nominated mIBA in the Tasman will provide the protection for Gould's Petrel and other Procellariiformes that utilise similar areas. These recommendations will be used for an ongoing international collaborative program aimed at characterising seabird hotspots.

**W3.6 Spatially explicit individual-based simulation models reveal at-sea behaviour and space-use of a seabird: implications for conservation**

Jingjing Zhang[1], George Perry[1], Graeme Taylor[2], Claire Postlethwaite[1], Ashleigh Robins[1], Todd Dennis[1]
*[1]University of Auckland, [2]Department of Conservation*

The movement trajectories of free-ranging animals can provide information regarding their behavioural responses to environmental change and human disturbance. However, little is known about the at-sea behaviour of most pelagic seabirds as because of the substantial challenges of observing free-ranging individuals for prolonged periods. Reliable estimates of the movement and space-use patterns of threatened species are critical for evaluating the long-term effects of anthropogenic influence and population persistence. Here we present a spatially-explicit individual-based model (SEIBM) parameterised with empirical movement data collected by high-resolution (every 30s) GPS devices for the grey-faced petrel (Pterodroma macroptera gouldi). Based on the behavioural states inferred from a Hidden Markov model of movement trajectories, and assumptions of correlated random-walk movements, we evaluated the extent to which our SEIBM could generate credible predictions of the bird's movement. We then explored how different intrinsic biological factors, such as movement modes and capacity, affect space-use patterns of grey-

faced petrels while at sea. We also investigated influences of change of environments on foraging success rate and population size of this species by running scenario tests that included climate changes and more frequent fishery activities. Our SEIBM identified factors that might regulate energy budgets of the bird as they explore the seascape. Modelling the at-sea movement of the grey-faced petrel in a biologically-informed way contributes to understanding of to the ecology of this species. Our study shows that given basic understanding of a seabird's movement ecology, SEIBM can be utilized as a promising tool of species conservation.

**W3.7 Influence of adult foraging strategy on chick growth and breeding success in the grey-faced petrel Pterodroma macroptera gouldi**

Karen Bourgeois[1], Jemma Welch[1], Sylvain Dromzée[1], Graeme Taylor[2], James Russell[1]
*[1]University of Auckland, [2]Department of Conservation*

The grey-faced petrel Pterodroma macroptera gouldi is endemic to the North Island of New Zealand. Although grey-faced petrels are overall not threatened in New Zealand, they are only abundant at a few sites, and in very small declining populations at most other sites (e.g. small island colonies and remnant mainland colonies). Causes for decline can be varied, but are generally introduced mammal predation or changes in oceanographic conditions. Independently of predation, marked variation in chick development and breeding success has been observed among colonies, particularly between those located along the East and the West coasts. Variation in foraging strategies, either through location of foraging areas or trophic levels used, is suspected to be a major factor driving the variation in these breeding performances. We investigated the role played by adult foraging strategy in the variation of breeding performances. East and West coast colonies were monitored for breeding success and chick development as well as for adult foraging strategy during the 2013 and 2014 breeding seasons. We deployed geolocators and GPS devices to identify foraging areas, determined the frequency of chick feeding and adult foraging trip duration, and evaluated trophic position by stable isotope analyses of adult and chick diet and their prey. We found that grey-faced petrels breeding on the East coast tended to travel further from their breeding ground to feed, foraging for a longer period and thus fed their chicks less frequently. Stable isotope analyses revealed different δ15N and δ13C values between East and West coast breeders suggesting the use of different trophic levels and foraging habitats during chick rearing. An understanding of seabird diet and foraging strategy is integral to their conservation and management, as monitoring seabird trophic niche dimensions, foraging areas and reproductive parameters can elucidate causes for population declines.

**W3.8 Tracking the Bermuda Petrel: Using Archival Geolocational Data Loggers to Determine the Pelagic Range of the Endangered Nermuda Petrel or Cahow Pterodroma cahow**

Jeremy Madeiros[1]
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The development of miniaturized geolocational data loggers, or tags, has in recent years revolutionized understanding of the movements, range and foraging areas for a wide range of seabirds. Here, the impressively large oceanic range and rapid rate of movement of the endangered Bermuda Petrel or Cahow (Pterodroma cahow) are reported, obtained with archival tags that log data for estimating daily position. The resulting tracks made from this data have revealed that Cahows can utilize the entire width of the North Atlantic Ocean during the year, from the Bahamas

archipelago to palearctic waters near Western Europe. It was found that Cahows can range up to 2000 miles (3200 Km) from their only breeding colonies on the island of Bermuda, covering a total of 1600 to 5000 miles (2360 to 8000 Km) on each provisioning trip to obtain food for their chicks. In addition, it was revealed that they can achieve daily distances of350-500 miles (560 -840 Km), probably with the assistance of strong winds around North Atlantic storm systems, which provide free energy. Another finding was that the adult population divides into two widely separated areas of the North Atlantic during the non-breeding season (June to October), with one-third of tagged Cahows remaining within 1000 miles (1600 Km) of the breeding colonies, between Bermuda and eastern North America. The other two-thirds of tagged birds moved 2500 miles (4000 Km) to the northeast in the other direction, concentrating to the north of the Azores Islands. It is likely that Cahows utilize their far-ranging and fast flying ability to take advantage of oceanic productivity over a large area of the North Atlantic, which is a possible factor in the past survival and continuing recovery of this endangered species.

**W3.9 Advances in Scientific Understanding and Conservation of the Black-capped Petrel (Pterodroma hasitata)**

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The Black-capped Petrel, also known as Diablotin, is a Caribbean endemic confirmed to nest only on Hispaniola. Since the first range-wide breeding surveys in 2006, the International Black-capped Petrel Conservation Group has united a diverse collective of researchers and conservationists to dramatically increase knowledge of the natural history and conservation status of this little-known endangered species. Surveys confirmed populations and assessed general conservation status at four historic sites in Haiti and the Dominican Republic. Nest searching led to the first nests ever monitored for this species in 2011, with >80 active nests found by 2014. Nest success ranged from 61-75%, with failures attributed to predation by animals and humans and abandonment. Starting in 2012, surveys with marine radar and thermal imaging vastly improved our ability to detect flyways and new nesting areas and to objectively quantify numbers of birds flying to and from nesting areas. Vocalization data collected with autonomous recording units, combined with radar data, show promise for developing activity indices at breeding sites. The conservation status of this species appears dire. Unbridled conversion of the remaining cloud forest slopes to agriculture and pasture is the chief threat at Massif de la Selle which harbors ¡Ý80% of the known global population. Flyway conservation threats include fatal attraction to light sources, including forest fires, urban light and communication towers. Ongoing conservation efforts coordinated by group members include 1) community outreach and environmental education; 2) nest searching and monitoring with endoscopes and camera traps, fitting breeding adults with satellite transmitters to study movements at sea, and deploying marine radar to the island of Dominica to search for breeding petrels; and 3) conservation planning using Open Standards for the Practice of Conservation to guide and document our decisions.

**W3.10 Gadfly petrels: distribution, status, threats and priority actions**

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After the species covered by the Agreement for the Conservation of Albatross and Petrels, the next most threatened group of seabirds are the gadfly petrels (Pterodroma and Pseudobulweria). They make up a complex, cryptic group found in tropical and temperate regions. Many are single island endemic breeders, often found in remote areas. Many are wide ranging when at sea, with some being highly migratory. We summarize the IUCN Red List status for the 39 species found in this group, showing that 1 species is Extinct, 6 are Critically Endangered, 8 Endangered, 12 Vulnerable, 4 near threatened and just 8 of Least Concern. Many of the species in these groups are known or thought to share similar ecological requirements on the breeding grounds where the IUCN assessment shows introduced predators, habitat loss/alteration, light pollution and vulnerability due to limited numbers of known nesting sites as some of the common threats. We present tracking data for 15 species from this group, data that has been submitted to the Global Seabird Tracking Database (www.seabirdtracking.org) by a wide range of researchers. We present a gap analysis of priorities for key species and sites which are still to be studied via tracking. We discuss conservation priorities for the group as a whole, including those for which species action plans have been developed, and suggest policy mechanisms that could be used to advance their conservation.

## S24 Skuas/Jaegers: Travellers between the Poles

### S24.1 Partitioning the World?s oceans: foraging ecology of south polar and brown skuas during the interbreeding period

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Environmental variability and interactions with human activities outside the breeding season are known to shape population dynamics of seabirds. A challenge in identifying the underlying mechanisms is the lack of information on seabird foraging during the interbreeding period. To overcome this poor spatiotemporal integration, we used miniaturized geolocators (GLS) and feather stable isotopes to investigate the foraging habitats (GLS, δ13C), dietary habits (δ15N) and activity patterns (GLS) of three populations of south polar and brown skuas during the interbreeding period. Skuas show species-, population- and individual-specific wintering strategies. All south polar skuas migrate northward, but birds breeding inland (Svarthamaren, Atlantic sector) winter primarily in the tropical Indian Ocean, while those breeding along the Antarctic continent (Pointe Géologie Archipelago, Indian Ocean sector) stay in the sub-polar north Pacific. Hence, each population encounters different environmental conditions, with sea-surface temperature ranging from 16°C to 29°C. Feather δ15N values suggest that most moulting birds from the two locations feed at similar trophic levels. Subantarctic brown skuas (Kerguelen, Indian Ocean sector) also migrate north after breeding, but, unlike south polar skuas, they are not trans-equatorial migrants and remain primarily in subantarctic/subtropical waters of the Southern Hemisphere. Hence, skuas show species-specific wintering strategies within the Indian Ocean, with south polar and brown skuas targeting different water masses. Skua species and populations have very similar activity patterns during the interbreeding period. They spend > 80% of their time sitting on the water, suggesting that food is plentiful on the wintering grounds. The study highlights the complexity of skua wintering strategies,

with striking between population heterogeneity that has important implications for likely demographic responses to environmental perturbation.

**S24.2 Contrasting foraging strategies of brown skuas in response to local and seasonal dietary constraints**

Ana Bertoldi Carneiro[1], Andrea Manica[2], Richard Phillips[1]
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Foraging strategies of individual seabirds can differ substantially, resulting in the exploitation of different niches. The aims of this study were to examine the movements and foraging behaviour of brown skuas during two consecutive breeding seasons, 2011/12 and 2012/13, at colonies with contrasting diet and prey availabilities. A total of 33 and 24 GPS and immersion (activity) loggers were deployed on breeding adults at Bird Island (South Georgia) and King George Island (South Shetlands), respectively. Birds breeding at Bird Island feed mainly by scavenging seal carrion and placentae on beaches, and to a lesser extent by predation of other seabirds, whereas the main food resources on land for birds at King George Island are penguin eggs and chicks. In contrast to birds breeding at King George Island, none of the brown skuas at Bird Island travelled to the sea to feed on fish, and there was no clear evidence for specialist bird predators, as all the tracked birds spent considerable time scavenging on the coast. Seasonal variation in diet at King George Island seems to reflect relative prey abundance and availability, as well as ease of capture; by late chick rearing, tracked birds had to supplement the food obtained on land by travelling to the ocean to forage outside the bay. The variation in activity patterns among individuals that had broadly overlapping foraging ranges while foraging at sea suggests either considerable variation in feeding success (reflecting the patchiness of prey), or a degree of specialisation in feeding behaviour. Despite the pronounced sexual size dimorphism, there were no effects of sex on foraging time or habitat use. The results obtained in this study underline the marked variability in foraging strategies among different populations of these adaptable and highly opportunistic predators.

**S24.3 Arctic Skua migration: linking individual consistency, migratory connectivity and contaminant loads**

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Seabirds are often used as model species in ecotoxicological studies as they are near the apex of most marine food chains, and therefore bioaccumulate high concentrations of certain pollutants. Most seabirds that breed in temperate and Arctic regions are migratory, and therefore spend a considerable part of the year away from their breeding areas thereby functioning as biovectors. Several studies have implied that migration may have considerable effects on seabird ecotoxicology. In this study, we have studied migration strategies in the arctic skua Stercorarius parasiticus. It breeds in arctic and subarctic areas, and in Svalbard and Northern Norway, it spends the nonbreeding part of the year (September through May) away from the breeding grounds. We have used Global Location Sensor (GLS) loggers to track the migration strategies of the same individuals over several years. This has revealed different individual wintering areas spanning large parts of the

Atlantic Ocean. We report that the individual birds repeatedly target the same winter area year after year. We have analyzed various pollutants such as heavy metals and PCBs to look for individual differences in contaminant load related to different wintering areas.

**S24.4 Intra-population variation in foraging behaviour of great skuas (Stercorarius skua) indicates differential effects of marine renewable energy developments and fisheries activity**

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Human activities in the marine environment are increasing at an unprecedented rate. Marine renewable energy developments (MREDs) and fisheries are examples of activities with the potential to affect seabirds. To predict potential effects of these activities, understanding of seabird movements at sea is required. Extending estimations of responses of seabird populations to marine conditions, to consider the influence of breeding status and intra-population variation, can improve predictions of the effects of MREDs and fisheries on seabirds. In Scotland, the great skua (Stercorarius skua) is in decline and vulnerable to impacts of MREDs and changes in the EU Common Fisheries Policy. As little is known about great skua movements at sea, we used GPS tracking devices to investigate foraging behaviour throughout the breeding season; from incubation to fledging or failure. We investigated consistency in behaviour, and population- and individual-level relationships with remotely-sensed environmental variables. Breeding birds were more consistent than failed breeders in their foraging destinations and flight directions from the colony. This is likely attributed to breeding birds targeting temporally and spatially predictable foraging habitats; a strategy employed by birds constrained as central place foragers to sustain foraging success. This behaviour was observed less in failed breeders. Great skuas showed individual variation in relationships with environmental conditions, particularly in response to demersal fishing activity. This likely indicates individual dietary specialisms; suggesting that populations of this generalist seabird species may comprise individual specialists. Differing behaviour throughout the breeding season, and between individual great skuas, suggests the potential for differential impacts of human activities on subsections of great skua populations, which should be considered during environmental impact assessments and in marine spatial planning.

**S24.5 Long-term trends and spatial variation of egg sizes in the Great Skua**

Sjurdur Hammer[1]

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Egg size may be a suitable ecological indicator as egg production is a demanding process. Some studies have shown long-term declines in egg size for individual species and localised areas. What we are missing however are long-term studies of multiple species and on a wider geographical scale. With a compilation of egg sizes from field data and museum collections, this study investigates the long-term variation of over 10,000 Great Skua Stercorarius skua eggs across a wide spatial scale from 1809 to the present time as well as long-term trends in egg size of three seabird species breeding in the Faroe Islands. Great Skua egg size showed significant spatial and temporal variation. A significant temporal trend is apparent for Great Skuas eggs in the Faroes and similar trends of changes in Great Skua egg size have also occurred in different areas suggesting either widespread environmental

change, or feeding conditions have changed similarly over these areas. However, in the Faroes other seabird species such as Guillemot Uria aalge and Northern Fulmar Fulmarus glacialis eggs, which have also been examined showed different trends from that in Great Skuas, suggesting not all species, respond similarly to changes in the marine ecosystem. Large-scale geographic differences of egg sizes at different colonies indicate a predictable latitudinal gradient in egg sizes, but trends at different colonies also suggest wide-ranging temporal changes, which are discussed in relation to changes in fishing practices.

**S24.6 Interspecies differences in parental role division during the breeding season in two Antarctic skua species**

Jan Esefeld[1], Matthias Kopp[1], Simeon Lisovski[2], Hans-Ulrich Peter[1]
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Skuas are among the top predator species in Antarctica. Bigger Brown Skua (Stercorarius antarcticus lonnbergi) and smaller South Polar Skua (Stercorarius maccormicki) breed sympatrically in the Antarctic Peninsula region and even form mixed pairs, resulting in hybrids. Both species are already known to exploit different prey species in this region, but knowledge about intersexual differences in foraging investment, especially in mixed species pairs, and time management remains limited to date. In this study on Fildes Peninsula, King George Island, South Shetland Islands we aimed to find intersexual differences in parental role division and compared them among different pair types. Therefore we measured birds for size and recorded behavioral and foraging patterns by GPS-tracking, observations in the nest territory as well as regular nest visits during the breeding season. Results show, that Brown Skua partners have a similar foraging flight pattern, using a wide variety of food sources. At the nest they also share incubation and chick guarding time equally. In contrast South Polar Skuas exhibit a clear role division with males flying farther and longer for foraging while exploiting exclusively marine prey, whereas females spend more time incubating and guarding chicks. This division is even more pronounced in hybrid pairs. Body measurements show the sexual size dimorphism to be small in Brown Skuas, bigger in South Polar Skua pairs and especially distinct in mixed species pairs. Accordingly, a clear relation of role division and magnitude of sexual size dimorphism of those pair types living in the same Antarctic ecosystem is indicated. Aside from behavioral aspects we used these findings to provide insights on the evolution of reversed sexual size dimorphism in raptorial birds in general.

**S24.7 Tracking Brown Skua population during non-breeding season - Diverse but individually consistent movement pattern**

Johannes Krietsch[1]
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Migratory seabirds spend most time of their annual cycle far off the breeding grounds. Hence an understanding of the mechanisms behind the distribution and movements of those birds is crucial not only for our general understanding of the species' ecology but also for our ability to estimate consequences of environmental changes on seabird populations. One major question is whether the at-sea distribution of pelagic seabirds is driven by external environmental conditions like food availability, which is often highly variable between years, or endogenously controlled mechanisms and therefore rather conserved at the individual level. Brown Skuas (Stercorarius antarcticus lonnbergi) are top-predators breeding on Sub-Antarctic islands and are known to migrate into

temperate latitudes of the southern hemisphere. In this study we analysed 47 annual migration tracks from 28 individuals breeding on King George Island. Our dataset includes repeated tracks from 16 individuals over two or three consecutive years. Remote sensed chlorophyll a images were used to identify food availability patterns We found that Brown Skuas from one population using a large but highly productive area - over the Patagonian Shelf and shelf break, and on the confluence zone of the Falkland Current and the Brazil Current - during the non-breeding period. However, most individuals using only a subset of the entire distribution suggesting a low migratory connectivity and furthermore individuals tend to consistently use the same areas between years. Those patterns suggest that Brown Skua populations might be able to adapt to changing or variable conditions in food-availability. However this adaptation is more likely be driven by high variation within a population rather than by within individual flexibility.

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