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TUES, 26 MARCH, 2030 h

Alfred Newton Lecture

Professor Lei Cao

Regional Ecology, Research Center for Eco-Environmental Sciences (RCEES), Chinese Academy of Sciences, China

Using waterbird telemetry data to support freshwater wetland conservation in China

Despite attention focused on coastal wetland loss in China, freshwater habitat is also subject to rapid loss. Declines in migratory waterbirds overwintering on the Yangtze River Floodplain since the early 2000s contrast with the favourable conservation status of the same species elsewhere in Far East Asia. Evidence suggested that factors away from Chinese wintering grounds could contribute, but we lacked waterbird flyway definition to understand where along their migratory corridors these species were potentially being impacted. Recent deployment of over 2000 telemetry devices on 42 species of waterbird throughout Far East Eurasia confirmed the Yangtze River Floodplain's outstanding importance for wintering cranes, herons, ducks, geese, swans and wading birds, breeding from western Yamal (70°E) to Anadyr (180°E) in the Russian Arctic, throughout the eastern Russian taiga forest, the Mongolian steppes and temperate China.

Unlike farmland-feeding waterbirds in Europe, North America, Japan and Korea, telemetry showed that Yangtze River Floodplain waterbirds are prisoners of their wetland wintering habitat, trapped by economic development, disturbance and heavy persecution. Continued wetland loss and degradation has therefore affected all species along their migratory flyways. Specialist-feeding wintering waterbirds are increasingly concentrated at Poyang Lake (PL 29°8'N, 116°17'E) because of large inundation area (1,400 km^2), exceptional water quality (the "last pot of clear water" in the Yangtze River Floodplain) and nature protection measures. Telemetry data has also shown how recent

proposals to construct dams around PL will affect water level recession patterns and waterbird feeding at the last major Yangtze River Floodplain wetland of global significance, necessitating swift action to safeguard the site and its waterbirds for future generations.

Professor Lei Cao of RCEES at the Chinese Academy of Sciences, researches effects of climate change, habitat destruction and human disturbance on movement patterns, distribution and abundance of migratory waterbirds on the East Asian-Australasian Flyway. Professor Cao's group has combined deployment of cutting-edge telemetry devices with international waterbird monitoring and research throughout Eurasia to generate a better understanding and create a basis for their effective future conservation. Professor Cao has published over 60 articles on ecology, ornithology and multidisciplinary sciences in international journals including *Nature, Current Biology, Biological Conservation, Ibis, Ambio, Aquatic Ecology, Aquatic Conservation* and *The Condor*.

Migration distance and body condition drive shorebird migration strategies and stopover decisions during southbound migration

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Birds migrate some of the longest distances for their body size compared to other animals. Migration strategies are variable across birds, but technological constraints have limited the ability to compare and determine drivers of migratory behavior of small-bodied, long-distance migrants. The development of tiny VHF transmitters (< 1.0 g) paired with automated radio telemetry allowed us to track small shorebirds and test hypotheses about migration strategies of 6 shorebird species from a subarctic stopover site, the southwestern coast of James Bay, Ontario, Canada during southbound migration. We predicted that species with extreme-long-distance migrations (~9,000 to 11,000 km from James Bay; pectoral sandpiper and white-rumped sandpiper) would be more likely to follow time-minimizing migration strategies compared to long-distance migrants (~5,000 to 7,500 km; least sandpiper, semipalmated plover, semipalmated sandpiper, and lesser yellowlegs) that may follow a more energy-minimizing migration strategy. We found that extreme-long-distance shorebirds

accumulated higher fuel loads during stopover, migrated at faster airspeeds, and were less likely to make a subsequent stopover in North America, consistent with a time-minimizing migration strategy. This pattern did not differ for adult and juvenile birds. Departure and stopover decisions were dependent on body condition of individuals for all species and age groups, and birds with poor body condition had lower apparent survival after departing the stopover site and before crossing the Atlantic Ocean. Birds in poor condition that did survive this leg of migration were more likely to take an additional stopover in North America. This study shows that migratory behavior of small, long-distance migratory shorebirds has predictable patterns based on migration distance, but these patterns are moderated by body condition of individuals which has fitness implications.

Alexandra Anderson is an avian ecologist interested the ecology and evolution of migration and how bird populations respond to environmental change. She is a PhD candidate currently working with the James Bay Shorebird Project, a collaborative team working to conserve shorebirds in the Canadian subarctic.

Consistent patterns despite different environmental conditions? How environment affects bird migration patterns over Europe

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The spatial and temporal patterns of broad front bird migration are governed by the distributions of landmasses, mountain ranges, and weather conditions. These conditions influence migration performance including energy consumption, and timing of departure and landing, and are therefore crucial to the survival of birds through the migration season. Hence, migrants prefer favourable environmental conditions, which consequently lead to concentrations of migration, and to the evolution of migratory flyways.

To learn more about the drivers of these temporal and spatial concentrations, we developed a computational framework to simulate Europe-wide nocturnal passerine migration at the resolution of individual birds using an agent-based simulation approach.

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We simulated the autumn migration of the ten most abundant Palaearctic long-distance migrants. The spatial and temporal distributions of millions of migratory birds are modelled at a temporal resolution of 30 seconds along the western European flyway. We modelled the behavioural responses of the individual birds to the environment as presented by the wind flow as well as geographic barriers such as oceans and mountain ranges. The spatial and temporal variations of the wind flow are simulated using a mesoscale weather simulation tool; the geographic barriers are detailed from high spatial resolution satellite imagery. The recently available Europe-wide weather radar data provide the initial spatial and temporal intensities of simulated birds.

A goal of this work is to predict the continental-wide bird movements in order to provide insights on how the environment modulates birds' movement patterns as well as the birds' energy conditions. In this study we focus on a relatively short period of autumn migration to describe in detail the interconnectedness of environmental conditions and migration intensity patterns on a European level.

Annika Aurbach is a computational biologist with a main research focus on modelling movement behaviour. Currently her primary work is the implementation of a temporal and spatially explicit forecast model for bird migration patterns over Europe to predict areas of high collision risk with renewable energies such as wind turbines.

Changes of nocturnality of seabirds during migration and influence of the moon

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Long-distance migration comes with costs, which individuals can minimise by adjusting the relative amount of time they spend in key activities: moving, foraging and resting. Several terrestrial birds are nocturnal migrants (which prevents migratory flight from interfering with foraging during the day, provides them with more favourable flight conditions, and might provide them with orientation cues at sunset/during the night), but seabirds, as they can fly and forage at the same time and make long search flights, might have different, more diurnal strategies. Additionally, some terrestrial migrants have been found to adjust their daily activity budgets when crossing ecological barriers such as the Sahara, and we can wonder whether seabirds also do so when they cross unproductive waters (e.g. around the equator). Last, although the moon has been found to have very little effect on the day vs. night organisation of activity of terrestrial migrants, previous results on Cory's Shearwater *Calonectris diomedea* suggest that this might be different for seabirds.

Although the daily activity budgets of terrestrial migratory birds is relatively well known, far less studies have been done on migratory seabirds, due to a lack of appropriate data. However, the recent development of tracking devices and immersion loggers (giving information on when birds are flying vs. on/in the water), allows us to investigate these questions in seabirds. Here, we gathered a large data set from a range of long-distance pelagic seabird migrants from several families, equipped with geolocators and immersion loggers in colonies all around the world and investigated their diel organisation of activities during migration, as well as the effect of the moon on these activity patterns.
We found for several species an increase in nocturnality during migration (compared with wintering), as well as a positive effect of moonlight on the night-time (relative to day-time) flight activity.

Anne-Sophie Bonnet-Lebrun is a biologist with a main research focus on spatial ecology, mainly in birds. She is particularly interested in using tracking data to understand individual-level spatial processes, such as habitat selection or migration.

The protandry paradigm revisited: is migration timing sex-specific throughout the annual cycle?

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Timing of annual activities, like breeding, migration, and moult, underpins the success of individual performance. In migratory birds, different demographic groups, however, might be constrained by varying factors when it comes to optimal timing of their annual movements. As such, males typically arrive at the breeding sites ahead of females – a phenomenon termed protandry – yet our knowledge regarding sex-specific migration timing at other stages of the annual cycle remains limited.

We applied and tested the protandry hypothesis across the entire annual cycle revisiting, quantifying, and challenging this long-standing spring arrival concept also for the autumn migration. Our dataset consisted of more than 350 annual migration tracks from 14 small-bodied Afro-Palearctic long-distance migratory landbirds from 25 European breeding populations.

In spring, we found marked differences with males departing Africa on average 3 days earlier and arriving at the breeding sites approximately 4 days ahead of females. In autumn, males initiated migration ca. 2 days earlier, but this pattern did not translate further upon arrival at the non-breeding sites. A cross-species comparison revealed that protandry, however, is not a ubiquitous pattern in all long-distance migrants. In addition, we found tight links between individual timing of migratory departure and arrival in both seasons, but only for males the timing of spring migration was linked to the timing of previous autumn migration.

The results illustrate that migration schedules and linkage between the timing of consecutive migration stages are substantially different for males and females. The species-, sex-, and season-specific differences in migration strategies are likely mediated by a combination of intrinsic (e.g., individual body condition and cross-seasonal carry-over effects) and extrinsic (e.g., competition for limited resources at the final destination) factors operating across the annual cycle.

Martins Briedis is a wildlife ecologist with a main research focus on avian migration ecology in the context of the full annual cycles. He is particularly interested in the concept of migratory connectivity from a spatio-temporal viewpoint, links between different annual phases, and interactions between migrants and the environment.

Do timing delays and winter site quality carry-over to influence productivity in Icelandic Whimbrel?

Camilo Carneiro[1,2*], Tómas G. Gunnarsson[2] & José A. Alves[1,2]

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When living in seasonal environments timing is crucial. Timing of breeding, in particular, is often linked to reproductive success and consequently has the potential to influence fitness. However, timing of breeding may be dependent on preceding stages of the annual cycle. Delays and/or sub-optimal conditions experienced in one phase of the year can affect subsequent events through carry-over effects. These links can be particularly apparent in birds breeding at high latitudes, due to the short window when suitable breeding conditions occur, and even more so for long distance migrants, that incur considerable energetic migratory costs and time constraints. Icelandic Whimbrels *Numenius phaeopus islandicus* breed mostly in Iceland and perform long non-stop flights to/from the wintering sites. Between 2012 and 2018, we tracked their migration using geolocators and surveyed their breeding phenology, investment and success at the individual level. Additionally, we measured the wintering habitat quality (through energetic balance) of three sites located at 5850, 4900 and 2880 km from Iceland and assigned the winter origin of breeding birds through stable isotope analysis. Here, we explore (1) temporal correlations along the annual cycle of Icelandic Whimbrels that may cascade to influence breeding phenology and success and (2) potential effects of wintering site on breeding onset and breeding investment.

Camilo Carneiro is a PhD student at the Universities of Aveiro and Iceland exploring the implications of long distance migratory strategies and variation of wintering habitat use on individual fitness. He investigates these links on Icelandic Whimbrels, developing fieldwork between Iceland and West Africa and using several individual tracking techniques (colour-rings, stable isotopes and geolocators).

Tracking seabird migration to identify priority areas for their conservation

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Many seabird species are long distance migrants that cover large areas of the ocean throughout their annual cycles. Seabirds are also one of the most threatened groups of birds, and tackling the threats they face, especially while at-sea, requires a good understanding of their seasonal movements to ensure effective protection of the key areas they use.

Tracking has proved to be a fundamental tool in seabird conservation, as it offers crucial information on the distribution patterns of individuals and populations. Some well-known applications include mapping the overlap between seabird distributions and threats such as fisheries by-catch, or the use of tracking data to identify marine Important Bird and Biodiversity Areas during different stages of the breeding cycle.

In this study we present a review of the use of tracking data in the conservation of migratory seabirds, along with some knowledge gaps, major challenges and priorities for future research. In particular, we explore the importance of understanding the drivers of flexibility in migratory behaviour at the population level (including the role of age) for the identification of priority sites for conservation. We will also present the results of a large scale collaborative study that resulted in a proposal for the creation of a Marine Protected Area used by more than 20 species of migratory seabirds during different stages of their life cycle (breeding, wintering and as a stopover site during migration), travelling from more than 100 colonies in the South and North Atlantic. Finally, we will present the major gaps in seabird tracking in the context of their conservation, and suggest possible links to the conservation of other migratory species, both marine and terrestrial.

Maria Dias is the Senior Marine Science Officer at BirdLife International, where she coordinates and develops the scientific work underpinning BirdLife's Marine Programme. Maria's PhD focused on the conservation of estuarine areas for migratory shorebirds and her post-doc research on the individual flexibility of migratory behaviour in seabirds.

Long-distance migratory shorebirds travel faster in spring, but fly faster in autumn

Sjoerd Duijns[1,2]*, Alexandra M. Anderson[3], Yves Aubry[2], Amanda Dey[4], Scott A. Flemming[3], Charles M. Francis[2], Christian Friis[2], Cheri Gratto-Trevor[2], Diana Hamilton[5], Rebecca Holberton[6], Stephanie Koch[7], Ann E. McKellar[8], David Mizrahi[8], Christy A. Morrissey[9], Sarah

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Neima[9], David Newstead[10], Larry Niles[11], Erica Nol[12], Julie Paquet[2], Jennie Rausch[2], Lindsay Tudor[13], Yves Turcotte[14] & Paul A. Smith[2]

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Long-distance migrants are thought to be more time-limited during spring migration compared to autumn. Although breeding-related time constraints may be absent in autumn, additional factors such as predation risk could lead to previous underestimations of time constraints en route. By using an automated radio telemetry system, we compared spring and fall movements of long-distance migrant shorebirds on a continent-wide scale. From 2014 to 2016, we deployed radio transmitters on 1,937 individuals of 4 shorebird species at 13 sites distributed across North America. Following theoretical predictions, all species migrated faster in spring compared to autumn migration. Differences between both seasons appeared to reflect differences in stopover duration. Despite this, all species had higher airspeeds in autumn, irrespective of seasonal wind differences. Arriving at the breeding grounds in good body condition is beneficial for survival and reproductive success and this energetic constraint might explain why airspeeds are not maximised in spring. We show that the higher airspeeds in autumn precede a wave of avian predators, which could suggest that migrant shorebirds show predation-minimizing behaviour. Our results reaffirm the important role of time constraints in spring, and suggest that both energy and predation-risk constrain migratory behaviour in autumn.

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Sjoerd Duijns is a behavioural ecologist, interested in the mechanisms by which organisms deal with the aspects of their (changing) environment and he's fascinated how animals respond to this. He aims to unravel this by integrating behaviour, demography and population dynamics using statistical and theoretical models with empirical data.

The influence of haemosporidian infections on flight bout durations, resting times and flight height in long-distance migratory great reed warblers

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How parasite infections alter migration performance of their hosts has remained a debated issue as past studies have found negative, positive or no response of host migration schedules and performance to infections. This particularly applies to small migratory birds whose migration behaviour could not be monitored in detail over longer time-intervals so far.
Therefore, we investigated how the migrations of great reed warblers are influenced by infections with blood parasites. To characterize migration behaviour during their whole journeys, we used newly-developed multi-sensor tracking devices that record light intensity, acceleration and air pressure. We retrieved such loggers from 24, 5 and 3 individuals from breeding populations in Bulgaria, Czech Republic and Russia, respectively. We determined migration routes and schedules, flight bout durations, resting times and flight heights, and we related those variables to the intensity of infections with haemosporidian parasite as determined by real-time qPCR.
While we found the onset of autumn migration to be delayed with increasing intensity of infection, the timing in other periods of the year was not related to infection. Flight bout durations and flight height were not significantly related to infection intensity. However, we found the maximum individual resting time to be decreasing with increasing infection intensity.
Thus, avian blood parasites seem to have mostly subtle effects, occurring at specific times and places only, which might explain the ambiguous results from earlier studies. Overall, our study sheds new light on the mechanistic pathways behind infection-related delays in migration timing of passerines.

Tamara Emmenegger is a biologist with research focus on bird migration and a strong interest in a mechanistic understanding of host-parasite interactions in migratory birds. She enjoys programming

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and developing methods for analysis as well as applying these on various question-driven research projects.

KEYNOTE

From local collective behaviour to global migratory patterns in white storks

Andrea Flack[1,2]

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In group-living organisms from bacteria to primates, small-scale inter-individual interactions create emergent behavioural patterns. Our ability to monitor movements, and interactions, of multiple freely-moving animals with submeter accuracy during global large-scale seasonal migrations opens up a host of new questions in the traditional field of animal migration research. We can now track multiple, possibly interacting, conspecific individuals simultaneously in order to understand, and protect, migrating animals in their natural habitat. In recent studies, my collaborators and I have used a comprehensive dataset of collectively migrating White Storks *Ciconia ciconia* to describe how soaring long-distance migrants use social cues for locating and exploiting thermal updrafts by relying on leading and following behaviour. Collective stork migration involves group cohesion among individuals with variable movement capacities and costs, indicating that group composition is essential for successfully reducing movement costs. We unravelled mechanisms of collective migration in a natural environment and suggest that integrating intraspecific interactions into the study of animal movements will enable a better, more mechanistic understanding of broad-scale ecological processes.

Andrea Flack researches the fields of animal behaviour and movement ecology. She aims at understanding how individual differences affect decision-making in group-living animals. She is currently a post-doctoral researcher at the Max Planck Institute for Ornithology. Her work explores the impact of social interactions on small and large scale migratory behaviour in white storks.

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KEYNOTE

Range-scale responses of migratory birds to climate change

James Gilroy
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Species distributions are limited, at least in part, by the suitability of local climatic conditions. With climate change, zones of climatic suitability for many species are shifting in space, meaning that species must either adapt to novel conditions within their current ranges, or shift their distributions by colonizing new sites. Migratory species face a unique challenge in this context, because they occupy multiple different areas across the course of the annual cycle, each characterised by their own set of bioclimatic conditions. Zones of climatic suitability at each stage of the migratory programme could therefore shift independently in space as the climate warms. In the absence of adaptation to new climates, migrants might need to track these season-specific shifts concomitantly, potentially necessitating changes in migratory distance and/or direction in order to colonize new areas of suitability. This presentation will explore the complex ways in which migratory species are responding to this challenge, using insights from long-term citizen science datasets, model-species case studies and evolutionary simulations. We will examine the extent to which migratory programmes are flexible enough to allow species to track multiple shifting climate envelopes, and explore how flexibility varies across different stages of the migratory cycle. Challenges and frontiers in this field will be explored, as well as the wider conservation implications of climate change for migratory birds.

James Gilroy is a Lecture in Ecology at University of East Anglia. His research combines ecological modelling, large-scale spatial analysis and field-based empirical studies to examine how movement behaviour influences the way species respond to environmental change. Alongside his work on migratory birds, he has a strong interest in exploring how human land-use decisions can be optimised to protect biodiversity, particularly in the tropics.

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KEYNOTE

Seabird migration in the anthropocene

W. James Grecian
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Animal migration is a widespread and diverse phenomenon allowing species to target seasonally varying resources. Nevertheless, the degree to which migratory behaviours are innate or learned is poorly understood. For example, individuals may exhibit long-term fidelity to specific wintering areas or shift winter destinations from one year to the next in response to changes in local food availability. Seabirds make some of the longest migrations known, traversing whole ocean basins and often targeting upwelling regions where the mixing of nutrient-rich cool water with warm surface layers fuels primary production and drives bottom-up cascades. By integrating conditions across wide geographic areas, seabirds are exposed to a range of environmental stressors and so can act as barometers of ecosystem function or environmental change. Recent advances in bio-logging technology has allowed vast amounts of data to be collected on animal movement, but the techniques available to analyse these data are still evolving. Using studies conducted across a broad-range of seabird species over the last decade, I will discuss the potential consequences of differences in winter strategies, the environmental drivers of diversity in wintering hotspots, and the anthropogenic threats posed to seabirds during migration. I will also outline some of the analytical approaches recently developed to answer these questions.

James Grecian is a a post-doctoral research fellow at the University of St Andrews.
His research focuses on understanding the distribution and behaviour of apex marine predators such as seabird and seals, particularly the effect that human activities such as offshore energy extraction, fisheries and climate change have on foraging behaviour and migration. To answer these questions, he uses a range of techniques including bio-logging, stable isotope analysis and quantitative modelling.

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Evidence for evolution in the advancing phenology of a migratory bird

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Global warming has modified the seasons, leading to increasingly earlier springs in many regions on earth. Some species of migratory birds are not sufficiently advancing the timing of migration and breeding to compensate for these earlier springs. Reproduction in these species may thereby become mistimed relative to the peak of food availability for raising their offspring. In some species, such mistiming is associated with local population declines. Flexible responses of birds to early springs may be constrained by the inherited, clock-based timing programmes that regulate long-distance migrations. In this case, evolutionary adjustments are the only viable mechanism for keeping pace with shifting phenology.

Therefore, it is imperative to understand whether circannual timing programmes can rapidly evolve, but detecting evolutionary change is difficult without experimentation. The Pied Flycatcher *Ficedula hypoleuca* is a model for studying constrained ecological responses to climate change. Using a laboratory experiment, we show that the phase of the flycatcher clock controlling spring moult, migration, and reproductive timing advanced by 6-12 days over 21 years, whereas no such changes occurred in autumn and winter. Our paired field records, collected in a citizen scientist project, show that a nearby population mirrored these changes, advancing egg-laying by 11 days in the wild. Furthermore, the spring time window during which flycatcher laydates were most sensitive to ambient temperature advanced by three weeks. These results support a role of microevolution in modifying spring phenology and suggest that the inherited timing programmes of long-distance migratory birds may be more labile than previously thought, leaving some scope for evolutionary rescue in a changing climate.

Barbara Helm is a researcher in Groningen, the Netherlands, to where she recently moved from Glasgow. She is keenly interested in migration, especially with respect to time-keeping. Her research revolves around biological rhythms of wild birds in natural and modified environments, applied for example to effects of urbanization and light pollution.

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Migration of wild and captive bred Asian Houbara

Yves Hingrat

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Asian migrant Houbara has benefited from population reinforcement since 2009 using captive-bred houbara (CBH). From 2009 to 2017, about 10 000 migrant Houbara were released in several sites in Kazakhstan and Uzbekistan. Different release trials were conducted either in late summer (prior to fall migration) or in spring (after spring migration). The monitoring of 741 captive-bred juveniles, equipped with GPS-satellite transmitters, showed that CBH migrate but their survival after full migration greatly varied between countries, release sites, years and season of release. After late summer release, return rates ranged from 14.4 to 57.4% in Kazakhstan and from 21.9 to 55.1% in Uzbekistan. After spring release in Uzbekistan, average return rate (51.4%) was higher compared to late summer release (34.5%). Using daily locations from 174 wild juveniles and 282 CBH which completed a full migration, we tested the effects of latitude, bird origin and season of release on departure dates, migration distance, migration duration, duration on stopovers and 'ground time' (time on breeding and wintering grounds). Globally, in Kazakhstan and in Uzbekistan, CBH departed later, migrate shorter distances and spend more time on stop overs as well as on wintering and breeding grounds when compared to wild Houbara. However, the latitude of release sites and years also had significant effects on migration parameters, while sample sizes between wild and CBH were not balanced through time and space. Interestingly, when controlling for site and year, Houbara released in spring departed at the same time than wild juveniles; whereas birds released in fall departed 7 days later. Our results highlight (1) the importance of the release method (timing of release) on the performances of translocated animals and (2) the importance and challenge of long-term and large-scale monitoring to uncover spatial and temporal sources of variation of animal demographics and avoid generalizing results gathered locally.

Yves Hingrat is a biologist which research focus on ecology and behaviour of bustards, mainly the North African and Asian Houbara bustard species. His researches aim improving conservation programmes on bustards combining in-situ ad ex-situ conservation actions for the restoration of houbara populations.

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KEYNOTE

Bright lights in the big cities: migratory birds' exposure to artificial light

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Billions of migratory birds fill the airspace over North America each spring and fall. Many species of migratory birds have evolved the capacity to migrate at night, and the recent and rapid expansion of artificial light at night has dramatically altered the nighttime sky through which they move. But risks to migrating birds from artificial light are not spatially nor temporally uniform, representing a primary challenge for mitigating potential hazards and developing action plans to catalog risks. I will draw from work leveraging more than two decades of weather surveillance radar data to quantify nocturnal migration, revealing how this remote-sensing platform can be used to identify threats from local to continental scales. Understanding when and where migrants pass, particularly the number of nights that comprise the majority of aerial movements, is of great conservation importance to simplifying this complex problem. I will show how we map seasonal and spatial relationships of these movements and how machine learning approaches can be used to forecast these events. This investigation highlights the challenge and value of targeted aerial threat mitigation, especially in the face of increasing risks to migrating birds from light pollution, wind energy, and collisions with structures.

Kyle Horton received his BS in Biology from Canisius College, US in 2011, MS in Wildlife Ecology from the University of Delaware, us in 2013, and PhD in Ecology and Evolutionary Biology from the University of Oklahoma, US in 2017. He is currently a Rose Postdoctoral Fellow at the Cornell Lab of Ornithology. His work on migratory birds employs a range of tools and approaches, including the use of radar, acoustics, and citizen science data.

ABSTRACTS | ORAL

Abstracts for the oral programme are in programme order. Poster abstracts will be added by the end of January 2018.

Contrasting migration and wintering movement strategies of two distinct populations of Red-necked Phalarope breeding in the Western Palearctic

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Non-breeding movement strategies of migratory birds are expected to be flexibly adjusted to the distribution and quality of habitat, but only few studies compare movement strategies between populations using distinct migration routes and wintering areas.

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In this study we explore the individual movement strategies of Red-necked Phalaropes *Phalaropus lobatus*, a species breeding in Arctic tundras but with a pelagic lifestyle in the non-breeding period. By collating geolocator data from nine sites between Greenland and Yamal, we show that two distinct migration routes and wintering areas occur within the Western Palearctic. Breeding populations from Greenland, Iceland and Scotland show a ~9200 km westward migration to the northern Humboldt Current in the Pacific, whereas those breeding in Scandinavia and Russia migrate ~6000 km to winter in the Arabian Sea. We use the contrast in availability of suitable stopover habitat along the migration routes and the difference in spatio-temporal variation in ocean productivity at the two wintering areas, to study differences in migration and winter movement strategies.

Migrations to and from the Pacific were performed with more frequent but shorter stopovers in autumn and at a higher migration speed in spring than migrations to and from the Arabian Sea. At the wintering grounds, individuals were resident in the stable conditions in the Humboldt Current but generally itinerant (i.e. using multiple sites) in the much more dynamic Arabian Sea. This study is one of few showing adjustment of large-scale movement strategies in response to habitat within a species. It also highlights the value of large international collaborations.

Yann Kolbeinsson is a biologist mainly focused on researching/monitoring cliff-nesting species around Iceland, as well as monitoring breeding waterbirds and open-land bird populations in northeast Iceland. Him and his colleagues have used geolocators in recent years as an important tool for better understanding population fluctuations of seabirds.

Does migration timing hamper the advancement of laying dates in Arctic migratory birds?

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Abstracts for the oral programme are in programme order. Poster abstracts will be added by the end of January 2018.

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Under climate warming, the optimal timing of reproduction is advancing for many animals. This is especially true in the Arctic region, where the rate of climate warming is amplified compared to more temperate regions. Advancement in laying dates of migratory birds can be constrained by their timing of arrival on the breeding grounds. Earlier arrival requires migrants to shorten stopover duration and/or to depart from the wintering grounds earlier. However, it is unclear to what degree migrants can adjust migration timing to Arctic conditions.

We tested whether reproduction and migration phenology advanced with earlier onsets of the Arctic spring in Arctic migratory birds breeding in Lapland, Svalbard and North-Western Russia. We compiled multi-annual tracking data from 9 species (including waterfowl, seabirds, raptors and shorebirds) and related annual timing of migration and reproduction to the local date of snow melt.

We find few and only weak trends in spring migration departure and arrival corresponding to date of snow melt, showing that most migrants do not adjust their migration to an earlier onset of Arctic spring. While waterfowl and shorebirds advance laying dates under earlier snow melt, this is not the case for raptors and skuas. Our results suggest that Arctic migrants are unable to predict the onset of Arctic spring from the wintering grounds and may have little leeway to advance arrival once underway. Timing of migration may thus constrain earlier laying in waterfowl and shorebirds. Raptors and skuas may be less driven to advance timing of reproduction and migration if their prey, lemmings and marine resources, do not advance in earlier springs. While the ability to adjust timing of migration may become an important determinant for population viability in a warming Arctic, the need to do so may strongly differ between species groups.

Thomas Lameris studies how climate change in Arctic regions affects migratory birds and to what extent birds can adjust to these changes. He conducts most of his research in Arctic Russia.

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Abstracts for the oral programme are in programme order. Poster abstracts will be added by the end of January 2018.

KEYNOTE

Tracking spoonbill migration in a changing world: from patterns to mechanisms

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Seasonal migration allows animals to exploit seasonal peaks of resource abundance while avoiding resource depression. To do so, they have to make decisions when to migrate and where to. Changes in any of the sites that migratory animals use during their annual cycle will affect the optimality of these decisions.

Using 25 years of mark-recapture data on Eurasian Spoonbills *Platalea leucorodia*, combined with several years of intensive fieldwork in a Dutch breeding colony, we show that the decision where to spend the winter is made in the first year of life. Moreover, birds that migrate short distances to winter in southern Europe are doing better than those that cross the Sahara to winter in West Africa, both in terms of survival and reproductive output.

While an increasing part of the population is now wintering in Europe, the northward shift in the wintering distribution of spoonbills is slower than would be optimal to achieve the highest fitness. There thus seem to be factors that prevent spoonbills from making optimal winter site choices. To better understand the role of genetic and environmental effects in shaping their migration strategies, we are now collecting data on genetic relatedness and are tracking the autumn migration of juvenile spoonbills and their parents with GPS-trackers. Some first results of this ongoing research will be presented during this seminar.

Tamar Lok is a post-doctoral fellow at the NIOZ Royal Netherlands Institute for Sea Research. She works at the interface of behavioural, evolutionary and population ecology and is particularly interested in better understanding the impressive variation in migration strategies observed in the wild.

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Abstracts for the oral programme are in programme order. Poster abstracts will be added by the end of January 2018.

Strong head-winds during Sahara crossings increase in-flight mortality rates of Black-tailed Godwits

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Migratory flights over large geographic areas without emergency stopover sites are predicted to have a higher risk of mortality due to unpredictable weather and wind conditions. However, because it is difficult to study in-flight mortality, the empirical evidence for this prediction is mostly lacking. Previous work on Black-tailed Godwits (hereafter: godwits) has revealed a relative high mortality-rate during crossings of the Sahara Desert, but the cause for this is unclear. To further investigate the heightened mortality risk of crossing the Sahara, we studied the relationship between the survival of satellite tagged godwits and their experienced wind conditions during this crossing. For more than 70 individuals making more than 150 Sahara crossings, we estimated wind conditions using a wind-based algorithm that calculated the most efficient path time-wise through a temporal 3D-grid in which we allowed individuals to switch directions and altitudes. We show that the wind-conditions during southward migration across the Sahara are less severe than during northward migration. This is most likely the result of predictable local trade winds that result in a higher frequency of tailwinds during southward migration and headwinds during northward migration. We also show a strong association between wind conditions during migration and survival; stronger head winds resulted in lower survival probabilities during migration. Wind conditions during migration can thus directly influence the population dynamics of a species and changing wind conditions as a result of global change could therefore have a profound influence on the viability of long-distance migration.

Jelle Loonstra is a PhD-student at the University of Groningen and is fascinated by the incredible amount of variation in migration. In order to understand this variation, his PhD research focusses on the developmental ecology of migration in Continental Black-tailed Godwits.

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Thermal soaring by raptors over temperate seas: the osprey exception?

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Large raptors on migration generally avoid crossing the sea and prefer making large detours to concentrate at straits and isthmus. The explanation generally given is that there are no thermal ascending currents over temperate seas to practice soaring-gliding flight. The Osprey *Pandion haliaetus* is an exception as it is able to cross several hundred km of open sea, presumably in sustained flapping flight. We tested the hypothesis that osprey may benefit from wind assistance when crossing the sea that would allow dynamic or thermal soaring flight. We equipped 5 juvenile ospreys with GPS-Accelerometer-Magnetometer loggers. All birds were able to find and use thermal uplift while crossing the Mediterranean Sea, on average 7.5 times per 100 km, and could reach altitudes of 900 m above sea surface. Thermals were weaker than over land, since the climb rate was 1.6 time slower than over land and birds had to flap when circling. The occurrence of thermals was correlated to water masses that were warmer than the air, inducing convective atmospheric movements. This finding leads reconsidering the ecology of raptors in migration and the definition of ecological barriers.

Flavio Monti is concerned with evolutionary biology, ecology and behaviour of birds (mainly raptors) and the integration of some aspects of basic research with applications in conservation biology and wildlife management around the Mediterranean Basin.

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Space-time interpolation of nocturnal bird migration at continental scale using weather radar

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Exhaustive 4D information of bird migration intensity with high spatio-temporal resolution has the potential to reveal detailed bird migration mechanisms, such as the importance of specific stopover sites, or varying migration patterns related to weather types or climate change. The use of weather radars in the field of ecology has created an exceptional opportunity for providing such rich datasets. However, although radars are scattered over extensive areas, their individual spatial coverage is limited, thus leading to large gaps between observations. As a result, the effective information about bird migration is a (multi-)point process, and interpolation is required to have the global picture of the migration. Classical geostatistical methods provided in standard packages fall short to provide accurate estimates and uncertainty at the targeted high resolution.

In this study, we created a geostatistical methodology specifically adapted to model and interpolate the areal density of nocturnal migrant birds. One advantage of this method is to rely uniquely on the space-time correlation contained in the data to obtain predictions at unknown locations, therefore it does not need covariates as is typically the case for machine learning approaches. The result is a set of maps of bird migration density at high resolution (15 min in time, 0.2° lat-long in space) together with the associated uncertainty induced by the interpolation process.

The proposed method is tested on a dataset covering North-Western Europe for a part of the 2016 autumn migration, and the results are validated by a cross-validation procedure and a comparison with independent X-band radar measurements. The results (available at www.zoziologie.raphaelnussbaumer.com/bmm-map) are promising and pave the way for an operational interpolation of bird migration data collected continuously by large networks of weather radars.

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Raphaël Nussbaumer is an environmental scientist finishing his PhD on the integration of complex spatial datasets in the field of hydrogeophysics. As a keen ornithologist, he is now working on applying these geostatistical methods to avian datasets.

ARUs: an effective technique for monitoring the European bee-eater migration

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Autonomous Recording Units (ARUs) has widespread as an effective and efficient alternative for monitoring vocally active wildlife. Many birds utter flight calls while migrating, and therefore recording of flight calls provide information on the migration behaviour for some species. In this paper we aimed to elucidate whether ARUs might be used to monitor the migration period for the European Bee-eater *Merops apiaster* in Northeastern Spain.

We monitored daily 3-4 acoustic monitoring stations (placed around beehives, one ARU per station, programmed to record during 30 minutes at six specific diurnal day-times (from 9:00 to 19:00) from 11th August to 20th September 2017. Beehives are known to be feeding areas for bee-eaters during diurnal migration where they make short-stops for feeding. . Recordings were analysed automatically using Song Scope 4.1.5.

In total, we collected 734 30-mins recordings (367 hours of recording) during the study period. We found a high and significant correlation (R^2 = 0.690, P < 0.001) between number of calls per recording and European Bee-eater abundance flying around ARUs estimated by human surveys. European Bee-eater migration in the study area peaked during the last week of August and was significantly higher during the first and last hours of the day, in agreement with prior results obtained in the study area by traditional field counts.

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We have shown that ARUs can be considered as a viable tool for surveying migration of the European Bee-eater on their stopovers. Our results might be also applied for other migrating fauna and it would allow researchers to amplify the spatial and temporal scales of the migration period.

Cristian Pérez-Granados is a biologist focused on steppe-bird conservation, but he is also interested in the development of Autonomous Recording Units for monitoring different aspects of birds' life, such as habitat occupancy, timing of migration or the predator-prey interaction.

Migration routes and winter ranges of Egyptian Vultures tracked from the Douro Valley, Spain-Portugal: the challenge of insecurity

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The Egyptian Vulture *Neophron percnopterus* population in Europe has declined by 50-79% in the last 40 years and is listed as Endangered on the IUCN Red List. As a migratory species the Egyptian Vulture faces multiple threats (e.g. poisoning; food shortages; electrocutions and collisions with energy infrastructure) which vary in intensity across the breeding and wintering ranges and along the migration routes. The European Union LIFE Rupis project aims to implement actions to strengthen the Egyptian vulture population in the Douro Valley trans-border region of Spain and Portugal, a current stronghold for the species with 135 breeding pairs being present. Here we present the results from the first year of GPS tracking nine individuals (five breeding adults; one non-breeding adult; a sub-adult; and two juveniles) from the breeding grounds in the Douro Valley, across the Strait of Gibraltar migration bottleneck, to their winter ranges in the West African Sahel. Of the eight vultures that migrated to Africa in 2017 (one juvenile overwintered in Extremadura, Spain), one juvenile was

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assumed to have died in southern Morocco while all of the adults and the sub-adult travelled to southern Mauritania and Mali (covering >3,200 km in 12-16 days). The five breeding adults traversed extensive winter ranges (mean±SE 95% kernel density contour = 22,836±4,344 km^2; n = 5) compared to their summer ranges (mean±SE 95% kernel density contour = 169±58 km^2; n = 5). Although the sub-adult vulture regularly visited protected areas in southern Mali, the majority of the vultures spent the winter periods in overlapping core ranges in the insecure and unprotected cross-border regions between Mali, Senegal and Mauritania. These preliminary findings illustrate the vulnerability of Egyptian Vultures along their migration route and in their winter ranges, and support calls for a "flyway approach" to Egyptian Vulture conservation in Western Europe and Africa.

Louis Phipps is the Research Officer for the Vulture Conservation Foundation which works towards the conservation and recovery of the four vulture species found across Europe. He is a conservation biologist with a particular interest in studying the spatial ecology of vultures using GPS tracking data to inform conservation actions.

KEYNOTE

Partial migration and population dynamics in a seasonally inhospitable world

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Major goals in contemporary ecology are to understand how populations will respond to environmental change and deterioration, including increasing frequencies of extreme climatic events. Progress requires detailed understanding of patterns of life-history and demographic variation arising within populations, including those inhabiting spatially-structured seasonally-varying environments. Seasonal migration is one key trait that has evolved to allow individuals to avoid seasonally inhospitable environments, but that can vary substantially within and among population members and potentially drive variation in reproduction and survival, including during and following extreme events. Yet, we still lack comprehensive understanding of how seasonal migration varies among different sets of population members, and of the consequent variation in reproduction and survival in the face of environmental variation. I use nine years of data on partially migratory

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European Shags *Phalacrocorax aristotelis* to illustrate the complexity of among-individual and within-individual variation in seasonal migration versus year-round residence arising in a meta-population system. I quantify associated variation in reproductive success and survival, and highlight key short-term and longer-term implications for population dynamic responses to environmental variation and change.

Jane Reid is a population and evolutionary ecologist interested in understanding how environmental, genetic and demographic variation combine to influence population dynamics and evolution. She uses long-term data from wild bird populations and sophisticated statistical and simulation models to understand population dynamics and evolutionary causes and consequences, with particular interests in mating systems and partial migration.

Favourable energy balance, but poor fitness, in Sanderlings wintering in tropical rather than temperate zones

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Abstracts for the oral programme are in programme order. Poster abstracts will be added by the end of January 2018.

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Evolutionary theories of seasonal migration generally assume that costs of longer migrations are balanced by benefits at the non-breeding destinations. We studied time budgets, intake rates, diet composition, food availability, thermoregulation costs and three components of fitness of High Arctic Sanderling *Calidris alba* at six non-breeding sites ranging in latitude between England (55° N) and Namibia (25° S). Birds at tropical sites had more favourable energy budgets, with more profitable trophic conditions and lower thermoregulation costs. Surprisingly though, survival probabilities were considerably lower in tropical West-Africa (Mauritania: 0.77 and Ghana: 0.76) than at three European sites (0.82, 0.83 and 0.85) and in Namibia (0.84). Sanderlings also more often stayed in the tropics during the first possible breeding season and occurred 5-16 days later at the last stop-over site during northward migration than birds wintering further north or south. Namibia-wintering Sanderlings tracked with solar geolocators staged in West-Africa during southward but not during northward migration. Migrating Sanderlings defy long distances but may end up in non-breeding locations with poor fitness prospects. We discuss that despite favourable wintering conditions, spring fuelling in the tropics is constrained.

Jeroen Reneerkens is an animal ecologist whose research focuses on migration ecology, reproductive strategies, seasonal interactions, individual trade-offs and their consequences for population demography, distribution, and conservation in High Arctic shorebirds. Sanderlings are his favourite research species and he coordinates a large international research collaboration involving thousands of citizen scientists.

Does landfill use influence the speed and efficiency of first-year migration in a partially migratory species?

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ABSTRACTS | ORAL

Abstracts for the oral programme are in programme order. Poster abstracts will be added by the end of January 2018.

Migratory birds are influenced by environmental change affecting their population size as well as migratory behaviour. Many populations are shrinking, however in the last three decades the Portuguese population of White Storks *Ciconia ciconia* has increased from 1500 breeding pairs in 1984 to 12,000 in 2014. This coincided with an increase in individuals no longer undertaking traditional migrations to sub-Saharan Africa but remain in Portugal all year-round. Changes to population size and migratory behaviour may have been facilitated by changes to food resources. This study aims to understand how food resources provided at landfill sites, predictable anthropogenic food subsidies (PAFS) , in Portugal influences first-year migration of this newly partially migratory population of white storks.

First-year migration is a crucial period as naïve individuals learn to undertake a successful migration. This study benefits from the deployment of 73 GPS transmitters on juveniles (2016 and 2017), providing high spatial and temporal resolution data on their movement behaviour. We investigated the influence of PAFS (proportion of fixes on landfill sites and proximity of nest to the landfill sites), on the speed and efficiency of route of first-year southward migration. Our results show that large juveniles, from nests close to landfill sites, are more likely to complete their first southward migration than smaller birds. In addition, we will show if there are carry over effects of landfill site use that influences the northward migration or if conditions in Africa are more influential.

Changes to landfill sites are currently prescribed by EU directives, leading to the closure of many sites and reducing organic waste in those that remain open. This study shows that the removal of this food resource will influence the survival of the migratory juveniles.

Kate Rogerson is an ecologist and forth year PhD student at the University of East Anglia, interested in the study of movement behaviour with GPS technology and how human modifications to the environment can alter animal behaviour which affects population demographics.

ABSTRACTS | ORAL

Abstracts for the oral programme are in programme order. Poster abstracts will be added by the end of January 2018.

Are tropicbirds resident or migrant? Migratory patterns of Red-billed Tropicbird in multiple Atlantic colonies

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Although knowledge of the migratory strategies and areas species use year-round is essential for understanding the basic biology and conservation of all species, it is lacking for many seabirds, particularly in tropical areas. Tropicbirds were previously assumed to be resident or dispersive, but light-based geolocators (GLS) are uncovering more complex patterns. Recent studies on Red-tailed *Phaethon rubricauda* and White-tailed *Phaethon lepturus* Tropicbirds have revealed that these species behave as partial migrants, while the migratory strategy of another species, the Red -billed tropicbird *Phaethon aethereus*, remains unknown. We deployed GLS on breeding adults from five islands in the eastern Atlantic, between 2015 to 2017: Sal (N=5), Boavista (N=5) and Raso (N=5) in Cape Verde, îles de la Madeleine (N=12) in Senegal and St. Helena (N=7) in the south tropical Atlantic. After recovering the GLS in following years, we determined migratory patterns and used wet and dry data to infer activity behaviour at sea. While some individuals remained close to their breeding colonies, others undertook westward migrations, confirming red-billed tropicbirds also behave as partial migrants. Migrating birds mirrored movements of western Atlantic tropicbirds, moving towards the mid-Atlantic ridge for the non-breeding period. Interestingly, migratory patterns and the proportion of partial migrants varied substantially across the different populations, suggesting a longitudinal segregation between migratory bird populations and a relatively strong migratory connectivity. Activity data showed tropicbirds spent more time foraging during the day and resting at night, indicating a mainly diurnal activity. Our results are essential in understanding the different threats this declining species is exposed to over the year and can aid in identifying marine Important Bird Areas in a vastly understudied area: the tropical Atlantic.

ABSTRACTS | ORAL

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Sarah Saldanha is a biologist whose main research focus are the movement ecology and conservation of birds. She is currently working on foraging ecology and migratory patterns of red-billed tropicbirds and brown boobies in West Africa.

European Turtle Doves migrating over sea and desert: links with population trends

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European Turtle Dove *Streptopelia turtur* is globally threatened because of its widespread declines on European breeding grounds in recent decades, albeit with some exceptions. The European population winters in the Sahel and migrates along three main flyways. Although the main cause of population decline is degradation of breeding habitat, aggravating factors could be conditions in the wintering grounds and hunting during migration (known to be unsustainable along the western flyway).

Hunting pressure varies spatially and is heaviest in south-central Spain. Previous tracking has shown that populations breeding in UK, western France and western Spain cross to Africa over Gibraltar, thus flying through the hunting hotspots, where hunting occurs during the peak of Turtle-dove migration. Spanish, British, French and Dutch populations have globally declined by at least 40% in recent decades; however, Turtle-dove numbers in Catalonia (NE Spain) appear to be stable.

On evidence that a single tracked Turtle-dove from southern France crossed over the western Mediterranean in a straight line to Algeria, we hypothesized that differences in population trends might be associated with different migration routes between Catalonian and central Iberian populations. Thus, in summer 2018 we tagged 11 breeding TDs with 4 gr Biotrack PinPoint GPS-Argos devices (7 in Catalonia; 4 in central Spain).

ABSTRACTS | ORAL

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Our results show that Turtle-doves from central Spain followed the traditional inland route through Gibraltar to western Sahel. In contrast, Turtle-doves from Catalonia migrate along coastal eastern Spain, over the sea and into Algeria, wintering further east. Differences in conditions in wintering grounds or in hunting pressure between both routes may account for the different population trends. Our discovery can potentially have consequences for conservation policies in light of the International Species Action Plan recently approved for the species.

Francesc Sardà-Palomera is a biologist interested in understanding species response to habitat and ecosystem alterations due to human activities, both from population and behavioural ecology perspectives, and aiming to benefit biodiversity conservation.

Flight behaviour in individual songbirds throughout the migration

Sissel Sjöberg[1], Lykke Pedersen[1], Thomas Alerstam[2], Kasper Thorup[1], Anders P. Tøttrup[1], Arne Andersson[2] & Johan Bäckman[2]

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Understanding animal migration is one of the most compelling and challenging problems of modern biology. For a long time, we have been hindered by the large geographical scale of migratory movements and the small sizes of most migratory animals. Recent advances in tracking technology are based on the use of miniature sensors for recording new aspects of individual migratory behaviour. We used accelerometer loggers to explore migratory behaviour in songbirds during the annual cycle, in combination with barometric sensors to measure flight altitudes. The birds performed their migration stepwise in travel segments and used strictly nocturnal flight schedules; however, some prolonged flights were recorded during passages of barriers. Both departure and landing times were conserved within each travel segment, and we do not observe any effect of total remaining migratory distance, which earlier has been suggested. The use of accelerometer loggers with barometric pressure sensors to estimate flight altitudes will open up new avenues for research and, importantly, advance our understanding of how small birds behave during migratory flights. We did not observed high flight altitudes to be related to the beginning of flights, indicating that birds do not start a migratory flight by sampling wind conditions before choosing a cruising altitude. Frequent

changes in flight altitudes rather indicate continuous regulation of flight altitudes in relation to winds throughout the flights.

Sissel Sjöberg is an ecologist with a main research focus on migratory behaviours in songbirds. She has a special interest in departure decisions, orientation and flight behaviours and how these are affected by environmental cues.

Life-history variation shapes migratory behaviour in birds

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Migration is a widespread phenomenon across the animal kingdom, spanning all major vertebrate groups. Although it has attracted scientific attention for millennia, many questions about the causes and consequences of migration remain unanswered. Here, we investigate how life-history variation shapes migratory behaviour in birds. To do so, we compiled a dataset of migratory strategies (migratory vs non-migratory) and seven key life history traits linked to reproduction, growth and longevity for 756 bird species. Phylogenetically-corrected principal components analysis of the life history traits captured variation of two components: fast-slow continuum and reproductive strategy. Using phylogenetic generalised linear mixed models in a Bayesian framework, we then explored the relationship between the migratory strategy and latitude, and the two life history components. We found a strong positive relationship between migration probability and pace of life: species with a faster pace of life had a higher probability to migrate. Overall, the reproductive strategy did not present a significant relationship with migration probability and latitude had a positive effect, i.e. species occurring in northern and southern latitudes had a higher probability of migrating than species from the tropics. Importantly, our results show that migration and pace of life are linked, which highlights the selection pressures that shaped bird species over evolutionary time.

ABSTRACTS | ORAL

Abstracts for the oral programme are in programme order. Poster abstracts will be added by the end of January 2018.

Andrea Soriano-Redondo is a conservation biologist working on population ecology and migration. She tries to understand the drivers of animal population changes such as climate change and animal translocations.

Forecasting bird migration at continental scales

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Billions of migratory birds cross the globe each year, and monitoring birds during migration provides important information on avian populations and ecology. However, monitoring efforts can be hampered by the unpredictability of birds' movements, which typically occur in spatiotemporally irregular pulses across the landscape. In this study, we applied machine learning methods to forecast the atmospheric distributions of migrating birds at a continental scale. We used over two decades of weather radar observations from 143 stations across the continental United States to identify associations between atmospheric conditions and bird migration intensity. Our models explained up to 81% of variation in migration intensity at altitudes up to 3000 meters, and performance remained high in forecasting events 1 to 7 days in advance. We identified key differences in the environmental correlates of migration between spring and autumn: in spring, air temperature was the dominant atmospheric covariate associated with migration intensity, while in autumn winds were more important. This contrast may reflect a seasonal difference in time and energy minimization strategies. Summing model predictions across the country, we found that avian migratory movements over the United States likely exceed 500 million individuals per night during peak passage. Bird migration forecasts have the potential to reduce collisions with buildings, airplanes, and wind turbines, inform a variety of monitoring efforts, and engage the public with the often-unseen phenomenon of nocturnal bird migration.

Benjamin Van Doren studies bird migration across scales, from individuals to continents. Currently a PhD student, he focuses on change and flexibility in migration and how environmental and endogenous drivers shape migratory behaviour.

ABSTRACTS | ORAL

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Understanding individual differences in migratory behaviour: an ontogenetic approach.

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Previous tracking studies have revealed that within some avian species there are large differences in migratory strategies among individuals. These include using different wintering areas and exhibiting differences in migratory timing. Repeated measures of the same individuals have generally shown that these differences are consistent across years. These observations lead to questions such as: Why is there consistent individual variation within some species and populations, but not others? And, how do these consistent differences arise — are they the result of genetic differences, plastic differences, or both? To start addressing these questions, we outfitted 40 juvenile Black-tailed Godwits (*Limosa limosa limosa*, hereafter "godwits") in 2016 and 2017 with satellite transmitters. We did this in our long-term study area in Fryslân, the Netherlands, where we have also tracked adult godwits from 2012 onwards. The satellite tags have allowed us to compare the first southward migration of juvenile godwits to the southward migration of adult godwits in the same and previous years. We found that adults consistently winter either north or south of the Sahara. Adults also exhibit consistently different migratory timing among individuals — for example, some cross the Sahara in the beginning of June, whereas others cross at the end of July. Furthermore, adult survival on southward migration is very high. The actual migration routes of adults and juveniles were similar. However, in contrast to the adults, juvenile godwits departed the Netherlands later, flew non-stop to West Africa more often and had higher mortality. Furthermore, the likelihood that juveniles wintered south of the Sahara depended on migratory timing: those juveniles that migrated later were less likely to successfully cross the Sahara. Lifelong tracking of these individuals will elucidate whether these initial differences among juveniles in migratory timing lead to the different annual routines observed in adults.

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Mo Verhoeven is interested in the variation in bird behaviour. He asks questions like: Why are there differences between species and within species? What is the source of this variation - genes, or the environment? Why is or isn't this variation selected against? Mo lives in the Netherlands and likes salty liquorice.

An ontogenetic perspective on migration learning and critical life-history traits in raptors

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Tracking studies are uncovering migration strategies for many species, often vastly more complex and diverse than ever imagined. The way in which these strategies develop, however, is largely unknown. At previous conferences I have presented preliminary results of a longitudinal tracking study of migratory development in European Honey-buzzards *Pernis apivorus*. I thereby argued that young buzzards mainly depend on social information to learn traditional flyways between Europe and Africa. However, based on additional data collection I must rectify that honey buzzards actually learn traditional overland flyways primarily by chance, whereby individuals learn completely different loop migration routines depending on stochastic early-life experiences. And this has major life-history implications.

Honey-buzzards could stay in Africa until their 5th calendar year (CY) before attempting a first return to Europe. It seems this is due to the high risk of mortality during the first return migration, such that birds were more likely to grow older by extending their stay in Africa. Individuals that survive their first return in CY3-4 certainly gain migratory experience by doing so, but spend too little time in their natal area to familiarize themselves with potential breeding sites. Four birds were tracked until CY6-7 but none bred successfully.

Slowly reproducing raptors usually minimize juvenile mortality through synchronized migration between age groups, allowing young birds to learn safe flyways by following elders. It seems this allows for faster recruitment too, with species like lesser spotted eagle breeding as early as CY4-5.

ABSTRACTS | ORAL

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The honey-buzzard migration system thus appears to exist at the limits of what can be maintained through stochastic migration learning. In my talk I will discuss how critical life-history traits allow for the maintenance of stochastic migration learning strategies across various raptor species, while necessitating the evolution of social migration in others.

Wouter Vansteelant is a behavioural ecologist with a keen interest in raptor migration. His current focus is on migration learning, trying to resolve how long-lived raptors learn to migrate under dynamic atmospheric conditions. Wouter is co-founder of the Batumi Raptor Count and acts as secretary of the Migrant Landbird Study Group.
