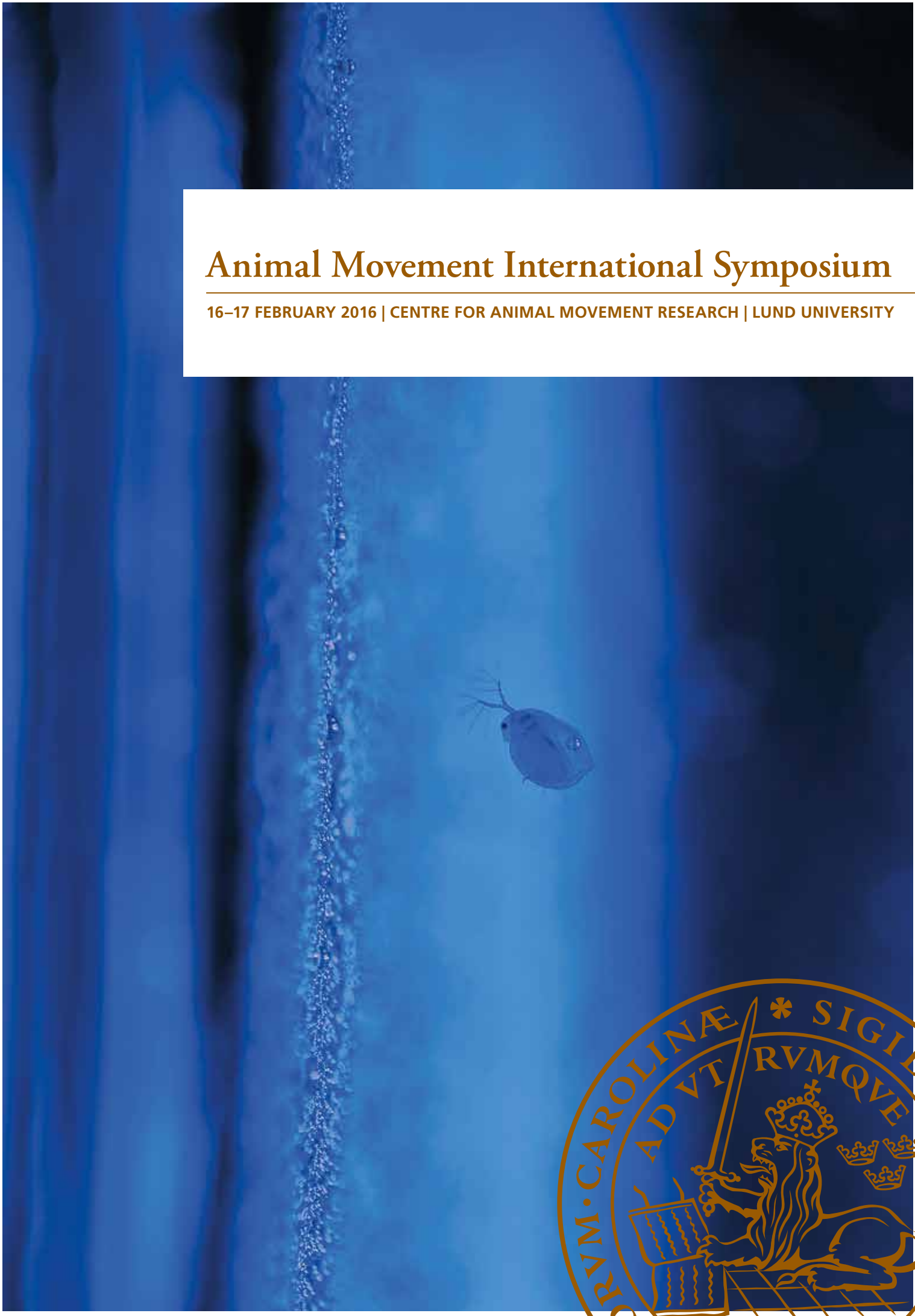

# Animal Movement International Symposium

**16–17 FEBRUARY 2016 | CENTRE FOR ANIMAL MOVEMENT RESEARCH | LUND UNIVERSITY**

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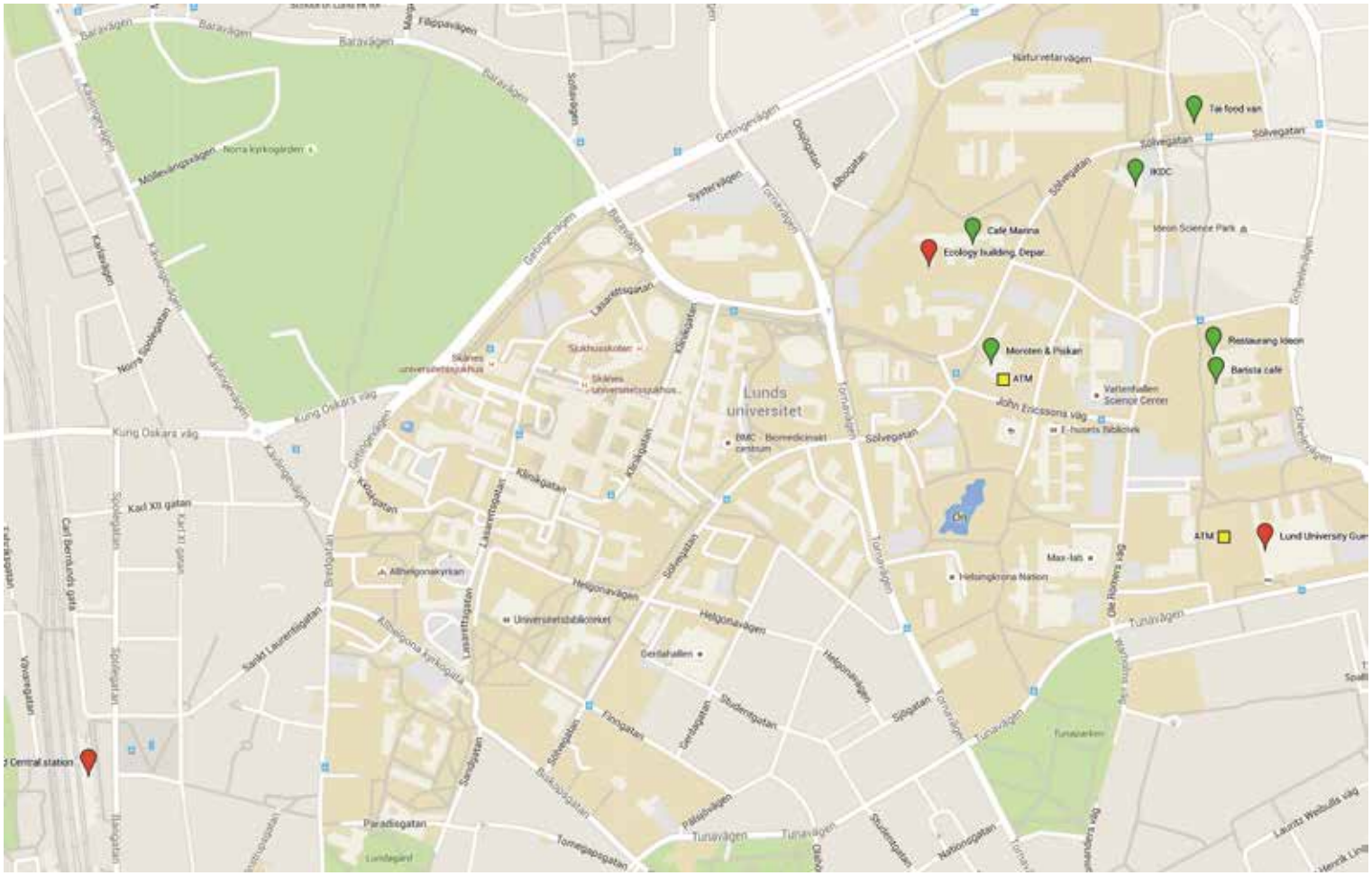
Cover photo by Aron Hejdström




# Animal Movement International Symposium

**BRIDGING THE GAP BETWEEN MODELLING AND TRACKING DATA**

## A CAnMove symposium 16–17 February 2016
## Welcome to CAnMove – Centre for Animal Movement Research and Lund University!

### WELCOME RECEPTION & POSTER INSTALLATION

Registration and poster installation on Monday 15 February will take place outside the Blue Hall in the Ecology Building, Department of Biology, Sölvegatan 37, Lund. The reception counter will be open between 17.00 and 19.00.

Registration and poster installation will continue on Tuesday 16 February at the same place and will be open between 08.00 and 08.30.

### LUNCH

We will serve free lunch sandwiches to all participants on both days (16-17/2) outside the Blue Hall.

### POSTER SESSION

The poster sessions will be on Tuesday 16 February outside the Blue Hall in the Ecology Building.

The first poster session is during lunch 11.50 – 13.00

The second poster session is before dinner, same place 17.50 – 19.30. During this time a cash bar will be open where wine and beer can be bought for cost price (only cash – Swedish Kronor).

### CONFERENCE DINNER

The dinner will be at Café Bryggan in Ingvar Kamprad Designcentrum at 19.30. All alcoholic drinks can be bought for cost price (only cash – Swedish Kronor).

### ORGANIZING COMMITTEE

Susanne Åkesson, Giuseppe Bianco, Anders Hedenström, Christina Rengefors (administration), Inger Ekström (communication)

### SPONSOR

We thank the Hans Kristianssons Minnesfond

# Programme

## Location: Blue Hall, Ecology Building, Sölvegatan 37, Lund

**MONDAY 15 FEBRUARY**

17.00 – 19.00 **Registration – Poster installation**

**TUESDAY 16 FEBRUARY**

08.00 – 08.30 **Registration – Poster installation**

08.30 – 08.40 **Susanne Åkesson –** CAnMove coordinator
Welcome Talk

**SESSION 1 – TRACKING ANIMALS ACROSS SCALES**

Chairperson – Susanne Åkesson

08.40 – 09.00 **Susanne Åkesson**, Lund University
A Continental View on Swift Migration

09.00 – 09.20 **Åke Lindström,** Lund University
Great Migrations by Great Snipe

09.20 – 09.40 **Sissel Sjöberg**, Lund University
Stopover Behaviour in Migratory Passerines, Studied by Automated Radiotelemetry in Falsterbo, Sweden

09.40 – 10.10 **Coffee**

Chairperson – Giuseppe Bianco

10.10 – 10.30 **Lars-Anders Hansson**, Lund University
Tracking Small Animals Using Nanotechnology

10.30 – 10.50 **Cecilia Nilsson**, Lund University
Tracking Bird Migration with Radar

10.50 – 11.10 **Mikkel Brydegaard,** Lund University
Laser Profiling Oscillatory Organisms

11.10 – 11.30 **Legstretcher**

11.30 – 11.50 **Christer Brönmark**, Lund University
Using PIT-tags to Track Seasonal Fish Migrations

11.50 – 13.00 **Poster session / lunch (sandwiches will be served)**

**SESSION 2 – MODELLING APPROACHES FOR ANALYSING MOVEMENT DATA**

Chairperson – Åke lindström

13.00 – 13.50 **Anders Hedenström**, Lund University
Flight Mechanics and Migration Performance

13.50 – 14.40 **Jessica V. Redfern**, National Oceanic and Atmospheric Administration (NOAA), USA
Cetacean Habitat Modeling and Risk Assessment in the Eastern Pacific Ocean

14.40 – 15.00 **Coffee**

Chairperson – Arne Hegemann

15.00 – 15.50 **Uffe H. Thygesen**, Technical University of Denmark
What's on a Tuna's Mind? Confronting Dynamic Optimization Models of Behavior with Tracking Data

15.50 – 16.40 **Maksym Romenskyy**, Uppsala University
Statistical and Dynamical Properties of Fish Schools in Two and Three Spatial Dimensions

16.40 – 17.00 **Legstrecher**

17.00 – 17.50 **John M. Fryxell**, University of Guelph, Canada
Recent Advances and Continuing Challenges in Modeling Movement

17.50 – 19.30 **Poster session / cash BAR (only Swedish Krona)**

19.30 **Dinner** (Ingvar Kamprad Designcentrum, IKDC)

## WEDNESDAY 17 FEBRUARY

### SESSION 3 – NEW FRONTIERS IN TRACKING METHODS

Chairperson – Tom Evans

8.30 – 09.20 **Alan M. Wilson**, Royal Veterinary College, United Kingdom
Energetics and Mechanics of Ranging and Hunting Locomotion in Large African Mammals: Fusing GPS, Inertial Measurements, UAVs and Aerial Survey Data

09.20 – 10.10 **Kalle Åström,** Lund University
Positioning and Tracking of Animals Using Computer Vision, Sound and Radio

10.10 – 10.30 **Coffee**

Chairperson – Jannie Linnebjerg

10.30 – 11.20 **Fredrik Gustafsson**, Linköping University
Tracking Rhinos (and Intruders) on the Smart Savannah

11.20 – 12.10 **David W. Winkler,** Cornell University, USA
Pushing the Limits for Tag Size and Life-span: Tiny Solar Tags and their Future in Animal Movement Research

12.10 – 13.00 **Group photo / lunch** (sandwiches will be served)

Chairperson – Anders Hedenström

13.00 – 13.50 **Ran Nathan**, The Hebrew University of Jerusalem, Israel
High-throughput Movement Ecology

### OPEN DISCUSSION

13.50 – 16.30 **Workgroup activity**

16.30 – 17.00 **Symposium closure**

**Talks:** 15 min + 5 min questions | 40 min + 10 min questions

# Abstracts oral presentations

## ACCORDING TO PROGRAMME

Susanne Åkesson
Department of Biology, Lund University, Sweden

### A CONTINENTAL VIEW ON SWIFT MIGRATION

The common swift is one of the most aerial bird species in the world migrating between breeding areas in the northern Hemisphere and wintering areas south of Sahara in Africa. The timing of movements as well as annual space use is critical for bird survival and may be expected to take place in relation to local peaks in food availability for insectivorous migratory birds. We have tracked the migration of a highly aerial bird species the common swift *Apus apus* by miniature geolocators, in ten populations across extensive parts of the European breeding range. The common swift has evolved a chain migration pattern, where the most southern breeding populations in Europe migrate to wintering areas furthest to south in Africa, while the northern populations remain in the most northern part of the wintering range south of Sahara throughout the winter. The observed chain-migration pattern has previously rarely been confirmed and the evolutionary scenario has not been explained. Chain migration may evolve under two main scenarios. First, when the suitability gradients during breeding and wintering increase towards the north and dominance is due to body size, or second, when the dominance is due to prior occupancy with suitability increasing towards the poles. Chain migration in common swifts is explained by differential movement timing, variation in suitability gradients and competition at different times of the year. We have investigated the timing of swift movements in relation to variations in resource availability, using NDVI (greenness) as a proxy for availability of insects.

Åke Lindström
Department of Biology, Lund University, Sweden

### GREAT MIGRATIONS BY GREAT SNIPE

The migration details of the Great Snipe *Gallinago media* were for a long time poorly known. In recent years year-around tracks from geolocators revealed a remarkable migratory behaviour (Klaassen et al. 2011 – Biol. Lett. 7:833–835, Lindström et al. 2016 – J. Avian Biol.: in press). The birds make very long and fast non-stop flights to their central African winter quarters, and surprisingly, they also overfly wide areas of seemingly suitable habitats. Some birds make a short stopover in northern Europe in autumn, but most birds embark on a trans-Saharan flight of 5000-6000 km directly from the breeding grounds. The average ground speed of the direct flights is around 25 m $s^{-1}$ (90 km $h^{-1}$). At least one bird has carried out the complete 7000 km migration in one flight. The winter sites are concentrated to an area around the equator, ranging 5°S–2°N and 14–19°E. The birds stay in their winter quarters for about 7 months, with no detectable changes in location during winter. Spring migration starts with a non-stop flight of 5000 km, followed by a slow migration (many short flights) through central Europe. All birds arrived the breeding quarters within a few days in mid-May. The peculiarities of these great flights are discussed.

Sissel Sjöberg
Department of Biology, Lund University, Sweden

### STOPOVER BEHAVIOUR IN MIGRATORY PASSERINES, STUDIED BY AUTOMATED RADIOTELEMETRY IN FALSTERBO, SWEDEN

Songbird migrants use stopovers between flight bouts to rest and refuel for the upcoming flights. Behaviours affecting where, when and how long to stay at stopover sites will affect how successful the overall migration is, as well as the reproductive success the coming seasons and could even be mortal. We studied these behaviours in some of our most common migratory songbirds by using an automated radiotelemetry system at the Falsterbo peninsula, southern Sweden. The automatic receiver system consists of three terrestrial stations at Falsterbo, and one offshore station at the research platform FINO 2, 50 km southeast from

Falsterbo in the Baltic Sea. The receivers continuously scan for radio signals and by using ID-coded transmitters we can track several individuals simultaneously. Our results show that stopover duration is affected by fuel load and weather conditions and differ between the migratory seasons. Furthermore, timing of departures on nocturnal flights are primarily determined by ecological factors and to a large degree affected by night duration. Birds with higher amounts of stored fuel departed before lean individuals indicating that they prepared for a longer flight. In addition, wind directions largely affect route choice across the Baltic Sea after departure from Falsterbo. Winds are the primary factor affecting flight duration for the first 50 km of flight after departure; interestingly we found additional negative effect of cloud coverage and positive effect of fuel load.

**TRACKING SMALL ANIMALS USING NANOTECHNOLOGY**

Lars-Anders Hansson
Department of Biology, Lund University, Sweden

A major problem when studying behavior and migration of small organisms is that many of the questions addressed for larger animals are not possible to formulate due to constraints. In aquatic ecosystems, this problem is particularly problematic for zoo- and phytoplankton, since tracking devices are too heavy to allow the organism to act naturally. However, recent advances in nanotechnology have made it possible to track individual animals and thereby to focus on important and urgent questions which previously have not been possible to address. We have taken on a novel approach to track movement and migratory behavior of millimeter sized aquatic animals using nanometer sized fluorescent probes known as quantum dots (Q-dots). Compared to previously used methods to label small animals, the nano-labeling method offers considerable improvements including >24 h fluorescence, allowing studies in both light and darkness (only weak excitation light is necessary), much improved optical properties, and also potential to study large volumes and even track animals at close to natural conditions. Hence, the method, developed in close cooperation between biologists, chemists and physicists, offers new opportunities to routinely study the behavior of small animals, such as responses to light, food and predation. The methodological advancements open up for new research areas such as diel vertical/horizontal migration (DVM), partial migration and individual differences in intra- and interspecific movements and migration, which will be discussed, and given examples of, during the lecture.

**TRACKING BIRD MIGRATION WITH RADAR**

Cecilia Nilsson
Department of Biology, Lund University, Sweden

Observing migratory birds in flight is notoriously difficult. With a tracking radar it is possible to remotely track even the smallest migrants, also at high altitudes and at night. A tracking radar follows one individual bird at a time, giving very accurate position and speed measurements. By using tracking radars we have been able to make exact observations of the flight behaviour of passerines on nocturnal migration, which has enabled us to test several hypotheses about adaptive values and constraints regarding migratory behaviour in different ecological contexts. For example, we have investigated flight speeds and were able to see that birds consistently fly faster in spring than in autumn. This could be due to optimality reasons, as there might be a higher selection pressure to arrive early at the breeding grounds in spring than at wintering grounds in autumn. At a site in southernmost Sweden, Falsterbo peninsula, we tested the hypothesis that coastlines affect the flight direction of migrants, and saw no evidence of small scale coastline effects. We have also investigated how winds affect birds aloft, and done comparative studies where we show that nocturnally migrating moths and passerines achieve similar ground speeds and flight directions by using contrasting responses to winds.

**LASER PROFILING OSCILLATORY ORGANISMS**

Mikkel Brydegaard
Lund Laser Centre, Lund University, Sweden

In recent years we have developed optical remote sensing methods for profiling living organisms in the biosphere. We strive to establish non-intrusive *in situ* laser radar surveillance of ecosystems and provide quantitative data on abundance, activity and fluxes. We normally operate with transects ranging from 10 m to 10 km

where organisms are observed and parametrized individually. In order to improve specificity for species, genders, payload and behavior we continuously seek to improve certainty of retrieved parameters and also seek to increase the number of retrieved parameters. In recent years we have particularly focused on high sample rates in the kHz range and retrieval of detailed modulation signatures from insects, birds and aquatic organisms. We apply molecular multispectral methods for addressing inherent pigmentation such as the melanization or from payload, e.g., in form of digested phytoplankton. We typically retrieve in the order of $10^4$ of observations meter per hour, thus our real time data provides opportunity to model the detailed activity patterns in relation to fast varying weather conditions or in relation to small topographic features such as preferences for individual plants. The large sample number also allow us to estimate the biomass spectrum over time. Our methods allows time lag correlation between different observation for the assessment of interaction strength between species or genders. Recently we expanded our lidar arsenal with an aquatic lidar with world record in terms of senility, tempo-spatial resolution and also with the highest number of spectral bands.

Christer Brönmark
Department of Biology, Lund University, Sweden

**USING PIT-TAGS TO TRACK SEASONAL FISH MIGRATIONS**

Migration is a common phenomenon in many organisms, terrestrial as well as aquatic, and considerable effort has been spent to understand the evolution of migratory behaviour and its consequences for population and community dynamics. We have for a number of years observed that cyprinid fish migrate out of shallow lakes and migrate into streams and wetlands in the fall and return back to the lake in spring. In this project we investigate the causes and consequences of this migration. In a conceptual model, we hypothesized that this is an adaptive behaviour in response to seasonal changes in predation (P) and growth (G) and that migrating fish change habitat so as to minimise the ratio between predation mortality and growth rate (P/G). By quantifying the migration of thousands of individually marked fish (PIT-tagged), we showed that actual migration patterns followed predictions with a remarkable accuracy, suggesting that migration patterns have evolved in response to seasonally fluctuating trade-offs between predator avoidance and foraging gains. The migration is partial and in recent studies we have also investigated individual differences in costs and benefits.

Anders Hedenström
Department of Biology, Lund University, Sweden

**FLIGHT MECHANICS AND MIGRATION PERFORMANCE**

Flight mechanics is the basis for optima migration theory that was presented some 25 years ago. It is a powerful tool when generating predictions about flight strategies, as well as the basis for the theory of stopover behavior and migration strategies. Now, 25 years down the road predictions about flight and migration have been tested many times, and sometimes they have stood the test when confronted with experiments and sometimes they have not. In the meantime, the basic flight mechanical theory has undergone several revisions and improvements in the light of empirical studies in the field and wind tunnels. I will review the current status of flight mechanical theory and exemplify what can be predicted about flight strategies and present new insights about migratory flight based on observations in terns and other species.

Jessica V. Redfern
National Oceanic and Atmospheric Administration (NOAA), USA

**CETACEAN HABITAT MODELING AND RISK ASSESSMENT IN THE EASTERN PACIFIC OCEAN**

Spatial planning provides a comprehensive framework for managing multiple uses of the marine environment and reducing environmental impacts. Spatially explicit risk assessments are a basic requirement of spatial planning because they link species distributions to the potential effects and distribution of human activities. Previous estimates of marine mammal abundance were available at spatial scales that were typically much larger than the scale of human activities. To provide finer-scale estimates of species densities, researchers at NOAA fisheries' Southwest Fisheries Science Center developed habitat models for 22 species or species groups

using 15 cetacean and ecosystem assessment surveys conducted in the eastern Pacific Ocean between 1986 to 2009 (Barlow et al. 2009, Forney et al. 2012). During the development of these models, many methodological aspects of habitat modeling were investigated: modeling frameworks, data sources, error structures, model selection, spatial and temporal resolutions of habitat variables, and spatial interpolation techniques. Generalized additive models were used to relate the number of individuals or encounter rate and group size to habitat variables. Model selection was performed using cross-validation on novel data. Smoothed maps of species density are available with associated standard errors and 90% confidence intervals.

These models have been used to assess the risk of ships striking large whales in a spatial planning framework (Redfern et al. 2013). In particular, an example of the connections between users of the marine environment and the possibility for conflict occurred in Southern California when the California Air Resources Board implemented the Ocean-Going Vessel Fuel Rule. Following implementation of this rule, ships began traveling on alternative routes that increased shipping traffic in military ranges and raised concerns for maritime safety; it also raised concerns about the risk of ships striking large whales. Habitat models were used to assess the risk of ships striking humpback (*Megaptera novaeangliae*) and fin (*B. physalus*) whales in alternative shipping routes derived from patterns of shipping traffic observed before and after implementation of the fuel rule. The route with the lowest risk for humpback whales had the highest risk for fin whales and vice versa. However, the analyses identified options for ameliorating the risk to both species. The potential for conflict among users was estimated by the overlap between the alternative shipping routes and areas used for military training and fishing. These analyses represent a powerful tool for balancing user-user and user-environment conflicts when evaluating optimal shipping routes.

*Barlow, J., M. C. Ferguson, E. A. Becker, J. V. Redfern, K. A. Forney, I. L. Vilchis, P. C. Fiedler, T. Gerrodette, and L. T. Ballance. 2009. Predictive modeling of cetacean densities in the eastern Pacific Ocean. NOAA Technical Memorandum NMFS-SWFSC-444. U.S. Department of Commerce, National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, CA.*

*Forney, K. A., M. C. Ferguson, E. A. Becker, P. C. Fiedler, J. V. Redfern, J. Barlow, I. L. Vilchis, and L. T. Ballance. 2012. Habitat-based spatial models of cetacean density in the eastern Pacific Ocean. Endangered Species Research 16:113-133.*

*Redfern, J. V., M. F. McKenna, T. J. Moore, J. Calambokidis, M. L. DeAngelis, E. A. Becker, J. Barlow, K. A. Forney, P. C. Fiedler, and S. J. Chivers. 2013. Assessing the risk of ships striking large whales in marine spatial planning. Conservation Biology 27:292-302.*

## WHAT'S ON A TUNA'S MIND? CONFRONTING DYNAMIC OPTIMISATION MODELS OF BEHAVIOUR WITH TRACKING DATA

Uffe H. Thygesen
Technical University of Denmark, Denmark

Recent advances in biologging techniques have provided us with a wealth of data about animal movements and behaviour, but our toolbox of modelling techniques for analysing this information has grown slower than our data bases. One overarching principle for interpreting the behaviour of animals is that it should be rational, i.e. close to optimal in an evolutionary sense. However, evolutionary principles rarely enter in a direct mechanistic fashion in statistical analyses of biologging data, largely due to the lack of a suitable statistical framework. Here, I will discuss recent and ongoing work towards such a framework for inference in dynamic models of fitness optimising behaviour. The central component in the framework is that behavior is assumed to be random, but such that the probability of a behaviour increases with the fitness resulting from that behaviour. This allows estimation of fitness components and trade-offs based on observation of animal behaviour, and ultimately provides a method for predicting animal behaviour in unobserved environments, for example in future scenarios, on a sound and rigorous basis. The framework combines behavioural ecology with theoretical and computational

statistics. I will demonstrate different computational methods, for situations where dynamic states and decision variables are observed or partly observed. I will draw on idealised simulation examples as well as real data involving vertical strategies of migrating eel and foraging tuna.

Maksym Romenskyy,[1] James E. Herbert-Read,[1] Ashley J. W. Ward,[2] and David J. T. Sumpter[1]
[1]Department of Mathematics, Uppsala University, Sweden
[2]School of Biological Sciences, University of Sydney, Australia

**STATISTICAL AND DYNAMICAL PROPERTIES OF FISH SCHOOLS IN TWO AND THREE SPATIAL DIMENSIONS**

Over the last decades, the scientific community has made significant progress in understanding the general principles of collective motion in animals and in fish in particular. Numerous studies have focused on the individual behaviour and emergent properties of fish schools and employed a large number of experimental and theoretical technics. However, assessing the dynamical properties of large groups of fish, rigorous statistical comparison between models and data and detailed examination of fish behavior in three dimensions remain a challenge. In this work we analyse the statistical and dynamical properties of Pacific blue-eye fish (*Pseudomugil signifier*) in two and three spatial dimensions through a combination of experiment and computer simulation. We propose a novel method to infer the inter-individual interactions in fish schools, discuss the ontogeny of schooling and suggest a new approach to model validation. Also we discuss how using a three-dimensional setup can broaden our understanding of the principles of dynamical self-organisation in fish groups under predation threat.

John M. Fryxell
University of Guelph, Canada

**RECENT ADVANCES AND CONTINUING CHALLENGES IN MODELING MOVEMENT**

In this lecture I will offer a highly idiosyncratic review of the rapidly-evolving field of animal movement, with twin objectives of (i) trying to anticipate where this field is most rapidly evolving and (ii) identifying where the most interesting, yet important, unresolved issues remain. Some of this will be framed around work conducted by my lab and a number of others on terrestrial systems, as examples of the exciting new opportunities afforded by technological and statistical advances as well as the typical challenges faced under field conditions.

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Alan M. Wilson
Royal Veterinary College, UK

**ENERGETICS AND MECHANICS OF RANGING AND HUNTING LOCOMOTION IN LARGE AFRICAN MAMMALS: FUSING GPS, INERTIAL MEASUREMENTS, UAVS AND AERIAL SURVEY DATA**

With tracking technology there is a continuous drive for more data, new data, higher resolution data and all at lower total power consumption. The suite of sensors commonly used include GPS, inertial sensors (accelerometers, gyroscopes and magnatometers) and pressure sensors. The cost, and power consumption of such sensors is now low with MEMS fabrication and accuracy is improving but challenges still exist in logging, storing, offloading and fusing data from these different sensors. I will discuss the benefits that are delivered through fusing GPS and inertial sensors in the measurement of high dynamics locomotion with particular reference to hunting and ranging in African Wild Dogs and Cheetahs. I will also explore our approaches for data reduction and the use of sensors to "dead reckon" and hence interpolate between GPS position fixes. UAV platforms are also showing promise as a new tool for wildlife biology. The legislative restrictions are evolving and modern commercial platforms are low cost and very capable. We have found that it is possible to construct accurate 3D terrain maps from such platforms to enable studies of environment and ranging. We are also developing a fixed wing aircraft platform for data capture from ranging and hunting animals.

Kalle Åström
Centre for Mathematical Sciences, Lund University, Sweden

**POSITIONING AND TRACKING OF ANIMALS USING COMPUTER VISION, SOUND AND RADIO**

There are many sensor functionalities that can be used for positioning and tracking in general. Many of these techniques require a first pass of calibrating the setup.

In many cases this can be viewed as generating a map and a reference coordinate system. Once this calibration is done subsequent sensor data can be used for positioning and tracking. In this talk I will give examples of research on both of these two steps (map-making and localization) using different kinds of sensor data (images, sound, radio) and several applications to tracking of animals.

**TRACKING RHINOS (AND INTRUDERS) ON THE SMART SAVANNAH**

Fredrik Gustafsson
Department of Electrical Engineering, Linköping University, Sweden

In collaboration with Kenya Wildlife Service, Linköping University together with Stimson Center, Washington DC, is running a pilot project in the rhino sanctuary Ngulia. The motivation comes from the escalating number of rhinos being poached, and the goal is to develop innovative cost efficient technology to digitise the two main tasks for the rangers: conservation and security. For both these tasks, the enabling technology is localisation of the main actors: rhinos, rangers and poachers. The presentation will describe the current status with a cloud based reporting system in Ngulia and advanced sensor systems being tested at Kolmården Zoo in Sweden. These sensor systems include GPS tags on animals, radar, EO and IR surveillance cameras, microphone arrays, radio arrays and drones.

**PUSHING THE LIMITS FOR TAG SIZE AND LIFE-SPAN: TINY SOLAR TAGS AND THEIR FUTURE IN ANIMAL MOVEMENT RESEARCH**

David W. Winkler
TABER, Cornell University, USA

Most birds are very small, and one of the standing engineering challenges for bird-tagging is developing useful devices that are less than 1 g in mass. In the TABER group we have achieved this by developing a family of tags that have no battery: they rely entirely on a solar cell for the energy necessary to drive digitally encoded radio transmissions from the tags. Lacking a battery, we expect them to remain functional longer than the birds we place them on are expected to live. This has allowed us to produce “life-time” tags weighing 0.4 to 0.7 g with a range of 1.5 to 2 km that transmit a distinctive ID code every second or so whenever they are in sunlight. These tags are already opening up some very interesting new facets and possibilities in monitoring the movements of passerine birds.

**HIGH-THROUGHPUT MOVEMENT ECOLOGY**

Ran Nathan
Alexander Silberman Institute of Life Sciences, the Hebrew University of Jerusalem, Jerusalem, Israel

The emerging field of movement ecology largely benefited from the recent development of new tracking technologies, enhanced computation abilities and powerful data analysis tools. Movement ecology studies have utilized those technological advances to better understand movement processes and predict movement patterns. Such technology-driven era offers new exciting opportunities but also entails significant challenges. In the first part of this presentation, I will summarize the major opportunities and challenges in movement ecology research, illustrated for various birds and bats. I will stress the need to promote a dynamic interplay between advancement of movement research by new tools (the Galisonian approach) and by new ideas (the Kuhnian approach). In the second part I will introduce a new tracking system called ATLAS which has been developed over the last 3 years by the Minerva Center for Movement Ecology. The system, based on “reverse GPS” technology, is capable of automatically and simultaneously tracking multiple small animals in a regional scale of 10-20 km wide, at high sampling frequency and GPS-level accuracy. We implemented the first prototype of this system at the Hula Valley (Israel) and our preliminary work has yielded a dataset of over 20 species and more than 200 million data points thus far. In the third concluding part of this talk, I will emphasize the need to reexamine previous dogmas, conceptions and assumptions, the broader scope and greater coverage enabled by current and emerging technologies, the apparent lag in developing new concepts and theories, and the management and analysis of big data, all still await future developments.

# Abstracts poster presentations

## ALPHABETICAL AFTER AUTHOR

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### PHENOTYPIC VARIATION IN METABOLISM AND MORPHOLOGY CORRELATING WITH FISH MOVEMENTS IN THE WILD: A STUDY COMBINING RESPIROMETRY AND TELEMETRY

Fish movements can influence nutrient dynamics and trophic status of aquatic environments, but the mechanisms driving phenotypic variation in fish movements in natural settings remain poorly understood. Metabolic rate can vary as much as threefold among individuals of the same size and age in a population and this variation could drive phenotypic variation in movements and activity levels. Two different hypotheses describing the relationship between resting metabolic rate and activity have been proposed: the performance model and the allocation model, suggesting positive and negative relationships, respectively. The two models have, however, rarely been tested in nature. Furthermore, body morphology could affect movements due to co-variation between cost of transport and morphology. Therefore, this study predicted that individual variation in movement is correlated with variation in metabolic rate and body fineness ratio. To test this prediction, we captured 23 wild European perch (*Perca fluviatilis*) in a lake, tagged them with telemetry transmitters, measured standard and maximum metabolic rates, metabolic scope and fineness ratio and returned the fish to the lake to quantify their individual movements. Metabolic rates were measured using intermittent flow respirometry, while the movement assay involved high resolution 2D-telemetry providing positions every 30 s over 12 days. We found no correlation between individual metabolic traits and activity, whereas individual fineness ratio correlated with activity. Independent of body length, and consistent with physics theory, slender fish maintained faster mean and maximal swimming speeds, but this variation did not result in a larger area (in square metres) explored per 24 h. Intraclass correlation coefficients indicated that activity levels were consistent within individuals. Testing assumptions and predictions of conceptual models, our study indicates that individual metabolism is not a strong determinant of animal activity, in contrast to individual morphology, which is correlated with in situ activity patterns.

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### PREDATORS FORAGE AT INTERMEDIATE PREY DENSITIES TO MAXIMISE THEIR ENERGY INTAKE RATES

Negative density-dependence is generally studied within a single trophic level, thereby neglecting its effect on higher trophic levels. The 'functional response' couples a predator's intake rate to prey density. Most widespread is a type II functional response where intake rate increases asymptotically with prey density, which predicts the highest predator densities at the highest prey densities. In one of the most stringent tests of this generality to date, we measured density and quality of bivalve prey (Edible Cockles *Cerastoderma edule*) across 50 km² of mudflat, and simultaneously, with novel Time-Of-Arrival methodology, tracked their avian predators (Red Knots *Calidris canutus*). Because of negative density-dependence in an individual cockle's quality, the predicted energy intake rates of Red Knots declined at high prey densities (a type IV, rather than a type II functional response). Resource-selection modelling revealed that Red Knots indeed selected areas of intermediate cockle densities where energy intake rates were maximised given their phenotype-specific digestive constraints (as indicated by gizzard mass). Because negative density-dependence is common, we question the current consensus and suggest that predators commonly maximise their energy intake rates at intermediate prey densities. Prey density alone may thus poorly predict intake rates, carrying capacity and spatial distributions of predators.

### CHARACTERISING THE UNKOWN AND UNOBSERVABLE: THE USE OF AN UNSUPERVISED LEARNING APPROACH IN ACCELEROMETER DATA

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The recent increase in data accuracy from high resolution accelerometers offers substantial potential for improved understanding and prediction of animal movements. However, current approaches used for analysing these multi-variable datasets typically require existing knowledge of the behaviours of the animals to inform the behavioural classification process. These methods are thus not well-suited for the many cases where limited knowledge of the different behaviours performed exist.

Here, we introduce the use of an unsupervised learning algorithm. To illustrate the method's capability we analyse data collected using a combination of GPS and Accelerometers on two seabird species: razorbills (*Alca torda*) and common guillemots (*Uria aalge*). We applied the unsupervised learning algorithm Expectation Maximization to characterise latent behavioural states both above and below water at both individual and group level.

The application of this flexible approach yielded significant new insights into the foraging strategies of the two study species, both above and below the surface of the water. In addition to general behavioural modes such as flying, floating, as well as descending and ascending phases within the water column, this approach allowed an exploration of previously unstudied and important behaviours such as searching and prey chasing/capture events.

We propose that this unsupervised learning approach provides an ideal tool for the systematic analysis of such complex multi-variable movement data that are increasingly being obtained with accelerometer tags across species. In particular, we recommend its application in cases where we have limited current knowledge of the behaviours performed and existing supervised learning approaches may have limited utility.

### VERY HIGH RESOLUTION GPS TELEMETRY ENABLES EASY ANALYSES OF SOARING BIRD FLIGHT

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Rapid advances in bird telemetry equipment allow obtaining data at higher spatial and temporal resolutions, widening the scope of questions that can be investigated utilising this method. Having advanced far beyond being a tool for studying large scale migration routes or habitat selection patterns, modern GPS trackers are becoming more and more instrumental in analysing increasingly finer details of bird movements, providing insight into their behaviour, energetic and other aspects.
The objective of our study was to investigate the capacity of very high resolution GPS telemetry to characterize soaring bird flight. We applied pattern classifier algorithm of Framework4 software (Swansea University) to categorize eagle flight using measurements of 3-axial acceleration, magnetometry and altitude change recorded at 1 Hz. Pattern classification was aided by visual inspection of flight trajectories logged by GPS at the same frequency of 1 Hz. Fitted pattern classification was further applied to classify several hour sequence of recorded eagle flight. We further investigate applicability of this approach on low resolution GPS and sensor telemetry data collected at 1 minute intervals.
Our results reveal that when logged at very high resolution, traditional GPS telemetry coupled with sensor information allow accurate and easy characterisation of soaring bird flight. Recording bird movement data at such resolution and two-way communication via GPRS protocol is becoming increasingly feasible, particularly with flexible remote setting control and the use of geofencing.

### FIRST MONTH OF INDEPENDENCE AT SEA – CONTRASTING MOVEMENT STRATEGIES AMONG JUVENILE ALBATROSSES AND PETRELS

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Animal movement is a fundamental eco-evolutionary process yet the behaviour of juvenile animals is largely unknown for many species, especially for soaring seabirds which can range widely over the oceans at low cost. We present an unprecedented dataset of 98 juvenile albatrosses and petrels (nine species), tracked for the first three months after independence. There is a startling diversity within and among

species in the type and scale of post-natal movement strategies, ranging from area-restricted to nomadic patterns. Spatial scales are clustered in three groups that range from <3000km to >6000km from the natal nest. In seven of the nine species, the orientation of flight paths and other movement statistics show strong similarities between juveniles and adults, providing evidence for innate orientation abilities. Our results have implications for understanding the development of the foraging behaviour in naïve individuals and the evolution of life history traits such as survival, lifespan and breeding strategy.

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**IFORAGING BEHAVIOUR ACROSS 3 YEARS: HOW DOES IT RELATE TO BREEDING SUCCESS?**

Connecting movement ecology and demography is import to improve the conservation of seabirds. How do conditions at sea determine breeding parameters at the land based colony? At their largest colony in the Baltic Sea: Stora Karlsö island, the common murre (*Uria aalge*) population has been increasing over the last several decades. However, during the past ten years increasing foraging trip durations and reduced pair co-attendance times potentially indicate that parents are working harder when foraging. During three years chick-rearing murres were tracked by GPS and TDR (time-depth recorder) devices. We recorded much greater foraging trip durations and ranges during 2014 over 2009 and 2015. Contrasting behaviour between years may reflect changes in the marine ecosystem. During the last ca. 30 years there has generally been increased volumes of de-oxygenated bottom water (aka. dead bottoms) in the Baltic Sea, though with occasional oxygen rich salt water inflows from the neighbouring North Sea, leading to fluctuating de-oxygenation levels against a longer term upward trend. The main prey for murres (fish of clupeid spp.) can respond to these changes in two, non-mutually exclusive ways. Either staying in surface waters, thus avoiding the dead bottoms; or moving away from areas of deeper water to shallower seas. At the study colony, shallow water (<40 m) near the island quickly gives way to a deep water channel (>60 m), but with shallower waters further away (ca. 50 km) the other side of this deep water channel. These factors potentially lead to two contrasting responses by the murres, if clupeids are in more surface waters they are more accessible thus requiring shallower dives. Conversely if moving to areas of shallower water, murres will be required to forage further from the colony, where these conditions exist. This study looks to use colony based breeding studies in combination with telemetry studies and ecosystem knowledge to understand the complex links driving ecosystem changes.

Morten Frederiksen, Sébastien Descamps, Kjell Einar Erikstad, Anthony J. Gaston, H. Grant Gilchrist, Kasper L. Johansen, Yann Kolbeinsson, Jannie F. Linnebjerg, Mark L. Mallory, Laura A. McFarlane Tranquilla, Flemming R. Merkel, William A. Montevecchi, Anders Mosbech, Tone K. Reiertsen, Gregory J. Robertson, Harald Steen, Hallvard Strøm, Thorkell L. Thórarinsson
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**WINTER DISTRIBUTION OF BREEDING THICK-BILLED MURRES IN THE ATLANTIC: A MULTI-COLONY GEOLOCATION STUDY**

The thick-billed murre is one of the most numerous Arctic-breeding seabirds in the Atlantic sector, although many breeding populations are declining. Although large numbers of birds have been banded in some breeding areas and at-sea surveys have revealed the location of major wintering concentrations, the winter distribution of specific breeding populations remains poorly known. This has hampered conservation efforts, as it has been difficult to link specific threats in the wintering areas (e.g. hunting, oil pollution) to specific breeding populations. To address this, we collated data from geolocation studies of adult breeders in 19 breeding colonies in Canada, Greenland, Iceland and Norway (including Svalbard), including a total of 354 bird-years over the period 2007-2014. All data were processed in a standardized way. Results showed that the largest numbers of birds occurred in the northwestern Atlantic (Davis Strait, Labrador Sea, shelves off Labrador and Newfoundland). Substantial numbers also wintered around Iceland. Distribution patterns appeared to be structured largely by prevailing currents. Thus, birds from NW Greenland and Arctic Canada dominated on the Newfoundland Shelf, while breeders from Hudson Bay on average occurred further north on the Labrador Shelf and in the Davis Strait. Wintering populations on the West Greenland Shelf and in the northern Labrador Sea were dominated by breeders from Iceland and

Svalbard, and these populations also made up the vast majority of birds wintering around Iceland. We had no data from the large Russian colonies on Novaya Zemlya, but these birds are suspected to winter mainly in the Barents Sea, along with the small population from mainland Fennoscandia. The winter distribution of juvenile and immature birds remains poorly known.

**DETECTIVES IN FISH BEHAVIOUR: THE CHALLENGE OF SEPARATING PREY FROM PREDATOR IN TELEMETRY OBSERVATIONS**

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Acoustic telemetry allows for automatic tracking of undisturbed aquatic animals for long time periods with high spatiotemporal resolution. This has given researcher unprecedented possibilities to investigate individual behaviour such as habitat use and activity patterns. In turn, the resulting data can be used to characterize the behavioural ecology of different species, as well as challenging different hypotheses relating to mediators of behavioural change. Critical to the analyses of acoustic telemetry data is to separate signals representing the tagged animal from signals that were observed after the animal suffered predation, fishing or other mortality, or simply expelled a tag that then became stationary on the bottom. In field studies this is not a trivial task, as the true fate is not known unless the tagged animal (or the tag) is re-sighted. The researcher therefore typically has to judge the fate on the basis of the patterns in the signal detections, a process that can easily become very subjective. We developed a dichotomous fate assessment key that can be tailored to acoustic telemetry studies in both marine and freshwater studies, allowing for replication of the fate assignment by independent investigators. The most challenging part of the key is to find where the detection pattern changes from that of the tagged fish to that of a predator. In order to develop objective criteria for this, we compare detection patterns from the several fish species in different study environments. Our aim is to develop behavioural parameters that can be used as good classifiers for different kinds of behaviour, which in turn can be used both for describing the behavioural ecology as well as for identifying predation events.

**FOLLOWING DAIRY CATTLE AND STUDYING SOCIAL INTERACTIONS BETWEEN ANIMALS USING IMAGE ANALYSIS AND MACHINE LEARNING ALGORITHMS.**

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The efficiency of an automatic milking system (AMS) relies on a passage rate of cows through the waiting area. In an enclosed waiting area, cows of different rank compete for entering the milking station and they are exposed for a variety of social interactions. In order to assure high number of visits per cow per AMS unit it is important to understand hierarchy between animals and social interactions that might occur during waiting times. The competition between cows of a different rank to enter the AMS unit could also result in a number of aggressive interactions, which could compromise the individual performance of cows and endanger their health and welfare. The aim was to monitor the waiting area in a free stall dairy by the use of three surveillance cameras to detect occurrence of social interactions by using improved image segmentation and tracking methods. The surveillance system observed 250 cows having free access to any of four milking stations during 24 hours over a period of two weeks. A classification system, investigating features from pairs of cow shape models, was developed. The identification of social interactions using the system and crosscheck with ethogram containing descriptions of all the interactions was tested on a set of video sequences. The social interactions were identified based on collision of geometrical shapes segmented from the image and positively identified as cows by experienced observers. The system showed the potential for further development and variability of results depending on a complexity of observed interactions.

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**QUANTIFYING HABITAT USE IN SATELLITE-TRACKED EIDER DUCKS IN THE CANADIAN EASTERN ARCTIC**

Migration strategies should maximize the fitness of birds, and thus, fluctuations detected in routes and timing during both fall and spring migrations suggest that biotic and abiotic factors also vary seasonally and across years. In Arctic environments, sea ice cover has undergone major changes in recent decades in response to global warming, and variations in sea ice conditions could influence habitat use by limiting the accessibility to foraging site for migratory seabirds. Using satellite tracking data, we aim to investigate the migratory pattern and habitat use of eider ducks during the non-breeding season to identify their use of key marine habitats in the Hudson Strait, Nunavut, Canada over two different time periods (2001-2004 and 2012-2014). We will evaluate stopover sites used by eiders through: i) coastal sea ice conditions measured using Radarsat satellite images, and ii) food resources determined by boat-based benthic invertebrate sampling. We expect that the main staging sites used by eiders will be related to areas of open water (i.e. ice-free) offering access to benthic resources, and that the phenology of migration will be associated to the timing of ice-breakup and freeze-up. In the actual context of accelerated development and change in the Arctic, it is of paramount importance to identify the factors that affect coastal seabird distribution to ensure the identification and protection of critical habitats that contributes to biodiversity conservation.

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**MODELLING THE PROPULSIVE POWER OF FLAPPING FLIGHT IN VERTEBRATES**

Flight can be an expensive mode of transport, as it requires accelerating air down at rates sufficient to counteract the pull of gravity. Still many animals use flight for a variety of purposes. The cost of animal flight has often been studied using models developed for man made aircraft. For fixed wing aircraft the energetic cost as a function of flight speed can be expressed in terms of weight, wing span, wing area and body area, where more specific aerodynamic details are included in coefficients. However, flying animals flap their wings to produce thrust. It still makes sense to use the simple fixed wing model, incorporating the effects of flapping into the coefficients of the model. However, in practice these effects have been ignored.

Here we present a model that does take into account the effects of the reciprocating wing motion on the coefficients of the fixed wing aerodynamic power model for forward flight. The coefficients are explicitly formulated in terms of thrust requirement, wingbeat frequency and stroke-plane angle, for optimized wingbeat amplitudes. The expressions were obtained by simulating flights over a large parameter range using an optimal vortex wake method combined with a low level blade element method.

The results imply that previously assumed acceptable values for the induced power factor are strongly underestimated, and they also illustrate the dependence of profile power on wing kinematics is less than assumed in previous models. This model allows to rapidly make estimations of the aerodynamic power of vertebrate flight, taking into account the effects of the flapping wings, without having to run a complete simulation of the flight.

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**THICK-BILLED MURRES FROM THE HIGH ARCTIC HAVE THE LUXURY OF BEING LAZY!**

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. 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.

**APPLICATIONS OF KHZ-CW LIDAR IN ECOLOGICAL ENTOMOLOGY**

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The advantages of utilizing kHz-lidar in insect detection and monitoring, as well as a robust method of reducing and parameterizing insect properties from the data, are presented. The ability to systematically and efficiently detect, identify and monitor insects are of great interest from an ecological, as well as an economic and social, point of view. Important areas of concern are evaluation of pests, disease vectors and pollinators. Laser radar (lidar) methods have previously been developed for the purpose of monitoring and mapping aerosols and gases. Our research group have in recent years explored opportunities for the applications in ecological entomology. Lidar measurements has the potential to provide continuous and extensive monitoring of insects, which is impossible for manual methods e.g. collection in pheromone traps. Information about insect properties such as size, velocity and wing beat frequency can be extracted from lidar data.

Due to their natural wing beat cycle, flying insects are seen as blinking scattering particles, meaning that the backscattered lidar signal is modulated. The frequency content of the wing beats has been proven of high value for species classification purposes. The fundamental frequency of insect wing beats can vary between 10-1000 Hz, and the signal can contain up to 20 harmonics. A lidar system with a kHz sampling rate are thus required to obtain the harmonic content. Our research group has developed a kHz-continuous wave lidar system, relaying on inexpensive diode lasers. The system has been used in field campaigns aimed at insect detection. With this system, range resolution is obtained by sharply imaging the laser beam onto a line-detector using a setup based on the Scheimpflug principle. A method for reducing kHz data into relevant parameterized observations, such as wing beat frequency, velocity and size has also been developed.

**GROUP FORMATION AND EFFICIENCY OF MIGRATORY SPECIES**

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Individual preferences and social behavior are central traits of group formation in humans and other social animals. Being in a group is often a big advantage for those individuals performing complex tasks that are usually difficult, or impossible, to be carried alone. Schooling is an example of such complex collective dynamics and it is a common feature in several fish species performing seasonal migrations from the spawning to feeding areas. Combining an evolutionary individual based models and a novel framework based on network theory we demonstrate that three factors can control school formation and migration behavior of social fish: the strength of the social group, the relative number of informed individuals and the preference each individual has on the particular feeding area. While sociality and information ability are associated to the long-term evolutionary process that have selected them, the preference is a short-term property of single individuals and is related to the experience and memory of certain places. Intensive fishing and habitat degradation can reduce the frequency of those traits in the population up to a point at which migrations to feeding and spawning grounds are suddenly stopped.

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**RECONSTRUCTING DEMERSAL FISH MIGRATIONS IN ALASKA USING ARCHIVAL TAG DATA AND A HIDDEN MARKOV MODEL**

Commercially valuable demersal fish species such as Pacific halibut (*Hippoglossus stenolepis*), Pacific cod (*Gadus macrocephalus*), and sablefish (*Anoplopoma fimbria*) are known to move large distances during seasonal spawning migrations based on tagged fish release and recovery locations. Knowledge of migration characteristics such as timing, extent, pathways, and proportion of fish that undertake them each year are important for the management of these species, yet these details cannot be obtained by release and recovery locations alone. Our goal is to use electronic archival tags that record depth, temperature, light levels, and the earth's magnetic field to reconstruct movement pathways of tagged demersal fish in Alaska over the course of a year. To accomplish this, we are adapting a Hidden Markov Model (HMM) developed for Atlantic cod in the North Sea to accommodate geolocation data obtained from demersal fish in Alaska. The primary geolocation method for demersal fish in Alaska consists of linking maximum daily depth to bathymetry maps, but other geolocation information such as tide amplitude/phase, light-based longitude, temperature-depth profiles, or magnetic field information may be available as well, depending on the data set available for each fish. In addition to the incorporation of multiple geolocation variables, the HMM will allow for different rates of movement for different movement states (e.g., foraging vs. migrating) and provide estimates of uncertainty for daily position estimates as well as the most likely path. Here we provide a description of the model, the geolocation data available for demersal fish in Alaska, and initial results from simulated trajectories in the study area.

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**SPATIAL AND TEMPORAL PATTERNS IN THE ANNUAL CYCLE OF AN AERIAL INSECTIVOROUS BIRD - THE EUROPEAN NIGHTJAR**

The cyclical movement between spatially separated areas enables migrants to take advantage of local seasonal peaks in food abundance across a fluctuating resource landscape. In obligate insectivorous birds the annual movement often includes journeys of thousands of kilometres when migrating between e.g. high latitude breeding grounds and the tropical wintering ranges. Long-distance migration can be associated with both direct and indirect costs, affecting future breeding success and thus the migrant´s fitness. The development of miniature logging devices has enabled the collection of spatial and temporal data for explorations on a range of adaptations in, (and environmental interactions on), migrants throughout the annual cycle.

Here, geolocators were used for an initial exploration on the annual cycle of the aerial insectivorous European nightjar *Caprimulgus europaeus*. Contrary to our expectations, the twelve tracked representatives of the potential "fly-and-forage"-migrant alternated long stationary periods with distinct migratory flights. Even more notable, the birds distributed themselves far outside the currently known wintering range. Further, negative effects of distinct annual events on the duration of subsequent stops indicate a temporal synchronisation of the individuals when approaching the breeding season. Despite this, there was a positive relationship between the departure from the wintering range and the arrival to the breeding area. This indicates that some temporal variation from a spatially and temporally distant event may be transferred into the breeding period with potential fitness effects as a possible consequence.

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**MODELING THE MOVEMENT PATTERNS AND HABITAT USE OF FRESHWATER FISH BASED ON SPECIES-SPECIFIC FEEDING STRATEGY (WORK IN PROGRESS)**

The fish community of the Milada Lake, Czech Republic has changed dramatically following the introduction of the top-predator, the wels catfish (*Silurus glanis*). Acoustic telemetry has revealed in a considerable detail the movements of the catfish and its potential prey species: the rudd (*Scardinius erythropthalmus*), the

roach (*Rutilus rutilus*) and the perch (*Perca fluviatilis*). These three fish species differ in their feeding preferences and thus should differ in their behavior and movement parameters. A simulation model of each of the fish species in the lake will reveal the encounter rates of the prey fish with the predatory wels. Time to encounter should reveal whether the species-specific movement patterns are the driver of the susceptibility of each of the species to predation and whether wels introduction is responsible for the change in the fish community. The major challenge is selecting the most suitable model of fish movement patterns, i.e. correlated random walk models vs. informed mechanistic models based on fish habitat preference and food choice. However validation of the assumptions on fish movement for the model can be performed using data from an independent data set on fish movement in Lake Most, Czech Republic.

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**TRACKING, MAPPING AND RECONSTRUCTION: A HOLISTIC APPROACH TO INVESTIGATING VISUAL NAVIGATION OF DESERT ANTS**

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For over 100 years scientists have sought to reveal the underlying mechanisms allowing insects to visually navigate their complex worlds. Crucial to this endeavour is the validation of hypotheses against real animal data in identical experimental scenarios. To date, this has largely been limited to laboratory or sanitised field settings leading to the risk of non-obvious but fundamental cues being overlooked. In this work we describe our efforts to resolve this issue by creating a holistic test-bed complete with real ant paths and an accurate model of their habitat in which the data was gathered allowing navigational models to be trained, tested and validated in the ant's world. Firstly, we describe a novel semi- automated visual tracking approach used to record the position and pose of ants both as they forage naturally and then undergo experimental manipulations in their natural environment. We then describe a novel software pipeline able to convert 56 laser scans into a photorealistic mesh of the 800sqm area surrounding the ant nest complete with an undulating ground surface and over 1,700 individual plants. Finally, we show how the resultant habitat model can be used to recreate the animal's visual perception allowing for model testing and validation in a hitherto unprecedented detail..

**MOVEMENTS OF COMMON NOCTULE BATS IN RELATION TO WIND TURBINES IN AN ANTHROPOGENIC LANDSCAPE**

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Many countries try to counter global climate change by protecting habitats and by promoting energy production from renewable sources. Yet, the large-scale erection of wind turbines shows unexpected conflict with conservation goals since wind turbines may kill large numbers of birds and bats. Thus far, it was almost impossible to investigate the movement of bats in relation to wind turbines to assess the risk of mortality in bats from local populations. Here, we used miniaturized GPS loggers to investigate movements and habitat use of the common noctule bat *Nyctalus noctula* (Schreber, 1774) in the Uckermark, in northern Germany, a landscape characterized by intense crop production and a high density of wind turbines. During summer 2014, we tracked eight common noctule bats. To assess preferences for habitat types and behaviour in context to wind turbines, we ran generalized mixed effects models which compared the GPS data to correlated random walks. During midsummer, female noctules traversed the land on long foraging trips and repeatedly came close to wind turbines. In contrast, males recorded a few weeks earlier followed a daily routine of commuting straight to well defined areas where they foraged intensively and then returned straight to their daytime roost. Both sexes preferred water bodies and avoided arable lands, yet this pattern was more pronounced in males than in females. These findings underline the importance of semi-natural foraging grounds like water bodies for the persistence of populations of *N. noctula* in agricultural dominated landscapes. Furthermore, our data show that wind turbines might constitute a potential threat not only for migratory but also for local noctule bat populations, particularly for females.

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**CONTRASTING EFFECTS OF WIND CONDITIONS ON RADAR RECORDED SOARING MIGRANTS IN ITALY**

Environmental conditions are paramount in shaping migration properties in birds. Fitness-related costs induced by atmospheric conditions have modulated the evolution of migration timing and flight performance in long-distance migrating birds. We studied the effects of wind conditions on the flight of soaring raptors in a migratory bottleneck (the Strait of Messina, Italy) while crossing an ecological barrier (the Mediterranean Sea) to better understand how birds respond to environmental conditions. This work combined radar measurements of soaring birds using an x-band radar located at the Strait of Messina during the 2014 spring migration with local meteorological measurements. We tested two main research predictions regarding the effects of the wind on migrating birds: 1) tailwind assistance (TWA) facilitates migration, thereby increasing the density of migrating birds; 2) TWA positively affects the ground speed of migrating birds. We also tested the effects of other atmospheric variables on bird density and flight speed. Our results suggest an unexpected negative effect of TWA on the density of soaring migrants, likely resulting from the tendency of the birds to alter their flight route under different wind conditions. Under TWA birds likely undertook a direct cross-sea flight while headwinds facilitated a detour above land. As predicted, bird ground speed increased with increasing TWA, suggesting that tailwind assistance may substantially increase the speed of flight, helping to reduce the duration of the journey. We additionally found that soaring raptors preferred flying when crosswinds were prevalent. Our work demonstrates the complicated response of migrating raptors to atmospheric conditions at multiple spatial scales and the need to consider the regional scale when studying the effects of the environment on migrating birds.

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**UNDERSTANDING OPTIMAL LIFE-HISTORY STRATEGIES IN CYCLIC ENVIRONMENTS**

The life of many organisms across the globe is determined by cyclic environments (e.g. annual seasons, day-night cycles) and life history events, such as reproduction, need to be scheduled accordingly. Migratory birds, in particular, respond to seasonal environments by undertaking regular long-distance journeys between otherwise separated regions. They provide a mobile link between ecosystems, and the timing of their migration as well as their population dynamics might have a stabilizing effect on local biodiversity. Conserving such a fragile biological setup requires a better understanding of the population dynamics and the underlying patterns of behaviour of migratory birds – more so since changes in climate and land use have started to affect their populations. For this, a user-friendly and flexible tool is needed which integrates a mechanistic view of migration with empirical data. We therefore implemented a state-based dynamic optimization model which calculates the optimal, fitness-maximizing timing of different behaviours like reproduction and migration. Stochastic dynamic programming is used to derive the optimal decision matrix for different cyclic environments, different levels of energy reserves, health status, breeding status and age of individuals. Then, cohorts of individuals using optimal decision-making can be simulated forward in time. Our approach allows predicting environment specific life histories and assessing the population-level consequences of anthropogenic impacts. It is particularly useful for generating hypothesizes which can then be compared to field data. The recent advances in tracking migratory birds simplify the validation and the parametrization of the model. Here, we present the general methodology and discuss future perspectives of this tool that provides a link between modelling and tracking data.

## COMBINED EFFECTS OF HABITAT FRAGMENTATION AND INDIVIDUAL MOVEMENT DECISIONS SHAPE DISEASE DYNAMICS

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Individual movement decisions shape biodiversity patterns and thus also disease dynamics across spatiotemporal scales [1,2,3]. In concert with heterogeneous environments, variability in host movements will change contact and transmission processes by bridging between locally unstable host-virus interactions [4] with consequences for the speed of the epidemic front [5,6,7]. Spatially-explicit individual-based models provide a suitable experimental system in which individual variability in movement patterns of the host can be combined with a quantitative description of the infection process. Recently, Riley et al. (2015) [8] proposed the incorporation of more flexible and accurate movement assumptions as a current challenge for spatially-explicit disease models.

Within our modelling study, we aim to expand these disease models by including movement algorithms which are more complex than the assumptions used in earlier disease models, such as reaction-diffusion, displacement rules, or various types of random walks. As a starting point we use a well-established spatially-explicit individual-based model (SwifCoIBM) investigating classical swine fever (CSF) in its social host, the wild boar (Sus scrofa) [9,10,11]. In this epidemiological model, the infection of the host follows susceptible-infected-recovered (SIR) epidemics. Using a set of heterogeneous landscape scenarios (varying the amount as well as the autocorrelation of habitat), we will compare the effect of different habitat-dependent movement assumptions on disease persistence. Examples for such movement assumptions are rare long-distance dispersal events versus small-scale exploring trips, avoidance of open fields and/or urban areas, changes in movement behavior due to infection (e.g. increased aggressiveness behavior and contact rates in foxes infected by rabies), seasonal aggregations on so-called transmission islands (e.g. waterholes or feeders), or variation in the perceptual range of the individuals.

In a further step, we will introduce seasonal landscape dynamics, e.g. crop growth or harvesting in agricultural landscapes, allowing for transient connectivity windows [12]. These may act as seasonal corridors, thereby synchronizing or desynchronizing disease dynamics. The incorporation of spatiotemporal landscape dynamics may be another important factor rarely considered in both, movement and disease models. Thus, with our modeling approach we aim to contribute to understanding complex disease dynamics by unravelling the mechanisms behind heterogeneity in host behavior and contact processes [13].

[6] *Eisinger D. & Thulke H.-H. 2008: Spatial pattern formation facilitates eradication of infectious diseases. Journal of Applied Ecology 45: 415–423. DOI: 10.1111/j.1365-2664.2007.01439.x*

*[4] Hagenaars T.J., Donnelly C.A. & Ferguson N.M. 2004: Spatial heterogeneity and the persistence of infectious diseases. Journal of Theoretical Biology 229:349–359. DOI: 10.1016/j.jtbi.2004.04.002*

*[3] Jeltsch F., Bonte D., Reineking B., Leimgruber P., Balkenhol N., Schröder B., Buchmann C.M., Mueller T., Blaum N., Zurell D., Böhning-Gaese K., Wiegand T., Eccard J.A., Hofer H., Reeg J., Eggers U. & Bauer S, 2013: Integrating movement ecology with biodiversity research-exploring new avenues to address spatiotemporal biodiversity dynamics. Movement Ecology 1:6. DOI: 10.1186/2051-3933-1-6*

*[5] Jeltsch F., Müller M.S., Grimm V., Wissel C. & Brandl R. 1997: Pattern formation triggered by rare events: lessons from the spread of rabies. Proceedings of the Royal Society of London Series B 264:495–503. DOI: 10.1098/rspb.1997.0071*

*[9] Kramer-Schadt S., Fernández N., Eisinger D., Grimm V. & Thulke H.-H. 2008: Individual variations in infectiousness explain long-term disease persistence in wildlife populations. Oikos 118:199–208. DOI: 10.1111/j.1600-0706.2008.16582.x*

*[10] Lange M., Kramer-Schadt S., Thulke H.-H. 2012: Disease severity declines over time after a wild boar population has been affected by classical swine fever—Legend or actual epidemiological process? Preventive Veterinary Medicine 106:185–195. DOI: 10.1016/j.prevetmed.2012.01.024*

[11] *Lange M., Kramer-Schadt S., Thulke H.-H. 2012: Efficiency of spatio-tem*poral vac*cination*

*regimes in wildlife populations under different viral constraints. Veterinary Research 43:37. DOI: 10.1186/1297-9716-43-37*

*[7] McCallum H. 2008: Landscape structure, disturbance, and disease dynamics. In: Infectious disease ecology: the effects of ecosystems on disease and of disease on ecosystems, eds. Ostfeld R.S., Keesing F & Eviner V.T., pp. 100–122. Princeton University Press, New Jersey, United States.*

*[1] McIntyre N.E. & Wiens J.A. 1999: Interactions between habitat abundance and configuration: experimental validation of some predictions from percolation theory. Oikos 86:129–137. DOI: 10.2307/3546577*

*[8] Riley S., Eames K., Isham V., Mollison D. & Trapman P. 2015: Five challenges for spatial epidemic models. Epidemics 10:68–71. DOI: 10.1016/j.epidem.2014.07.001*

*[2] Schweiger O., Heikkinen R.K., Harpke A., Hickler T., Klotz S., Kudrna O., Kühn I., Pöyry J. & Settele J. 2012: Increasing range mismatching of interacting species under global change is related to their ecological characteristics. Global Ecology and Biogeography 21:88–99. DOI: 10.1111/j.1466-8238.2010.00607.x*

*[13] Tompkins D.M., Dunn A.M., Smith M.J. & Telfer S. 2011: Wildlife diseases: from individuals to ecosystems. Journal of Animal Ecology 80:19–38. DOI: 10.1111/j.1365-2656.2010.01742.x*

*[12] Zeigler S.L. & Fagan W.F. 2014: Transient windows for connectivity in a changing world. Movement Ecology 2:1. DOI: 10.1186/2051-3933-2-1*

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**MODELLING AND MAPPING SPECIES CONNECTIVITY USING CIRCUITSCAPE AND LINKAGE MAPPER TOOLS**

Our poster presents landscape ecological applications that are successfully used by Calluna AB (ecological consultancy company) for dealing with landscape transformation issues, in particular, urban expansion. With the help of ArcGIS Spatial Analyst package and tools as Circuitscape, Linkage Mapper, we are able to efficiently model potential habitats, migration corridors and barriers of wild animals, birds and insects.

Presentation examples:

1. Circuit theory studying barrier effects of the railway on wild animals.
2. Network theory analysing habitat connectivity and migratory corridors of several species in urban landscape.
3. Cranes observation hotspots in conflict with the wind power turbines.

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**THE NAVIGATION COMPONENT OF MOVEMENT**

Animals are thought to navigate using a map and compass mechanism when navigating from unfamiliar locations. Models of navigation can predict initial orientation and tracks based on this concept. For example, there are several different models for long distance navigation from unfamiliar places based on a grid map and I will present a comparison of four of these models. These models produce different predictions depending on the assumptions we make about the capability of the animals. Thus when movement is solely determined by navigation, distinguishing between hypotheses is, in some cases possible. However, movement is, of course, influenced by other factors. So I would be interested in discussing how the navigation component of movement can be extracted from experimental data for comparison to model predictions.

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**CONSISTENCY OF NON-BREEDING MOVEMENTS IN A LONG-DISTANCE MIGRATORY SEABIRD, THE LONG-TAILED SKUA**

Flexibility in annual movement routines may allow migrants to successfully cope with changing resource availability or weather conditions. However, only few studies have reported on individual flexibility/consistency and often analysed only part of the non-breeding period. We quantified individual consistency in non-breeding movements in an Arctic-breeding long-distance migratory seabird, the Long-tailed Skua (*Stercorarius longicaudus*), to investigate whether consistency is a repeatable trait, and whether the degree of consistency varied with two intrinsic factors: sex and subspecies.

We analysed 94 annual tracks from 36 individuals, spanning a five-year period. Nearest-neighbour analyses were performed to calculate between-track distances on a daily basis over the entire non-breeding period, except around both equinoxes. Bootstrap procedures were used to test for differences in between-track distances within and between individuals, sexes and subspecies.

The two subspecies breeding in the North Atlantic ranged widely over the Atlantic Ocean, south to the Agulhas Current, and routes did not differ detectably between sexes or subspecies. Individuals were generally consistent in their routes, irrespective of sex or subspecies. However, several individuals from Sweden (*S.l.longicaudus*) showed large-scale switches (of up to several 1000s of kilometres from previous routes) in some years. Interestingly, such switches occurred after arrival at their usual wintering area and in some cases were repeated in later but not necessarily subsequent years. These results suggest highly individual, large-scale spatial memory, and are in line with the exploration-refinement hypothesis. Future work should aim to quantify the effect of environmental conditions on intra-individual variation in movement patterns. The analysis of repeated tracking of individuals is a promising avenue for migration studies.

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**ANALYSING GPS TRACKS OF MIGRATING MONTAGU'S HARRIERS BY USE OF HIDDEN MARKOV MODELS**

Liesbeth Verlinden

Bird migration and migrating behaviour is a phenomenon that fascinates both scientists and the public. Due to developments in animal-borne tracking devices, such as GPSs, during the last decades, our knowledge about animal movement has greatly improved. However, high resolution GPS data exhibits some typical problems, such as autocorrelation, that need to be dealt with properly.

Hidden Markov Models are a special type of discrete-time state space models. They allow to connect the observations of the movement to underlying and unknown, or hidden, behavioural states. These states are assumed to be generated by a Markov chain to which the Markov property applies. By this the models allow to incorporate the serial dependence of autocorrelated data.

I examine the suitability of Hidden Markov Models to analyse bird migration tracking data. For this I model the tracks of 8 Montagu's harriers that were followed during their migration from the Netherlands to their wintering grounds in Africa. Data was gathered in autumn 2012 and 2013 and datapoints were taken every 15min during daytime (6am- 6pm).

Based on the data I fit a basic 2-states model. Assessment via graphical presentations gives a good fit. The first state seems to correspond with a behaviour in which the birds only move little without having any directional preference. This can correspond to resting and foraging behaviour. The second state seems to correspond with real migrating behaviour, with the birds covering larger distances in a specific direction.

The next steps will be assessing models with more behavioural states and adding covariates. This could finetune the current results and place the birds' migrating behaviour in relation to their environment.

Overall, if the quality and characteristics of the data allow it, Hidden Markov Models can be a mathematically simple and computational tractable way to model bird movement tracks, with ecologically intuitive results.

**A METHOD FOR RECONSTRUCTING MOVEMENT TRACKS FROM DEAD-RECKONING AND POSITION FIXES APPLIED TO HUMPBACK WHALES**

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Detailed information about location and movement of marine mammals is often crucial in studies on natural behaviour and potential disturbance effects. Combining dead-reckoning data with Fastloc-GPS and other position fixes should provide good opportunities for reconstructing georeferenced fine-scale movement tracks of these animals, and should be particularly useful for marine animals which spend most of their time under water. Computationally efficient, Bayesian state-space models were developed to estimate humpback whale locations through time in the hori-

zontal plane. Positional observation models were based upon error measurements made during calibrations. High-resolution 3-dimensional movement tracks were produced for 13 humpback whales using a relatively simple process model in which errors caused by water current movements, non-location sensor errors, and other dead-reckoning errors were accumulated into a combined error term. Compared to tracks derived only from position fixes, the inclusion of the dead-reckoning data (i.e. speed, body posture) greatly improved the level of detail in the reconstructed movement tracks. Cross-validation analysis showed a clear improvement in the predictability of out-of-set data was observed compared to more conventional track reconstruction methods. During calibration tests, Fastloc-GPS observation errors were found to vary by number of GPS satellites received and by orthogonal dimension analysed; visual observation errors varied most by distance to the whale. By systematically accounting for these observation errors in the position fixes, the developed model framework provided a quantitative estimate of location uncertainty that can be appropriately incorporated into analyses of animal movement. This generic method has potential application for a wide range of marine animal species and data recording systems.

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**MIGRATION OF THE THRUSH NIGHTINGALE *LUSCINIA LUSCINIA* TRACKED WITH GEOLOCATORS**

Understanding the factors shaping long-distance migration, requires detailed spatio-temporal information on the migration routes chosen by individual birds. The thrush nightingale *Luscinia luscinia* is a classic example of a species that track the reversed seasonality between the northern and southern hemispheres for breeding and wintering, respectively. Based on geolocator tracks, we describe their impressive migration. The birds performed a ~17,000 km long, anti-clockwise loop-migration, visiting five major non-breeding staging areas lasting 26-99 days each. The birds were not experiencing constant high vegetation greenness but the stopovers generally coincided with local maxima. Constantly being in the right place at the right time is only possible with an itinerant strategy. Timing of movements between each stopover is crucial and likely controlled to some degree by environmental cues. We will test which cues could be related to this control.

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**HIGH RESOLUTION GPS TRACKING OF COMMON CRANES FUELS DETERMINISTIC AND INDIVIDUAL BASED MODELLING OF FLIGHT TRAJECTORIES**

Tens of thousands of Common Cranes cross the southern Baltic Sea (Arkona Basin) between Sweden and Germany twice a year during seasonal migrations. Soaring landbirds like cranes rely on meteorological conditions producing thermal uplift during their long-distance migrations. As thermals are not produced to the same extent over water as over land these birds rely on more energetically expensive flapping flight when crossing large bodies of water. The objective of this study was to assess flight trajectories of migrating cranes as they cross the Arkona Basin. Crane flight data over the Arkona Basin was collected using high resolution telemetry of birds equipped with GPS transmitters. Flight tracks in 3D were recorded at 30 second intervals providing detailed altitude measurements and horizontal positions. The telemetry data together with collected rangefinder tracks were related to topographic and dynamic meteorological variables (by linear interpolations between 1 hour time steps) and further used for modelling crane flight trajectories. A generalized linear mixed model (GLMM) was first fitted aiming to characterize crane flight altitudes in relation to the meteorological and topographic conditions. The GLMM equations (with different intercept levels for tail, head, easterly and westerly winds) were further used for parametrizing an individual based model (IBM). In addition to the altitude equations, the telemetry data provided information regarding flight speeds and flight directions also used in the parameterization. Further descriptions regarding migration initiation was based on the collected rangefinder data as well as on information from literature. The IBM was used for simulating flight patterns of

Common Cranes over the Arkona Basin during the entire season of autumn migration (September-October) and was implemented in the Agent Based Modelling lab in the Mike by DHI software. The initial results indicated that the flight altitudes of Common Cranes is, as expected, weather dependent and ranges from a few meters to around 1000 m. For example during strong headwind and poor visibility, the birds fly lower while during sunny tailwind conditions they fly higher. The birds also gradually loose height with distance from the departure coast. A combination of fine resolution telemetry with statistical and numerical modelling consequently gives us the possibility to describe and predict weather dependent, stochastic flight altitudes. The model setup operates at a fine "practical" scale suitable for informing management regarding conflicts with anthropogenic constructions e.g. wind farms and potential mitigation measures.

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