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Observing the Earth through animals

The great German natural scientist Alexander von Humboldt had a simple but ingenious idea 200 years ago. If one knows the individual parts of a system and can describe their interaction, it should be possible to understand the overall system. While such approaches are highly advanced in physics and chemistry, ecology is lagging well behind. The main reason for this is that the observation of the individual parts is very difficult to impossible in ecology – or at least used to be. Above all, the sometimes global movement of individuals within a multitude of species presents great challenges for scientists. Just imagine wanting to monitor the movements of planktonic organisms in the sea or the annual migration of around 20 billion songbirds.

However, major progress has been made in movement ecology – the study of the global movement of organisms – in recent years. On one hand, the theoretical basis for the description of movement has improved significantly and has been adapted to the basic laws of physics. On the other, a wide range of new technologies partly based on consumer microelectronics have emerged which can also be deployed for the study of animal movements.

A NEW GLOBAL, SPACE-BASED EARTH MONITORING PLATFORM WILL BE LAUNCHED IN SPRING 2017 – THE ICARUS SYSTEM.

A new global, space-based platform for observing the Earth is also set to be launched in spring 2017 – the ICARUS system. This will enable small, autonomously operating sensors attached to animals to be read and programmed worldwide. ICARUS is an acronym for “International Cooperation for Animal Research Using Space”, a global alliance of animal ecologists who deploy space technology in their research.

Such global animal observation programs also have many practical applications, including forecasting zoonotic diseases, such as Ebola, Bird Flu and the West Nile virus, and enabling nature conservation measures by NGOs and GOs. A memorandum of understanding exists, for example, between the Food and Agriculture Organization of the United Nations and the Max Planck Institute for Ornithology/Radolfzell Sub-Institute on the study of the spread of global epizootic diseases that can also pose a danger to humans. The 121 nations which have signed the Bonn Convention on the Conservation of Migratory Species are also supporting the developments of the ICARUS initiative, as well as Movebank, the global animal movement database launched by our department.

ICARUS is thereby developing a technology platform but also represents the globalization of the approach to research in the movement ecology of animals. This also required a formal alliance of the animal ecologists working in the wild, the ‘International Bio-Logging Society’ which will hold its 6th biannual world conference in Konstanz in September 2017, organized by the MPIO Radolfzell Sub-Institute. The “Bio-logging decade” will be declared at this conference where, starting in 2018, all animal and movement data worldwide will be converged and processed based on uniform data standards and global comparability. The data analysts will establish an automated link to the Earth observational data, for example, from the European Copernicus Programme or from NASA.

A movement ecology cluster is currently being set up jointly between the Max-Planck Society and the University of Konstanz with four new professors working in this field to ensure the future-oriented circulation and application of this scientific approach. This cluster initiative will ensure that all the structural requirements are met to globally support and spearhead this scientific discipline, which is expanding enormously.

A key element of this new research field is also the understanding of the collective behaviour of animals being made possible by Iain Couzin’s Department at the MPIO Radolfzell Sub-Institute in collaboration with his professorship at the University of Konstanz. Studies in animal ecology previously primarily focused on individual observations or solely local interaction of individual animals. The main reason for this was the lack of our technical capability to observe the interaction of animals in the wild. By focusing on collective behaviour and deploying state-of-the-art observational methods, the interaction of animals can now be observed – for example, an entire troop of baboons in high resolution in the wild – and linked with environmental data. The enormous data sets collected in this way – e.g., some 20 million GPS points on 30 baboons in 6 weeks – allow wild vertebrate animals and their interaction for the first time to be treated as small physical particles whose regular patterns of behaviour can be described and predicted.

The activities of the former ornithological station in Radolfzell have been expanded thanks to these new global technology opportunities and developments in the scientific theory of animal movements. Nevertheless, the ringing of birds remains an important part of population monitoring and understanding global migratory movements and their changes in the Anthropocene period and the age of climate change.

The methods of engaging the public – which now no longer just include bird-ringing amateurs but instead also target a global audience or citizen scientists via the digital 'Animal Tracker' app – have also been enhanced at the ornithological station in Radolfzell. This app enables citizen scientists worldwide to link animal observations with data from electronic animal transmitters and thus make a significant contribution to the understanding of animal ecology. Amateur observations are particularly important in parts of the world which are not continually visited by biologists, such as the Sahel zone or Central Africa, where many European birds spend the non-breeding season.

From a scientific perspective, the ICARUS approach first and foremost enables two of the major unresolved issues in animal ecology and evolution to finally be answered: Firstly, the ontogenetic development of young animals and the formation of characteristics and behavioural patterns during their youth and entire life. From our understanding of humans, we know that our individual decisions are heavily influenced by our own life histories. This is no different in the animal world and only a life-long observation of individual animal behaviour can shed light on decisions that ultimately affect the Darwinian fitness of individuals.

The second key point that is so far unresolved in ecology is the survival or death of animals. It was previously virtually impossible to determine where individual animals died or where they encountered problems on their life-long journeys. Such selection events are vital to comprehending animal psychology and ecology, as only then can the manifestation of characteristics be understood as an evolutionary response to selection events. The importance of this new approach in global animal ecology made possible in part by the ICARUS technology cannot be emphasized strongly enough, as we were previously able to determine very little about the ultimate reasons for the emergence of characteristics in animals.

It is also evident in this respect that research into global animal movements has direct applications, for example, in the fields of nature conservation and the fight against global zoonotic diseases. In projects with the FAO, for example, we are examining how fruit bats move in Southeast Asia or Africa. We are thus creating the foundations for identifying the host and location of the Ebola pathogen between outbreaks. Such knowledge is ideally achieved using sentinels which are indicator species such as fruit bats that fly over the African continent in their millions as observers of the Earth with inherent animal intelligence.

Further applications are determining Bird Flu outbreaks in parts of Southwest China. Here, ducks and geese are fitted with sensors and are then able to indicate outbreaks of disease. Here, too, ducks and geese are our best allies in the early detection of global zoonotic diseases and act as in-situ observers of the Earth, forming a global network of intelligent sensors.

WE ARE USING TRACKING TO INVESTIGATE TWO MAJOR SCIENTIFIC ISSUES: ANIMAL DEVELOPMENT DURING YOUTH AND THE SURVIVAL AND DEATH OF INDIVIDUAL ANIMALS.

A further example is the use of animals as sentinels for global change, including climate change. Satellite transmitters have been attached to storks at the Radolfzell ornithological station for around 30 years in order to monitor their movements. This follows on from the ringing of storks for 100 years, which was started in Rossitten on the Curonian Spit of the Baltic Sea by our predecessor ornithological station as part of the Kaiser Wilhelm Society. Today, hundreds of young storks are fitted with transmitters in the nest to help understand their development during youth, survival strategies and physiology.

On one hand, this contributes to nature conservation; on the other, also to the understanding of the evolution of bird migration in the period of climate change, as the observations of the storks ringed in 1910 can now be compared with those of 2010. Today, however, we can record their GPS positions second by second and at the same time measure the 3D wind field, wind turbulence and thermals. Such information can soon be fed into weather forecasting and climate predictions.

It has also become evident from observing storks in Africa that many feeding grounds of storks are found in areas where migratory locusts deposit their eggs. As bioindicators, storks can therefore act as our "tracking dogs" in identifying the largely unknown spatial distribution of the egg-deposition and larval emergence areas of one of the greatest pests known to humankind. Our measurements allow us to understand the evolution of animal movements, to protect these animals and to use the information from individual storks as environmental markers.

The applications of the new global observational technologies are now also making experiments in the wild on the evolution of bird migration possible for the first time. The partial migration of blackbirds from Spain to Russia via Germany is being observed and experimentally altered at our Institute in Jesko Partecke's Working Group. As in the traditional experiments of my predecessor Peter Berthold, birds that possess particular migratory characteristics are being bred in captivity.

SCIENTISTS FOCUSSING ON ANIMAL MIGRATION REFER TO A 'GOLDEN AGE' IN MOVEMENT ECOLOGY.

Spanish blackbirds are resident birds, German blackbirds are partial migrants and Russian blackbirds are solely migratory birds. Groups of these blackbirds can now be put together in the Institute's aviaries to produce purely migrants or non-migrants or mixtures of these characteristics. The offspring of these blackbirds can then be released into the wild and we can observe, for the first time, how individuals from a known place of origin and a known genetic background make decisions in the wild on whether to migrate or not. The offspring of Russian migratory blackbirds can thereby be released into the wild in Germany, Spain and Russia, and the offspring of Spanish resident blackbirds can also be monitored in Germany, Spain or Russia. We are also investigating in detail the genetic and genomic basis of this behaviour through collaboration with the University of Konstanz and the MPI for Evolutionary Biology in Plön.

Using new transmitters that indicate the behaviour of blackbirds, additional parameters can be determined, such as the annual cycle of movements and orientation and navigation in the wild. This is an important advancement, as such experiments could almost exclusively only be conducted in the laboratory in the past. An additional miniaturized data logger is implanted into the blackbirds which measures their energy consumption and shows how the Russian blackbirds regulate their lipometabolism during migration and afterwards in comparison to other blackbirds.

This integrated approach, from genomics to physiology to global movement and survival, now allows us, for the first time, to explore many of the major still unresolved questions concerning bird migration. The answering of such questions also improves our understanding of the biological basis of complex characteristics in the life history of organisms. There are few more important decisions in the life of an organism than leaving its home and migrating to a new continent without knowing what awaits it there.

Overall, the conceptual and technological innovations in our field of research can herald a new era in global animal ecology which has the potential to change human society. The scientists working in this field are currently talking of a 'golden age' in movement ecology. Animals will soon be our best means of observing the Earth. A global network of sophisticated, intelligent sensors – the eyes, ears and noses of animals – will provide us with information about life processes on planet Earth. The collective intelligence of the global movement and behaviour of animals will enable us to observe and forecast phenomena such as natural catastrophes that could previously not be predicted, because technical observations are outrivalled by the collective sensing capacity of animals.

The tremendous value of such animal observations to human society is currently being evaluated by the World Biodiversity Council, the "Intergovernmental Platform on Biodiversity and Ecosystem Services". Animals and humans will be brought closer together as part of this digital approach, and people will better protect and conserve animals as their "global tracking dogs". Humboldt's vision might also be able to be implemented in ecology over the next two decades.