

Ramon Hegedüs - SCAR-6CI Fellowship 2008/09 report

The project was originally intended to investigate the physical (optical) basis for compass orientation in Antarctic marine birds by means of polarized skylight and to measure the availability of this information to the animals under various cloud conditions in the natural environment of the open ocean and at sites on ice. Beyond that it was suggested to study the reflected polarized sun- and skylight from fat and fish oil spills in the Antarctic region and analyzing how these sources of information can be used in foraging decisions in albatrosses and other oceanic birds. The proposed research had been planned to be carried out in a research expedition on board the Swedish Icebreaker 'The Oden' in collaboration with the Swedish Polar Research Secretariat. Due to unforeseen funding problems arising for such a scientific campaign that would have incurred high costs, the expedition could not take place and for these reason an alternative research scenario has been followed.

At Lund University, Sweden, field experiments were performed to study the compass calibration of one predominantly diurnal migrant, the dunnock (*Prunella modularis*), and two species of nocturnal passerine migrants, the sedge warbler (*Acrocephalus schoenobaenus*), and the European robin (*Erithacus rubecula*) during autumn migration. For this purpose cue-conflict experiments were carried out, in which the orientation of birds was recorded in circular cages under natural clear and simulated overcast skies in the local geomagnetic field, and thereafter the birds were exposed to a cue-conflict situation where the horizontal component of the magnetic field (mN) was shifted $+90^\circ$ or -90° at two occasions, one session starting shortly after sunrise and the other ca. 90 min before sunset and lasting for 60 min. During cue-conflict exposures and orientation tests I measured the patterns of the degree and direction of skylight polarization by imaging polarimetry and subsequently evaluated the acquired data. Our results showed that all species oriented both under clear and overcast skies, so that their preferred direction correlated with the expected migratory orientation towards southwest to south. For the European robin the orientation under clear skies was significantly different from that recorded under overcast skies, showing a tendency that the orientation under clear skies was influenced by the position of the Sun at sunset resulting in more westerly orientation. This sun attraction was not observed for the sedge warbler and the dunnock, both orientating south. Our study also concluded that all species showed similar orientation after the cue-conflict as compared to the preferred orientation recorded before the cue-conflict, and thus, the birds did not seem to have recalibrated any of their celestial or magnetic compasses as a result of the cue-conflict exposure.

The outcome of these studies was reported in a scientific paper that is currently under peer review in *Journal of Experimental Biology* [1].

I also made a significant contribution to the research on challenging bird orientation in Arctic regions carried out by the Centre for Animal Movement Research, Lund University, with the lead of Susanne Åkesson. An expedition to the North Pole for conducting this scientific work had taken place earlier (before SCAR fellowship). The principal point of this research was to study how migrating birds are able to orient themselves in extreme conditions, where the steep geomagnetic field lines make it difficult to use an inclination compass, there are no stars visible in the polar summer, and a time-compensated sun compass might be difficult to use in constant daylight. For such purpose, a displacement experiment was performed with young northern wheatears (*Oenanthe oenanthe*) to investigate their ability to find a meaningful migratory orientation in the most extreme polar region,

at different locations at and near the geographic North Pole. The birds were captured at breeding sites in northeast Russia (Provideniya) and taken onboard an icebreaker. Thereafter they were displaced to 12 experimental sites on land at Wrangel Island and at sea ice along a transect crossing the North Pole where the birds' orientation were recorded repeatedly in circular orientation cages under natural sky conditions. Celestial polarization patterns were measured by full-sky imaging polarimetry during experiments. The birds showed significant mean orientation at four of the experimental sites, while at the rest of the sites the birds' mean orientation was scattered. The mean orientation coincided with the initial great circle direction as calculated from the test location and to the expected wintering area in East Africa at three of the sites. At two of these sites the orientation was not different from the direction towards the sun, while at one site it was different. We found a higher degree of scatter for experiments during days with high temporal variation of the geomagnetic field compared to days with magnetic quiet conditions, suggesting an effect of and potential use of the geomagnetic field in the bird's directional choices despite the very steep magnetic field lines. For sites with low fluctuations of the geomagnetic field, a more scattered orientation was found under clear skies compared to under overcast skies with limited access of orientation cues (i.e. predominately geomagnetic). My major contribution to this work was data analysis concerning the acquired polarimetric images.

A scientific paper has been written on these finding that was submitted to *Journal of Experimental Biology* [2].

During these studies and inspired by the demand on efficient processing of polarimetric data for various purposes especially in the biological context, I made efforts to develop the PolarWorks software that serves as a versatile tool for evaluating polarization data acquired by imaging polarimetry, comprising evaluation and visualization procedures and a graphical user interface. In this way PolarWorks is also a major outcome of this fellowship. The software is now being utilized both for research and teaching purposes at Eötvös Loránd University, Budapest, Hungary, at Centre for Animal Movement Research, Lund University, Sweden, and at Division of Science, Mathematics and Computing, Bard College, Annandale-on-Hudson, New York, USA.

Another outcome of the project concerns the method itself used in bird orientation tests, which were carried out both in [1] and [2] as described above. The most commonly used technique involves a funnel-shaped cage, the so-called Emlen-funnel, with net topping and sloping walls, on which white paper is attached. In the original method the ink from a pad placed on the floor of the cage is transferred to the white paper by the bird's feet as the bird expresses migratory restlessness trying to escape from the cage. The escape direction, where the pigmentation is stamped on the paper, could later be visually evaluated and the preferred migratory direction of the bird recorded. The original method was later modified, and the white paper was exchanged to a paper with a soft surfacial pigment layer, e.g. Tipp-Ex paper or Thermo paper, on which the scratches generated by the bird's claws could be easily recorded without the bird's plumage being colored by the ink. Based on the registrations of scratches in the pigment of the paper, the numbers of scratches were counted in different sectors along the circular paper and the preferred mean orientation was calculated using circular statistics. This method has been widely used by scientists studying avian orientation on different continents involving a wide range of passerine migrants. Sometimes the bird's migratory restlessness is so intense that more than thousand jumps can be recorded during one hour and the evaluation of the results become very tedious and sometimes almost impossible when Tipp-Ex or Thermo paper are used as recording medium. Under some conditions it might even be hard to

estimate directions at all, if the scatter is large or the scratches from small songbirds are too faint to be recognized in the pigment of the paper by the naked eye. Observer bias is also a potential problem when humans are evaluating the bird papers, and double blind methods is recommended but is labour intensive and can in practice be hard to fulfil. All these limitations have led us to develop a new way to classify migratory activity on registration papers on the basis of claw marks in the pigment layer. Instead of relying on visual classification by humans we employ a computer-based, automated evaluation procedure in order to obtain the mean orientation and activity on bird orientation papers. Preliminary results were produced by comparing the performance of the proposed assessment algorithm with that of visual counts done by humans on computer generated orientation papers, for which “true directions” are known. The computer-generated orientation papers were prepared to have different levels of activity and scatter. We have seen that the proposed algorithm for scratch distribution assessment performs very well in terms of approximating the ground truth as well as it closely matches the results obtained by experienced test persons who performed visual counting. This is an on-going research, and our planned next steps are carrying out extensive comparisons of visual counting, computer estimation and ground truth for various computer-generated papers as well as for real papers and integrating the proposed algorithms into a standardized and robust automated evaluation procedure. A preliminary report on this research was already done, and a scientific paper is to be submitted later when it becomes complete [3].

Based on the above described studies it has to be also concluded that, even though the originally intended research project could not be carried out, our findings about how birds use compasses to orient themselves and what information may be used for navigation in extreme conditions near the North Pole are valuable in context of a general project on orientation and sensory ecology of foraging birds in the Antarctic environment (to be executed in the future).

Financial Statement

Items	Costs
Technical equipment (camera, lens, polarization filters)	2500 EUR
Travel expenses	550 EUR
Living expenses	4000 EUR
Total	7050 EUR

Acknowledgments

I am grateful to SCAR for awarding this fellowship that granted a special opportunity for me to study bird orientation in relation to physical factors that can significantly influence the animals' performance. I would like to express my thanks to Susanne Åkesson at Lund University, Sweden and all other collaborators (PhD students, technicians, etc.) in our experiments as well as Gábor Horváth at Eötvös Loránd University who helped and inspired me in designing experimental setups for polarization measurements and improving data analysis tools.

References

- [1] Susanne Åkesson, Catharina Odin, Ramón Hegedüs, Mihaela Ilieva, Christofer Sjöholm, Alexandra Farkas, Gábor Horváth (2014) Avian compass calibration: comparative experiments with diurnal and nocturnal passerine migrants in South Sweden. *Journal of Experimental Biology* (submitted)
- [2] Susanne Åkesson, Jannika Boström, Julia Delingat, Ramón Hegedüs, Eugene Khlebosolov, Olga Khlebosolova, Ulf Ottosson, Gábor Horváth (2014) Challenging navigation in young migratory northern wheatears *Oenanthe oenanthe* displaced to the North Pole region: avian orientation under extreme conditions. *Journal of Experimental Biology* (submitted)
- [3] Ramón Hegedüs, László Neumann, Rafael Garcia, Gábor Horváth, Mihaela Ilieva, Susanne Åkesson (2014) Towards the computer-based evaluation of registration papers for funnel-shaped cages used to record orientation in migratory songbirds. *Animal Behavior* (to be submitted)