Solving the mystery of bird migration: Tracking small birds from space

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Introduction

The aim of this project is to use the satellite for mounting an antenna that should be part of a radio-tracking system capable of locating small birds with intercontinental migrations anywhere along the route. Such a system would have enormous potential in animal migration research and would greatly improve our possibilities for predicting effects of e.g. future climate change on ranges of migratory species. Furthermore, this system would make it possible to conduct experiments involving migratory birds that would hold great promise for solving some of the true mysteries of bird migration: how do inexperienced, young migratory birds manage to find their way to unknown wintering quarters on their own, thousands of kilometres from were they were born.

Bird migration is among the most fascinating natural wonders. Large numbers of even small migratory birds, not heavier than a normal letter, are every year travelling enormous distances from breeding areas in Europe to wintering quarters in e.g. Africa. In geese and storks the route is learned from experienced conspecifics, but in many other species the young birds are travelling these distances alone, without any guidance from parents or other experienced conspecifics. A well known example showing that the migratory orientation programme is inherited is the cuckoo *Cuculus canorus*, in which the parents leave the nest long before the chick is able to fly.

Despite many years of research into how birds find their way, we are still lacking fundamental knowledge about the navigational capabilities in migratory birds. Thorough experiments have been performed to show how the migratory orientation programme is expressed in captive migrants, and we have much knowledge about the compasses used by migratory birds. However, we have very little knowledge about how the migratory orientation programme is carried out in free-flying birds.

Two possible hypotheses can explain how birds are able to follow their migratory routes. Either they fly in a certain direction for a certain amount of time or they fly towards a certain goal. An impressive experiment was carried out by the Dutch Perdeck [1] in the fifties and sixties, in which more than 11,000 starlings *Sturnus vulgaris* were displaced away from their normal migratory route. These experiments showed that the young inexperienced starlings continued their migration in their original direction. This demonstrated that starlings are likely to locate their wintering area by flying in a certain direction. However, the starling is a social migrant where the migration direction is presumably much influenced by accompanying flock members. Furthermore, the starling is a short-distance migrant, and these experiments cannot necessarily be generalised to long-distance migrants with much stronger demands for precise orientation. Since these experiments, only very few experiments have been performed to increase our knowledge about the migration programme and the effect of external factors, as e.g. topography, on how and where birds migrate.

With the rapid development of small-sized radio-transmitters providing accurate location information anywhere on earth, time seems ripe to test orientation performance with data obtained using advanced tracking techniques. Most important would be to perform displacement experiments similar to those performed by Perdeck [1]. Such an experiment (displacing very large numbers of birds) is not feasible today due to ethical and logistic reasons, but the use of satellite telemetry can drastically reduce the number of animals needed for experimentation. A similar study has recently been conducted with white storks *Ciconia ciconia* [2] but with highly unexpected results that could not be attributed to any single hypothesis. However, the white stork is, like the starling, a highly social migrant, and selection on a narrow migration route in that species probably is not as strong as on other long-distance migrants with restricted wintering quarters. Thus, to further investigate the innate migratory orientation programme we should ideally conduct displacement experiments with long-distance, non-social migrants with concentrated migration routes. At the moment such experiments can only be performed on night migrants using conventional radio telemetry. The development of a satellite-based system relying on even smaller tracking devices than those in use today will enable us to follow even such long-distance migrants on their migration all the way to the wintering areas. Such detailed tracks will undoubtedly reveal many surprises and new insights into the function of the migratory orientation programme in free-flying birds.

An ideal study species for investigating the inherited migratory orientation programme would be the cuckoo (Fig. 1). It is a long-distance migrant, but we have very little knowledge about actual migration routes and wintering grounds. Furthermore, the cuckoo is one of the largest species among the night migrants where we are certain that individuals migrate singly without any guidance from experienced conspecifics.

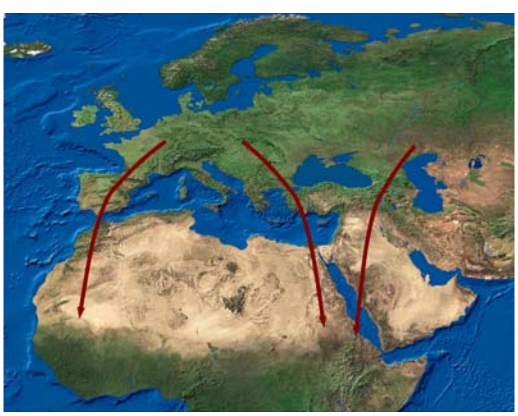

Figure 1. Migration routes of European cuckoos. The exact routes and wintering quarters as well as separation between wintering populations are not known.

Today satellite tracking of birds is exclusively done using the ARGOS system [3]. This system has been in operation since 1978 and uses satellites in low-earth orbit at an altitude of 850 km. The estimation of transmitter locations is based on the Doppler effect, and at least four contacts with the transmitter are needed for accurate location estimates.

Methods

The cuckoo is around 330 mm in length and weighs approximately 110 g (Fig. 2). Since birds should not carry more than an absolute maximum of 5 % (and preferably not more than 2 %) of their weight, the maximum weight of the transmitter should be around or less than 5 g. Currently, the lightest transmitter designed to use the Argos system weighs 12 g. It is 43 mm long, 18 mm wide and 14 mm high and based on solar power [4]. The antenna is an additional 178 mm long. This transmitter has an acceptable length, but it is still too heavy for the proposed study species. Thus, the weight of the transmitter needs to be reduced.

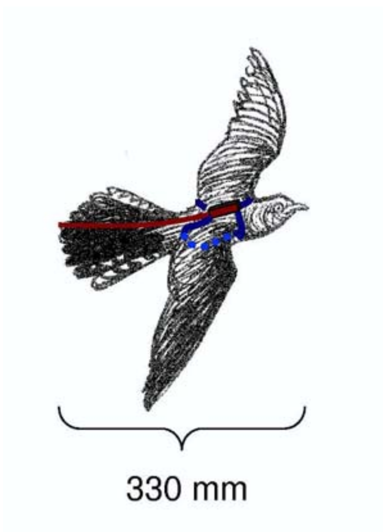

Figure 2. A cuckoo fitted with a transmitter 'backpack' including antenna.

I propose two factors that could help reduce the weight of the transmitter: (i) The satellite should use simple detection of the signal to locate the transmitter (Fig. 3) and (ii) only one fix is needed to infer effects of displacements or approximate wintering area.

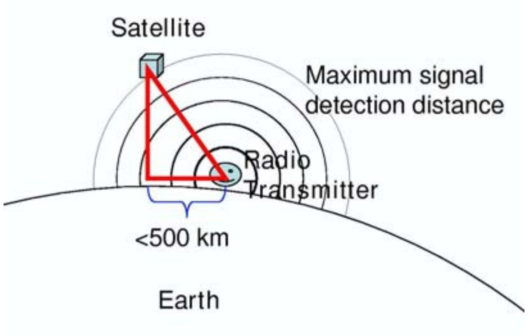

Figure 3. The proposed system for approximate location of radio signals transmitted from a ground-based transmitter [see also 5].

Regarding (i), the required accuracy for this type of tracking is low. Since the bird may have travelled more than 5,000 km, a location within ± 500 km would still be very important. Thus, the antenna should be able to just detect the signal within this range. Then the position of the satellite can be used for location estimates (Fig. 3). Using this idea, Cochran & Wikelski [5] argue that it should be feasible to track even smaller transmitters than the ones proposed here from the ISS, which is in orbit at 400 km. The location estimates may to some degree be corrected using the strength of the received signal. Regarding (ii), the low number of fixes needed for important results makes it possible to minimise the requirements for battery life, which could further decrease the weight of the transmitter battery.

The satellite shall be placed in low-earth orbit, in as low an altitude as possible, as this would decrease power output needed from the transmitter. The technical details and specifications of the receiver will have to be worked out as part of the project. The transmitters will be either standard or custom-made models from e.g. Microwave [4] or Televilt [6].

Thus, the proposed payload consists of an antenna optimised to receive signals from the small ground-based transmitter. The project will have four parts: (i) To design the system, which will be a task for engineers or students at DTU. (ii) To build the antenna to use for mounting on the satellite; this is also a task for engineers or students at DTU. (iii) Making the system work on a number of test cases including using the system on real migratory birds; this will be done in collaboration between DTU and a team of biologists lead from the Zoological Museum who will fit the transmitters to the birds. Biology students are expected to take part in this work, but additionally, the Zoological Museum collaborate with a number of volunteers to capture and ring birds. (iv) Performing a displacement experiment using the small transmitters; this will be done by a team from the Zoological Museum.

Output

In addition to the scientific interest in the results, there is considerable public interest in the subject. Thus popular articles and popular talks (in Danish) are planned to accompany the scientific papers from the project.

References

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