Appendix 3 to J. Rabøl 2022: Magnetic orientation in night migrating passerines. – Dansk Orn. Foren. Tidsskr. 116: 61-66.

Juvenile European Robins tested in funnels without sight of sunset nor stars in magnetic fields where magnetic N was deflected towards W or E showed no response to the magnetic field

(Med et dansk resumé: Unge Rødhalse testet i tragte om natten uden stjerner med magnetisk N vendt mod geografisk Ø eller V viste ingen orientering i forhold til magnetisk N)

Abstract Funnel experiments under an artificial overcast sky with juvenile European Robins in autumn 2013 showed that the birds were not using a magnetic inclination compass for their migratory orientation; both controls and experimental birds in inverted magnetic fields were significantly oriented in about the standard direction. Therefore, in autumn 2014 new experiments were carried out to investigate the logical alternative that the migratory orientation in overcast were steered by a magnetic polarity compass. However, no evidence was found as the orientation was about standard in reference to geographical N in both controls and experimentals where magnetic N was deflected towards geographical E or W.

Introduction

No one doubts the importance and significance of a magnetic compass in the migratory progress of passerine birds. According to Wiltschko & Wiltschko (1995) the magnetic compass in birds used for migratory orientation is an inclination compass.

However, Rabøl *et al.* (2002) in four series of orientation experiments found no evidence of a magnetic inclination compass, and tests by Rabøl (2022 Appendix 2) gave clear evidence that a magnetic inclination compass was not used in freshly trapped migrant European Robins *Erithacus rubecula* tested in autumn 2013 in funnels on the island of Christiansø in the central Baltic under condition of no sight of the sunset nor the stars. Rabøl (2010) found weak evidence of a magnetic compass in cue-conflict experiments, but no involvement of a magnetic compass in a calibration process together with sunset and stellar compasses. Furthermore, Rabøl (2019) could not demonstrate a significant thorough presence of a magnetic compass in more than 70 compass conflict experiments with more than 1300 freshly trapped passerine migrants tested sunset/early night or night on Christiansø. Furthermore, on the fringe of relevance in this connection, Rabøl (2014) found no evidence of magnetic gradient navigation.

Evidence for use of a magnetic inclination compass comes from long term caged birds. Perhaps freshly caught migrant birds a) make use of a magnetic polarity compass, or b) not at all of a magnetic compass. As the Robins tested in inverted magnetic fields (Rabøl 2022 Appendix 2) largely showed the same standard orientation as the control birds a) was considered the likely scenario.

Clearly, the next step was to make probable that a magnetic polarity compass was in use in the 2013 tests. Therefore, orientation experiments on Christiansø in autumn 2014 were designed for that purpose: birds were tested in magnetic fields where mN was deflected towards gW or gE, and the resultant magnetic vector had the same intensity and inclination as the natural magnetic vector on Christiansø. The expected orientation in reference to mN should then be around standard, or at least the same in controls and experimentals.

Material and methods

Experiments were carried out during night starting two hours after sunset, i.e. all sight of the setting sun had disappeared. Experiments lasted for about two hours and because of the translucent but not transparent plastic covering of the funnels the test-condition was the one designated 'overcast' (e.g. Rabøl 2010). We controlled that no stars nor any part of the surroundings could be seen through the plastic cover.

Experiments were carried out on the following dates in September: 17, 19, 20, 21, 23, 26, 27 and 29. Each night 16 birds were tested: eight controls, four experimentals where mN was deflected towards gW, and four experimentals where mN was deflected towards gE.

The birds were trapped on Christiansø as grounded migrants (more than 95% juv.) the same or the preceding day as the experiments were carried out during night, i.e. what may be designated short time caged birds were used contrary to the situation in most experiments by e.g. Wiltschko & Wiltschko where long time caged birds were investigated. The birds were caged (plastic baskets) in the shielded garden of the Miller's House in the middle of the island and fed by mealworms. The baskets (two birds in each) were covered with a wooden plate to shield for the sun, rain and Eurasian Sparrowhawks *Accipiter nisus*. The caged birds had no direct sight of the sun nor the sky but could probably establish the rough relation between their magnetic and sun-based compasses. During early night the birds were transported in small cans to the Bastion of the Queen where the funnels and magnetic fields were placed screened away from the passing light from the lighthouse situated in the direction of NW-NNW. As in earlier experiments (Rabøl 2022 Appendix 2) no photo-taxic response was found towards the passing glow (sometimes rather prominent, mostly invisible for the naked eye) from the lighthouse. The birds were transferred directly into the funnels without previous stay in baskets within the deflected magnetic fields, and the birds inside the plastic funnels were supposed to be able to sense the magnetic field in order to use their magnetic compass. The funnels were painted with chalk on the inner slopes. The hopping and fluttering bird left its footmarks in the chalk and the pattern was inspected for top(s) of activity. Birds were tested only once and then released. We used the same system of notations for direction and amount of activity as described by e.g. Rabøl (2010, 2014).

Results

As there seems to be no significant differences between the patterns observed on the eight nights, I summed all orientations in the three major groupings. Both the controls and the W- and E-experimentals were significantly oriented in about SSW (Figs 1-2). The controls oriented 199º - 0.401 (N = 51, $P < 0.001$), the W-experimentals 208º - 0.561 (N = 23, $P < 0.001$) (or considered as bimodally oriented 222º/(42º) – 0.524 (N = 25, P < 0.001), and the E-experimentals 201º - 0.490 (N = 20, $P < 0.01$).

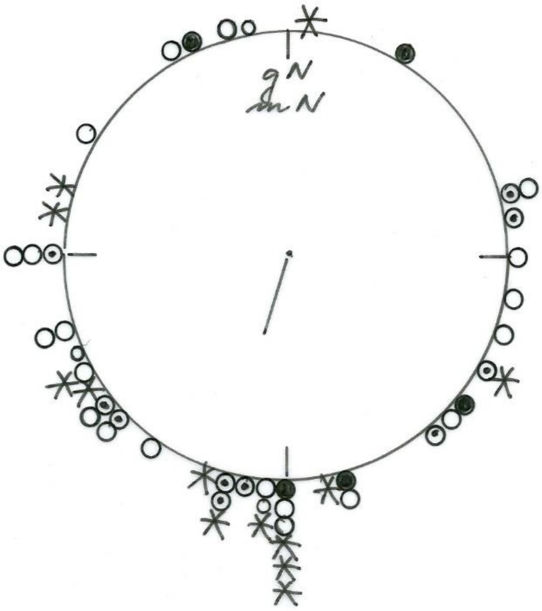

Fig. 1. The orientation of the controls in reference to magnetic and geographical N (which are coinciding). As normal for funnel experiments under overcast / + ’overcast’ the concentrations – both individually and as a sample – are smaller than when birds are tested under condition of a starry sky. Anyway, the sample mean vector 199° – 0.401 (N = 51, P < 0.001) is very significant and close to the standard direction of about SSW-SW.

Kontrollernes orientering. Gennemsnits-vektoren er signifikant og rettet mod SSV.

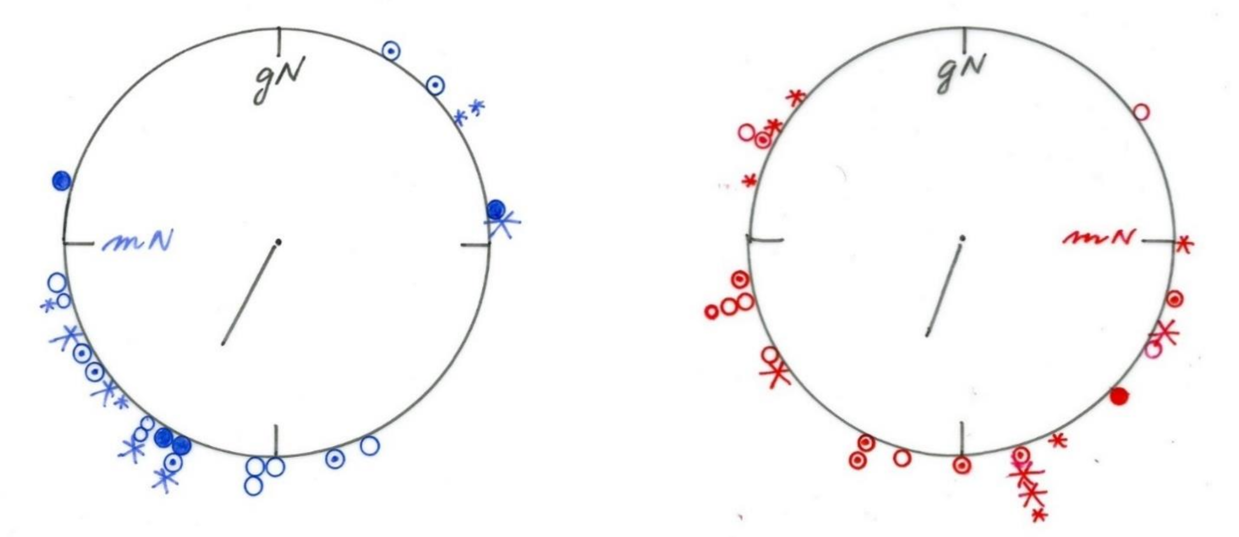

Fig. 2. The orientation of the experimentals i reference to geographical N. The left figure denotes the W-deflected birds (blue), and the right figure the E-deflected (red). The W-deflected birds seem bimodal in their sample pattern and by means of doubling the angles the axial mean vector was calculated as 222°/(42°) - 0.524 ($N = 25$, $P < 0.001$). Treated as a unimodal pattern the sample mean vector comes out as 208° - 0.561 ($N = 23$, $P < 0.001$). According to normal practice the pattern should therefore be considered as unimodal. The E-deflected birds seem unimodally distributed and the sample mean vector was calculated as 201° - 0.490 ($N = 20$, $P < 0.01$). Clearly there seems to be no significant directional difference between the W- and E-deflected experimentals. If the two samples are combined the sample mean vector is 205° – 0.527 ($N = 43$, $P < 0.001$).

Forsøgsfuglenes orientering i forhold til geografisk N (gN) og magnetisk N (mN). I begge tilfælde ses en signifikant SSV-orientering i forhold til gN. Et magnet-kompas synes således helt uden indflydelse.

Discussion

The correspondence in orientation between the W- and E-deflected birds is indicative of a compass in action in reference to geographic N. However, the lack of use of a magnetic compass in charge was really surprising; especially because most scientists lead by Wiltschko & Wiltschko consider the magnetic compass as more important and basic than the celestial compasses. Perhaps the birds were able to sense out the natural magnetic field from the hybrid-field? (or – what is technically the same – exclude the artificial magnetic field). However, according to convention only the composed field could be sensed.

As no sight of the sunset nor the stars were available the most obvious explanation is that the orientation was directed by a spurious outside source in reference to gN such as a low frequency source of sound towards SSW, or a light source in the same direction. However, there seemed to be no such sources directed in the standard direction nor in any other direction (except the occasional light glow from the beams of the lighthouse towards NW/NNW). Clearly, neither the sunset nor the stars can direct the migratory orientation under the conditions experienced.

The conclusion should be that the orientation seems to be guided by a compass reference or an orientation system not yet or normally appreciated.

For me these results are a signal that we are far from understanding what is going on in migrant birds, and our nice conceptional system of compasses and their system of dominance and calibration is breaking down or at least fade away. Until now I often said that compass orientation alone is not sufficient to describe and understand migratory progress in juvenile birds: we also have to think in terms of gradient/coordinate navigation. But this is something else; a third system. One may guess that the birds are able to maintain and express an intended migratory direction at least for one or two days and nights without a guiding outside compass reference. Perhaps it is an inertial response (Barlow 1964) in some way? The results link to an experiment by Rabøl (1975) who observed the same about SE-orientation in four groups of short-timed caged, funnel-tested Robins at Blåvand, westernmost Denmark. The four groups were tested under conditions of: 1) undisturbed magnetic field and stars on the sky, 2) undisturbed magnetic field and + 'overcast', 3) destroyed magnetic field and stars on the sky, and 4) destroyed magnetic field and + 'overcast'. 4) is difficult to explain without involving something else than stars and magnetic field; perhaps inertial orientation is involved. Also, the 'mysterious' significant orientation in reference to geographic N under 'overcast' conditions (Rabøl 2019) could be understood as inertial responses.

Perhaps it matters a lot whether the birds tested in the funnels are short time caged or long-time caged birds. Perhaps caged birds for a long time deprived migratory actions tend to use more compass orientation (on behalf of navigation), and under overcast/'overcast' conditions rely more on a magnetic compass reference than an inertial system. The latter is supposed to decay during long time captivity. Experiments with freshly trapped migrants are more connected to natural behaviour in actual migration than experiments with long term 'cagebirds' as often used e.g. in the experiments by Wiltschko & Wiltschko. Perhaps use of a magnetic compass reference is a sort of basic reaction when other possibilities are weakened or outfoxed by the experimental treatment and condition. The weak – if any – influence of a magnetic compass in the dominance/calibration experiments by Rabøl (2019) could also be understood in this way.

K. Thorup (pers. comm.) offered another possible explanation: the orientation was in some way or another steered by the sound of the sea/the waves on the coast. The birds were housed in the sheltered garden of the Miller's House at the top in the middle of the island. In principle there could have been some calibration of sound-directions by the magnetic or the sun compass. Down on the Bastion of the Queen the funnels are more less sound-sheltered/deflected by stony walls on most sides.

The winds were recorded for the eight nights where the experiments were carried out. On four nights the wind was very low or calm. However, on 17 September, the wind vector was SE 6 m/s, whereas on 21, 26 and 27 September it was W 7-8 m/s, W 10-12 m/s, and W-WNW 8-9 m/s, respectively. As there seems to be no difference between the three control categories, W-experimentals, and E-experimentals, we summed the results and found the following sample mean vectors: 17 September: 201° - 0.638 (N = 12, P < 0.01), 21 September: 184° - 0.417 (N = 12), 26 September: 184° - 0.501 (N = 13, P < 0.05), and 27 September: 173° - 0.684 (N = 12, P < 0.01). The orientation was most westerly on the day of SE wind, but it looks like a coincidence, and clearly there seems to be no attraction or repelling of (something connected to) the wind direction.

In the 2013 experiments investigating the magnetic inclination compass (Appendix 2) a third group (29 September, 1 October and 2 October) was tested in a strong, vertical, and heterogenous magnetic field. As a group the birds were disoriented. However, the mean direction was close to standard (181° - 0.275, N = 16). Also, the samples of controls and magnetically inverted experimentals were disoriented (127° - 0.357, N = 19, and 209° - 0.473, N = 13, respectively). However, combined the orientation was significant (170° - 0.293 (N = 48, P < 0.05). Therefore, this experiment adds to the findings of (about) standard orientation in case of absence of both celestial and appropriate magnetic cues.

Perhaps people will maintain that the light intensity in these night experiments was too low for proper use of a retina-based magnetic compass. However, 1) the influence of a magnetic compass also seems low or lacking in my sunset/early night experiments (Rabøl 2019), and 2) the experimentals were significantly oriented – as the controls – in the standard direction.

Resumé

Unge Rødhalse testet i tragte om natten uden stjerner med magnetisk N vendt mod geografisk Ø eller V viste ingen orientering i forhold til magnetisk N

I efteråret 2014 testede jeg juvenile Rødhalse i tragte under en kunstigt overskyet himmel. Det skete med en forventning om, at de under den betingelse kun havde et magnet-kompas til rådighed for deres trækorientering. Hver nat testede jeg otte forsøgsfugle; fire i hvert sit kunstige magnetfelt, hvor den resulterende retning mod magnetisk N var drejet mod geografisk V, og fire andre i felter med resulterende magnetisk N drejet mod geografisk Ø. Hældning (70º nedad), og feltstyrken i de resulterende magnetfelter var ganske som i det normale magnetfelt i Danmark. Desuden testede jeg otte kontrolfugle i det normale magnetfelt (magnetisk N = geografisk N) for Christiansø. Den kunstigt overskyede himmel blev lavet ved, at tøjnettet over tragten var dækket af lysgennemskinneligt, men uigennemsigtigt plastik, hvorigennem stjernerne ikke kunne ses. Da forsøgene blev indledt to timer efter solnedgang, var der intet spor af denne tilbage.

I det foregående efterår (Rabøl 2022 Appendiks 2) havde jeg også testet Rødhalse under en kunstig overskyet himmel. Halvdelen af fuglene blev testet i et inverteret magnetfelt, hvor de magnetiske kraftlinier ikke som naturligt i Danmark gik 70º skråt ned i jorden, men 70º skråt opad. Ifølge den fremherskende opfattelse (først formuleret af W. og R. Wiltschko) burde det medføre en omvendt orientering mod ca. NNØ, fordi fuglene ifølge disse forskere ikke har et polært kompas, der som en

kompasnål peget mod den magnetiske nordpol. Ifølge disse forskere, har fuglene i stedet et inklinations-kompas, hvor retningen mod magnetisk N bestemmes udfra den mindste vinkel (i dette tilfælde 70º kontra 110º), som inklinationen (kraftliniernes hældning) danner med jordoverfladen. Jeg kunne imidlertid ikke påvise et inklinationskompas i aktion i disse 2013-forsøg. Forsøgsfugle og kontroller viste den samme ca. S-orientering, så enten brugte de et polært magnetkompas, eller også viste orienteringen tilbage til noget ukendt – eller var at opfatte som en taxi (mod lys, lyde e.l.) rettet mod S. Jeg kunne dog ikke finde nogen kilde til en mulig taxi i den retning.

Jeg formodede derfor, at forsøgene i efteråret 2014 ville vise, at Rødhalsene havde et polært magnetkompas. For år tilbage (Rabøl *et al.* 2002) havde jeg og flere kolleger skrevet en artikel baseret på fire forskellige forsøgsserier med mange forsøg, der heller ikke kunne påvise et inklinationskompas i aktion, og den artikel er aldrig blevet nævnt af det toneangivende par R. & W. Wiltschko i så meget som en af deres mange oversigtsartikler over magnetorientering. I 2014-forsøgene var der ingen forskel på kontrollerne og forsøgsfuglene med magnetisk N drejet i geografisk V eller Ø. Begge grupper orienterede sig i normaltrækretningen SSV i forhold til geografisk N.

Hvordan kunne det gå til? Mit bedste bud er, at Rødhalsene kan noget, som vi ikke kan, eller måske kan vi det i rudimentær form. Det kunne være en form for inertiorientering, som foreslået af Barlow (1964). Kort fortalt betyder inertiorientering, at fugle er i stand til at fastholde en trækretning ved hjælp af et (eller flere) gyroskop(er) (formentlig beliggende) i det indre øre over en varighed på i hvert fald i et døgn eller to. Efter længere tids ophold i fangenskab bryder systemet sikkert sammen, og fuglen vil slå over på sit magnetkompas (af inklinationstypen?), hvis den testes i fravær af solnedgang eller stjerner på himlen. Ellers vil sol- eller stjerne-kompasset som regel være dominerende. Der er således måske forskel på 1) frie fugle og fugle holdt en til få dage i fangenskab på den ene side og 2) lang tids fangenskabsfugle på den anden. Det kunne også forklare fraværet af magnetorientering i mine kompas-konflikt (dominans/kalibrerings) forsøg med fugle holdt i fangenskab i højst et døgns tid (Rabøl 2019).

Så måske var udfaldet af 2014-forsøgene sammen med 2013-forsøgene og de mange 'negative' kompas-konflikt forsøg (med Rabøl 2010 som en delvis undtagelse) slet ikke så dårlige set i tilbageblikket: Der må være en ny 'mekanisme' som nu fortjener en nærmere udredning.

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