Contents

Bird migration

Der Falke
Journal für Vogelbeobachter

Dear Readers,

The world of birds is full of fascinating stories. Perhaps one of the most impressive is the annual migration of many bird species from Europe to Africa and back. A Wood Warbler, for example, weighing only ten grams, (the same weight as ten paperclips) flies from Britain to Ghana, often using exactly the same stopover sites in Burkina Faso, to winter in the same group of trees as the year before.

Common Cranes. Photo: H.-J. Fünfstück.

Barn Swallows from Europe journey all the way to South Africa, thousands of kilometres over oceans, mountains and deserts – and return to exactly the same nest where they hatched the year before. Swifts, born in Europe, begin their migration to Africa in August to spend the winter in central Africa. In April they return to Germany, display their spectacular flight in our summer skies, again migrate to Africa and back and for the first time build a nest and raise young. Two years from fledging to the first brood, without touching the ground once – as far as we know!

In this special issue of DER FALKE, „Bird migration", we wanted to explore bird migration in all its facets and have pulled together input from some of the finest experts on this subject in Germany. To make the content available to a wider audience, we have had it translated into English and published it electronically. The PDF file is to be distributed free of charge, and we encourage you to forward the file to anyone you think might share our enthusiasm for bird migration and might be interested in this publication.

We, along with the expert board of DER FALKE, hope that we have brought the phenomenon of bird migration closer to you with this extra issue. If you view Wood Warblers, Barn Swallows, Wheatears, Cuckoos or Swifts with slightly different eyes in the future and share our enthusiasm for bird migration, then we have achieved our objective. We hope you will enjoy this special issue of DER FALKE.

Best wishes

Dr. Norbert Schäffer
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Contents Bird migration

The fascination of bird migration

The annual migration of millions of birds is one of nature's most fascinating spectacles. How do we find out about the migration routes and winter quarters of these birds; how do the birds know the right time to leave on migration, what their destination is, and how to find their route; and how do they manage to survive the journey of thousands of kilometres and the crossing of deserts and oceans? These, and many other questions, have occupied natural scientists for centuries.

Carl von Linné (1707-1778), in his *Migrationies Avium* published in 1757, still assumed that migrant birds hibernated at the bottom of water bodies. Even Heinrich Gätke, who painstakingly recorded which bird species migrated through Helgoland and when, was only able to speculate on their origin, and where they went to in winter, in his book *The Helgoland Bird Observatory Ornithological Station* published in 1891. The famous female 'Arrow Stork', which was shot in 1822 near Wismar, N Germany, with an arrow of East African origin embedded in its neck, provided an indication of where it had spent the winter, as did the first ringing of White Storks and Woodcocks in the 19th century with recoveries in Southern Europe; but it was only in 1899, when the Danish teacher Hans Christian Mortensen had the idea of fitting birds with small metal rings engraved with an individual number and address, that it became possible to shed some light on the migration routes and wintering areas of birds. Today, after a good 100 years of bird ringing (within Germany alone more than 20 million, and throughout Europe more than 120 million ringed birds), we have reasonably good information on the migration behaviour of many species (see pp. 16–19).

The arrow, of African origin, in the female 'Arrow Stork' of Wismar supplied information on the probable wintering location of the bird. Photo: R. Kinzelbach.

Birds like the Pied Flycatcher (below) marked with rings with a combination of numbers and letters can be individually identified. Photos: R. Nagel

The great success of scientific ringing is due to the numerous voluntary helpers who carry it out in their free time. There are some 800 volunteers in Germany and some 8,600 in Europe as a whole. The existence of such a large voluntary effort is a unique phenomenon in zoological research throughout the world. Most of the ringers now participate in special programmes, where very specific questions are worked on, and which are coordinated on a national or European level. Information on the recovery of a ringed bird usually reaches the responsible national ringing centre. Here, on the basis of the ring number, the date and place of ringing is established and both the finder and the ringer are informed of the ringing and ring recovery data. There is also an intensive exchange of information between national ringing centres, as ring recovery information very frequently comes from abroad.

Today there is a ringing centre in almost every country in Europe. In most countries there is only one national ringing centre. In Germany however, for historical reasons, there are three. These are the Institute of Avian Research 'Vogelwarte Helgoland' in Wilhelmshaven, the Hiddensee Ringing Centre in Greifswald and the Radolfzell Ornithological Station on Lake Constance (formerly the Rossitten Ornithological Station). Birds ignore political boundaries, so transnational cooperation is essential. For this reason the national European ringing centres came together in 1963 to form the co-ordinating organisation for European bird-ringing schemes (EURING) and agreed to use a uniform computer code for ringing and ring recovery data and to include their data in a common database (see pp. 34–35).

After more than 100 years of bird ringing in Germany the first common bird migration atlas is currently being produced. More than a million ring recoveries from birds ringed by the three German ringing centres, as well as more than 150,000 recoveries in Germany of birds ringed outside the country, allow for the first time a comprehensive record of the migration of bird species occurring in Germany (see pp. 16–19). New technology, such as satellite telemetry, GPS tracking, geo-location, or stable isotopes analysis, further extend this potential and permit previously open questions to be answered in details that ringing alone cannot provide (see pp. 20–25).

Hand-reared Garden Warblers can be used to demonstrate that there is a relationship between the length of the innate 'zugunruhe' and the distance to their winter quarters.
Photo: F. Bairlein.

» Migration as a result of inner drive

Young geese, cranes, or storks follow their parents on migration. Young Common Redstarts on the other hand migrate, as do most birds, alone and by night. How does a young redstart, or indeed a young cuckoo that does not even know its parents, know when it is time to begin migration, where its winter quarters are, and which route to take to them? How does it make its way?

For a long time it was assumed that bird migration was triggered directly by environmental factors. The mass winter migration of Common Buzzards, Eurasian Jays and Chaffinches on the occurrence of cold fronts or after snowfall is an example. Mass return migration is also noticeable when warm air infiltration occurs in Central Europe in spring. Northern Lapwings can hold out in Central France until they are able to exploit favourable climatic conditions and migrate rapidly into their Central European breeding grounds.

However, the situation of long-range migrants that winter in the tropics is very different. They leave their breeding grounds in midsummer when environmental conditions are still excellent. Similarly, they leave their tropical wintering areas with such precise timing, despite more or less constant environmental conditions, that they return to their breeding grounds on almost the exact date every year. What triggers the migration urge in those species?

One possible trigger for this precise sequence of migration is the seasonal fluctuation in hours of daylight, the 'photoperiod'. It was suggested that the decrease in daylight hours in summer and autumn triggers migration southwards, and the increase in daylight hours in spring triggers migration northwards. This, however, cannot be the case for birds that winter on the Equator as the number of daylight hours there is almost constant throughout the year. Nonetheless they return yearly to their breeding grounds with such precision that they are often termed 'calendar birds'.

These birds must have their own, innate calendar that determines the timing of their departure either in autumn, when they begin their first migration alone southwards, or in spring, on return migration to their breeding grounds. This possibility came to be confirmed experimentally, by rearing young birds using tweezers and subsequently keeping them in a cage under carefully control-

Migration routes (schematic) of Northern Wheatears marked with geologgers.

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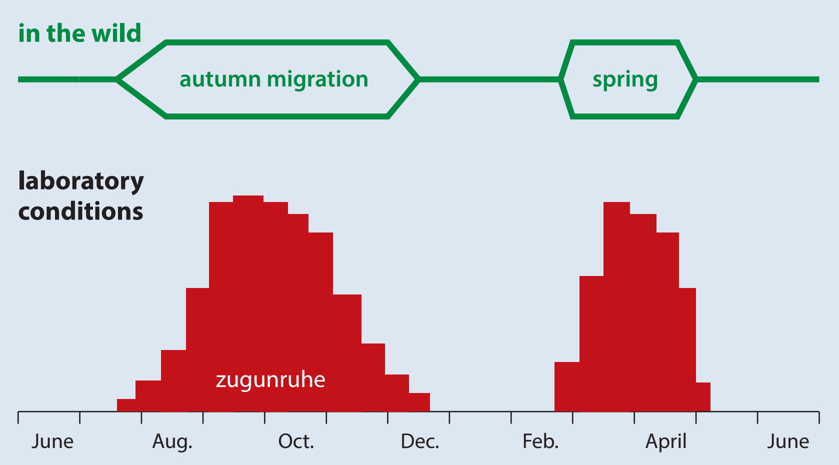
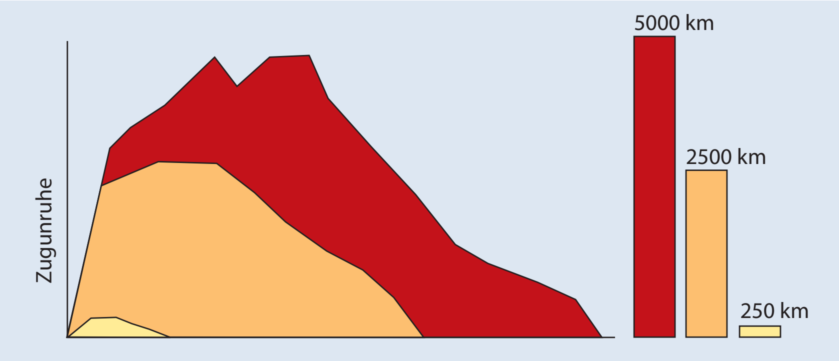


Schematic depiction of the migratory behaviour of Garden Warblers in the wild and under control conditions.



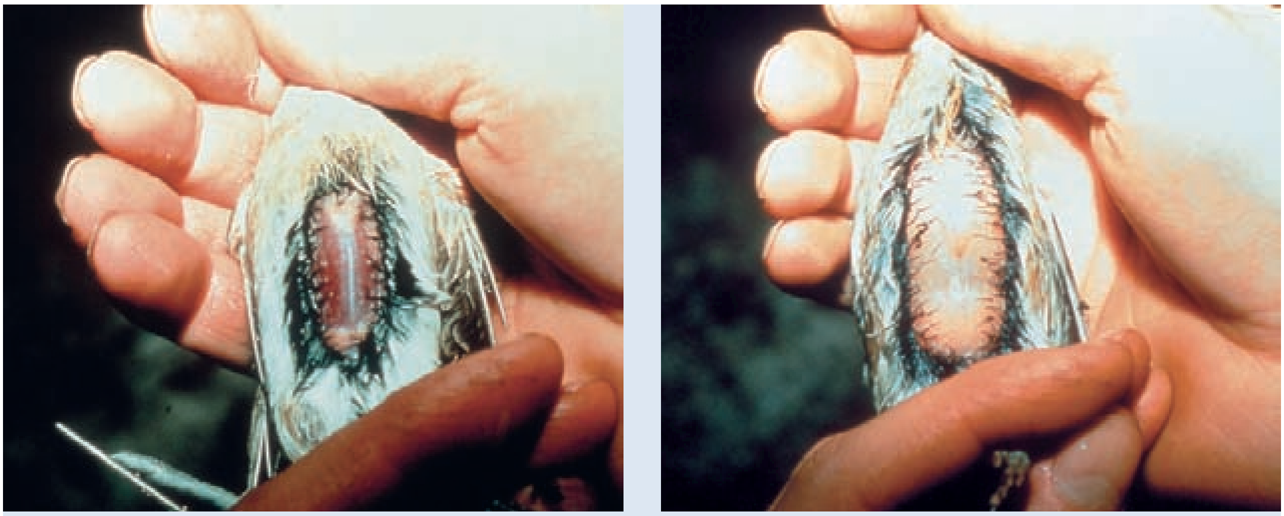
'Zugunruhe' and migration distance of the Garden Warbler (red), Blackcap (orange) and Marmora's Warbler (yellow) (after Berthold 2008).

led conditions with the same length of daylight, ambient temperature, humidity, and food. Under such conditions they demonstrate the same migratory behaviour as in the wild. They are only nocturnally active in their cage, as a manifestation of their nightly migration, when they would normally migrate in the wild. They demonstrate their nocturnal urge to migrate only during their species-specific migration periods.

This urge to migrate or 'zugunruhe' continues over the several weeks during which the birds would normally migrate to Africa. Subsequently the birds are inactive for several weeks until the nocturnal 'zugunruhe' resumes in spring when the bird determines it is time for its return migration. We know today that numerous migrant bird species possess such an inner annual calendar that ensures their preparedness for migration at the correct time and that they start and end their migration at the right point in time.

The degree of 'zugunruhe' that a bird produces in a migratory season also determines the distance the bird has to cover. Species that migrate only short distances, such as the Marmora's Warbler on Sardinia

Starlings cover only relatively short distances on their migration to their South European wintering areas. Photo: R. Nagel.



Fat is the fuel for migration. This fat is stored under the skin and is outwardly well visible on live birds. Left: a still quite lean Garden Warbler, not yet adequately equipped for a long flight. Right: a Garden Warbler with its migration fat, well prepared for the long journey. Photos: F. Bairlein.

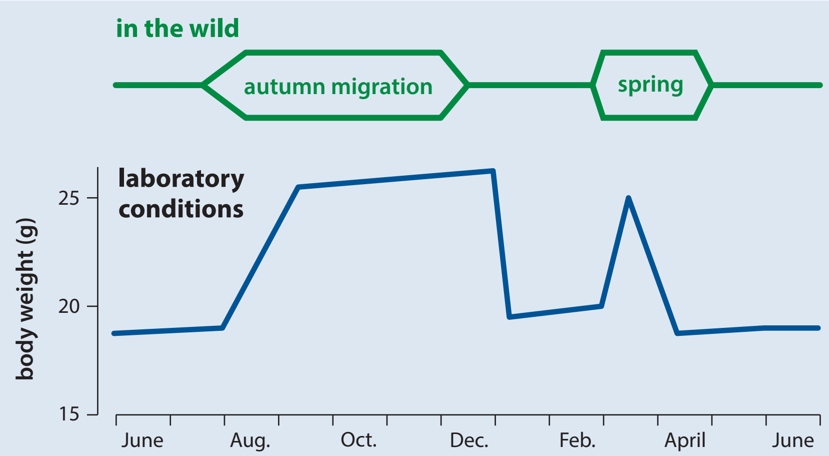
which only migrates as far as the North African mainland, demonstrate very little 'zugunruhe'. Whereas our indigenous Blackcap which winters in Spain, displays considerably more - corresponding to its longer migration route - but only half as much as the Garden Warbler that migrates twice that distance to West Africa. A close relationship, as an expression of species-specific innate migratory behaviour, therefore exists between the distances covered on migration and the total level of 'zugunruhe' exhibited in the cage. Inexperienced young birds migrating alone for the first time use this innate programme to automatically arrive at their winter quarters. They only need to fly for as long as their in-built migration time programme instructs them to, and so arrive precisely at their destination. They still however, need to know what the destination is and by which routes they might be able to reach it (see pp. 12–15).

» Fat is crucial

The energy costs of migration are immense. In particular, those species that traverse large ecological barriers such as oceans and deserts require enormous energy reserves. Only a few species, such as terns, can take up food without appreciably interrupting their migration flight. Most species must 'refuel' with energy before attempting a further stage of migration.

The principal energy (fuel) source for active flight during migration is fat. Long flights without corresponding fat reserves are impossible. The fat stored by a bird prior to the start of a flight determines the flight duration and thereby its distance. One of the most noticeable adaptations to the migration behaviour of many species is therefore a marked fattening at migration time - the so-called migratory fat deposition. Some species initially store only a small fat deposit, which is refreshed repeatedly at a series of stopover sites (refuelling stations). In contrast other species store huge amounts of fat. Garden Warblers for example, weigh between 16 and 18 g before autumn migration or in their African wintering areas. At migration time however, in both autumn and spring, a body weight of more than 37 g can be attained, more than doubling their fat-free starting weight. This increase is primarily attributable to the forming of an extensive fat layer under the skin.

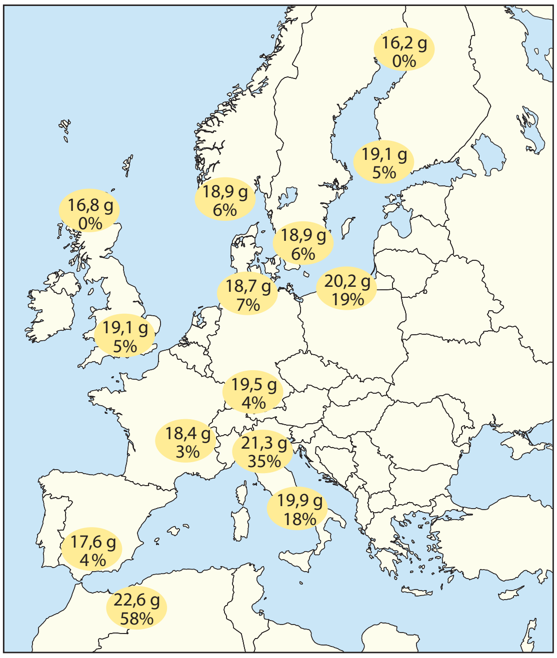
The basis of the fat deposition is an innate predisposition. Even under constant management conditions birds only put on fat at the time they would migrate in the wild. At the end of July young caged Garden Warblers become heavier in the same way as their conspecifics in the wild. As soon as the wild birds reach their optimal weight, they begin their migration to winter quarters. The caged birds however, cannot work off their built-up fat reserves in flight. Nonetheless the time comes when the caged birds also completely shed their excess fat. This occurs at the latest when their conspecifics arrive in their African



Garden Warblers store fat when in cages only when they would migrate in the wild. The short period of fat storage in spring corresponds to the more rapid course of migration.

winter quarters. At the stage when the captive birds believe that they are in Africa, they are lean and put on weight again only for return migration in spring. Species that have very long migration flights, such as the Garden Warbler, put on much more fat than short or mid-distance migrants like the Robin. Migratory birds therefore have an innate programme that determines for them both the timing and the amount of migratory fat deposition, independent of other external factors.

On the other hand, new studies on Northern Wheatears show that migratory distance alone does not determine the build-up of fat deposits; whether a large ecological barrier also has to be overcome without stopover or refuelling is another determining factor . Northern Wheatears that breed in Alaska, winter in East Africa after a migration route of some 15,000 km. In captivity however, they store a fat deposit only about half as large as Icelandic Wheatears, which only have to cover some 6,000 km as far as West Africa. In contrast to the Alaskan birds whose migration routes are almost completely over land with regular opportunities for stopover and refuelling, the Icelandic Wheatears must first fly over the Atlantic. This demonstrates that the amount of fat deposit stored is population-specific and inherent. Offspring of mixed pairs (i.e., those of an Icelandic and a Norwegian parent) exhibit an intermediate amount of fat deposit.



Average body mass, and percentage of Garden Warblers with more than 22 g body mass, at various trapping stations during autumn migration.

» Gaining fat - but how?

The occurrence of natural fat deposition in caged birds heralded a breakthrough in research into the mechanisms and strategy of fat deposition. The exciting questions this raises include how these birds can gain so much fat in so short a time, what preconditions for successful fat deposition must be fulfilled, how the birds know how heavy they are to discontinue weight gain, and how they lose the fat again in such a short space of time after the end of migration. These studies under controlled conditions are complemented by similar studies in the field. Here we concentrate our studies on the Northern Wheatear. This is a long-distance migrant that winters in the Sahel zone of Africa and which in Germany, for instance, migrates in large numbers via Helgoland. It is a bird of the open countryside and therefore easy to observe. Using bait it is also quite easy to lure it on to a weighing scale so that it can be weighed regularly without the necessity to continually trap it. In this way we gain an insight into its stopover behaviour, which to date was not possible for any other species. Only through this combination of studies in the field and in the laboratory is it possible to identify the complete extent of the preconditions for successful fat deposition, thereby creating the basis for effective conservation measures.

The migratory fat deposition occurs very rapidly, with daily rates of fat build-up of more than 10% of the fat-free body mass. At a suitable stopover site, Garden Warblers with a fat-free body mass of some 15 g can put on as much as 1.8 g of body weight daily. It was long thought that migratory birds only became fat simply because they ate more. Indeed, at this stage the appetite of migratory birds does increase enormously. So much fat cannot however, be gained through food intake alone. Garden Warblers also exploit food intake better than previously and use the fat content in their diet much more efficiently. In this way they are able to increase their net energy intake. More efficient exploitation is very advantageous for economic reasons. It reduces the effort expended on 'expensive' foraging and so increases the gain necessary for the build-up of fat deposits. The physiological mechanisms that form the basis for such a change in the efficiency of dietary exploitation are still widely unknown. It is however, interesting that these results were achieved for birds kept in constant conditions in captivity. It can therefore be assumed that this seasonal adaptation to the build-up of fat deposits at migration time is subject to inner control, which ensures quite independent of external factors, that such migratory birds attain a timely corresponding physiological disposition for migratory fat build-up.

In addition to increased appetite and better dietary exploitation, many species adjust their diet at migration time. Geese, for instance, select particularly protein-rich grasses and herbs. This seasonal dietary adjustment is particularly noticeable in many songbird species that predominantly feed on insects in the breeding season, but to a great extent consume berries and fruit for fat deposition at migration time. In the autumn Mediterranean stopover areas in particular, but also prior to spring migration from tropical Africa, berries and fruit play a large role in the diet of migrant birds. Many species, such as the Garden Warbler, then feed almost exclusively on berries and fruit, so that in Italian they are known as 'fig-eaters'. The importance of this fruit diet for migration time fat deposition was initially unclear, especially as fat gain from fruit appears paradoxical. Berries and fruit are generally considered to be low in energy and nutrient value. They contain a comparatively high proportion of water and in human dietetics play a large role as a reduction diet for the overweight. Recent studies show however, that fruit consumption by the Garden Warbler is of very critical importance for the build-up of fat deposits.

In so-called 'cafeteria' experiments, in which the birds are simultaneously offered a free choice of different diets, Garden Warblers always choose the most fat-rich feed. If at migration time they are offered insects and fruit however, they chose the fruit preferentially. These migratory birds also demonstrate a ravenous appetite for fruit richer in fat, or more precisely vegetable fats. Vegetable fats are particularly rich in long-chain, polyunsaturated fatty acids. If Garden Warblers are fed with two different feed mixes that are identical in total fat content but which differ in the proportion of unsaturated fatty acids, they choose the mix with a higher proportion of fatty acids. If they are fed exclusively with feed that does not contain these fatty acids, they are unable to build up migratory fat deposits. Interestingly enough, the fuel fat of migrant birds, in contrast to many other animal fats, is made up of over 60% of these unsaturated vegetable fatty acids. Some of these are essential for the bird and can therefore only be absorbed through its diet. The significance of unsaturated fatty acids for the metabolism of the bird in flight has not yet been clarified. However, it seems that it is particularly important for flight endurance. The feeding on berries and fruit by birds at migration time is therefore an important adaptation to enable the build-up of a very particular quality of fat.

Although they are known to be insectivores, at migration time Garden Warblers prefer to feed on fruit rich in unsaturated fats. Photo: H. Jegen.

These conclusions on the advantages of fruit consumption at migration time, derived from laboratory studies, are also confirmed in field studies. Birds on passage trapped on elderberry trees in autumn near Budapest were significantly heavier and demonstrated a much stronger fat deposition than birds elsewhere. The same goes for birds on stopover in the Mediterranean area caught on fig trees. Birds with access to fruit-bearing fig trees were consistently heavier and had a higher daily rate of fat deposit build-up than those in areas without figs, despite an overall similar and adequate availability of insects. European Robins in Mediterranean stopover areas with vegetables rich in fat also showed a higher level

For most bird species successful migration is closely tied to the availability of suitable stopover sites, for instance the Wadden Sea for many millions of Arctic migratory birds. Photo: R. Nagel.

of fat deposition than those in other areas. In addition, there is often a close connection between fruit availability and frequency of birds on passage at stopover sites. The quality of food at stopover sites therefore plays a very decisive role in successful fat gain, and thereby successful migration.

» Rest periods are essential for successful migration

For most species, successful migration is dependent on the availability of suitable stopover sites where they can refuel to stock up their fat reserves. In this respect it is essential to know the location of these stopover sites, how much fat the individual species require for their migration stages, and therefore the ideal distance between stopover sites. This is particularly important as suitable stopover sites are at a premium in an increasingly changing countryside.

Many Arctic wader species spend the northern winter in Africa. For these species, the Wadden Sea in the southern North Sea is a unique hub of their migration. It is used annually on migration by some 15 million birds in order to prepare themselves for their flight to Africa in autumn or in spring for the return to their Arctic breeding grounds. The individual migration routes vary from species to species. Species that make numerous stops require relatively little fuel for their short flight stages, but correspondingly many diverse stopover sites. This is very different for species that cover vast distances in a single flight or those that migrate through areas where a stopover with refuelling is not possible. These species need extensive fat deposition and they must be able to cope with the few, or indeed the only, suitable existing stopover sites. Knowledge of the migration strategy of individual species is therefore vital for the planning of conservation strategies. The amount of fuel stored for such flights is very precisely calculated. If a ‘planned’ stopover site is no longer available, such species usually have no possibility of diverting to another area. In such cases, but also when the conditions for adequate fat deposition are not fulfilled, continued migration or indeed later breeding success is endangered. It has been shown for Arctic geese that birds departing underweight from their stopover sites in northwestern Europe in spring have much less breeding success than birds with normal weight. This applies similarly to White Storks, which only breed successfully in our country if they are able to attain a suitable condition through nourishment in their distant African winter quarters.

Little is known about such fundamentals in the case of the majority of songbirds. Like many other species, Garden Warblers migrate from Central Europe to West Africa but also from Eastern Europe to East Africa. For birds migrating via the southwesterly route, the main fat deposition takes place in Northwest Africa, immediately prior to crossing the Sahara. This is different for Garden Warblers on the eastern route. They must attain their autumn fat deposition north of the Mediterranean. The reason for this is that there are an adequate number of stopover sites in Northwest Africa in the wide belt of Mediterranean vegetation in northern Algeria and Morocco along the northern fringe of the Sahara. In the

The critical stopover sites for many of the migratory birds that winter south of the Sahara are located in North Africa. Photo: F. Bairlein.

east, on the other hand, the desert extends as far as the Mediterranean south coast and precludes the possibility of fat deposition in this area. These birds must therefore refuel to the north of and before they cross the Mediterranean.

In spring the opposite applies. At this time the first significant fat deposits must be built up at the southern fringe of the Sahara. These birds also need the chance to refuel their energy reserves expended in crossing the Sahara. Studies at an oasis on the fringe of the Sahara in southern Morocco show that the great majority of the small birds stopping there in spring would not be able to reach their northern breeding grounds without refuelling. This applies not only to songbirds. After crossing the Sahara, Montagu's Harriers make a stopover of several weeks to prepare for their onward migration to their breeding grounds in the north. Study of the spatial and temporal progress of fat deposit build-up in migratory birds and identification of the necessary refuelling stations, is therefore, an important goal of current ecological bird migration research.

Barn Swallows roosting in an Acacia bush in the Etosha National Park in Namibia. Photo: K.-H. Loske.

» Crossing the Sahara – but how?

Some 200 European bird species winter south of the Sahara in tropical Africa. They therefore have to cross the Sahara twice a year on migration, which confronts them with a barrier some 2,000 to 3,000 km in width. The previous conception of bird migration to tropical Africa was characterised by the assumption that the Sahara is a completely inhospitable region for migratory birds, without shade, food, or water and consequently, without any possibility of stopover. It was therefore generally assumed that migratory birds traversed this ecological barrier in one

The Sahara is a vast ecological barrier for many northern birds that winter in tropical Africa. Photo: F. Bairlein.

single non-stop flight, beginning this stage of migration in autumn, north of the Mediterranean. More detailed studies in Algeria, Egypt, and Mauretania demonstrated however, that many migrant birds do not cross the Sahara in a single flight but rather in several stages, flying by night and resting by day.

These studies showed, in contrast to previous assumptions, that migratory birds of various species observed in the desert were generously fat. These birds landed at dawn or during the early morning, subsequently rested - mostly inactive and without feeding in the shade of vegetation and rocks - and resumed migration in the evening. Only a small proportion of them stopped over for several days and these were all quite lean. In contrast to the fat birds, they foraged actively during the stopover. They then resumed migration after they had stocked up sufficiently on fat.

These data present a different picture of the trans-Sahara migration of many migratory birds. Many of them land in the Sahara after a night spent on migration, where oases, but above all the numerous mountain and cliff areas, serve as stopover sites. These resting birds, most of which still carry sufficient fat, have no need to refuel. They simply require sufficient shade, spending the hot daylight hours saving on energy and water expenditure. The following night they resume migration. The passage of such birds thus occurs rapidly and unobtrusively.

The behaviour of the individuals that land without sufficient fat reserves to continue migration is different. If such lean birds land in a location without adequate food availability they are unable to resume migration. Nonetheless, it has been shown that these lean birds estimate the 'quality' of a site before landing and choose their stopover accordingly. How they do this is unknown; they probably estimate the amount of food available from the amount of visible vegetation. They usually land only in the larger oases rich in vegetation where it is likely that food can be found. During the day they then forage intensively. If they are able to adequately refuel in the course of the day they too resume migration the following night. If however, the fat deposition from a single day's foraging is insufficient for them to fly a further migration stage they remain in the stopover site for as long as it takes to adequately build up the fat deposit.

A bird in flight expends not only a great deal of energy; its muscle activity also produces enormous amounts of heat. This needs to be dissipated in order to avoid dangerous overheating of the body. Birds flying by day are also warmed by solar radiation. Birds can only dissipate such heat by water loss from the body, similar to human sweat. If no drinking water is available, the sole internal water source is oxidation water, created by chemical depletion of fat. A bird on migration thus requires its fat deposit not only for energy but also to act as its 'water bottle'. However, only some 10% of the extra heat can be dissipated by this oxidation water. The remaining heat is dissipated at the cost of the body water content. This means increasing body dehydration for the migrating bird. As birds can only tol-

The crevices in the mountain cliffs are favoured roosting sites for migratory birds in the Sahara. Photo: F. Bairlein.

erate a certain degree of dehydration without harm, the potential flight duration or distance is dependent on the ambient temperature. Long distance flights are not possible in high external temperatures as this would lead to a dangerous degree of dehydration for the bird.

A bird migrating across the desert has two alternatives. First, it can select a flight height where it is cooler. However, during trans-Sahara migrations at great heights, birds are often faced with headwinds. On energy-saving grounds they must avoid these by losing height, as flying into headwinds costs too much energy. At lower heights the birds then have following winds, but it is too hot for longer flights. Many migratory birds solve this conflict by migrating during the cooler hours of darkness, resting in the shade by day, resulting in a good water balance.

The precondition for successful migration is, in any case, that such birds possess adequate fat deposits, which they accrue by adequate nourishment in the stopover sites in advance of ecological barriers. This not only applies to birds that have to cross the Sahara but also, for instance, to Icelandic Wheatears that build up their fat deposits on Helgoland in spring for their long transoceanic journey.

Intact habitats are thus essential. but, in many places are endangered by destruction and degradation (see pp. xx and xx). At the same time migratory birds are exposed to changes as a consequence of global climate change (see pp. xx to xx). Modern avian research in the field as well as in the laboratory, provides data in a number of ways that is not only fundamentally necessary for identification of the specific threat factors and the planning of effective conservation measures, but also contributes to our understanding of the way birds react to the varied anthropogenic changes that confront them. In this respect international cooperation is absolutely essential. Only in this way can the full extent of species-specific threat factors be identified and from there the necessary conservation measures planned and implemented.

Franz Bairlein

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Outdoor aviaries for captive breeding of Northern Wheatears at the Institute of Avian Research, Wilhelmshaven, Germany. Photo: R. Nagel.

Migratory bird orientation:

10,000 miles without TomTom®?

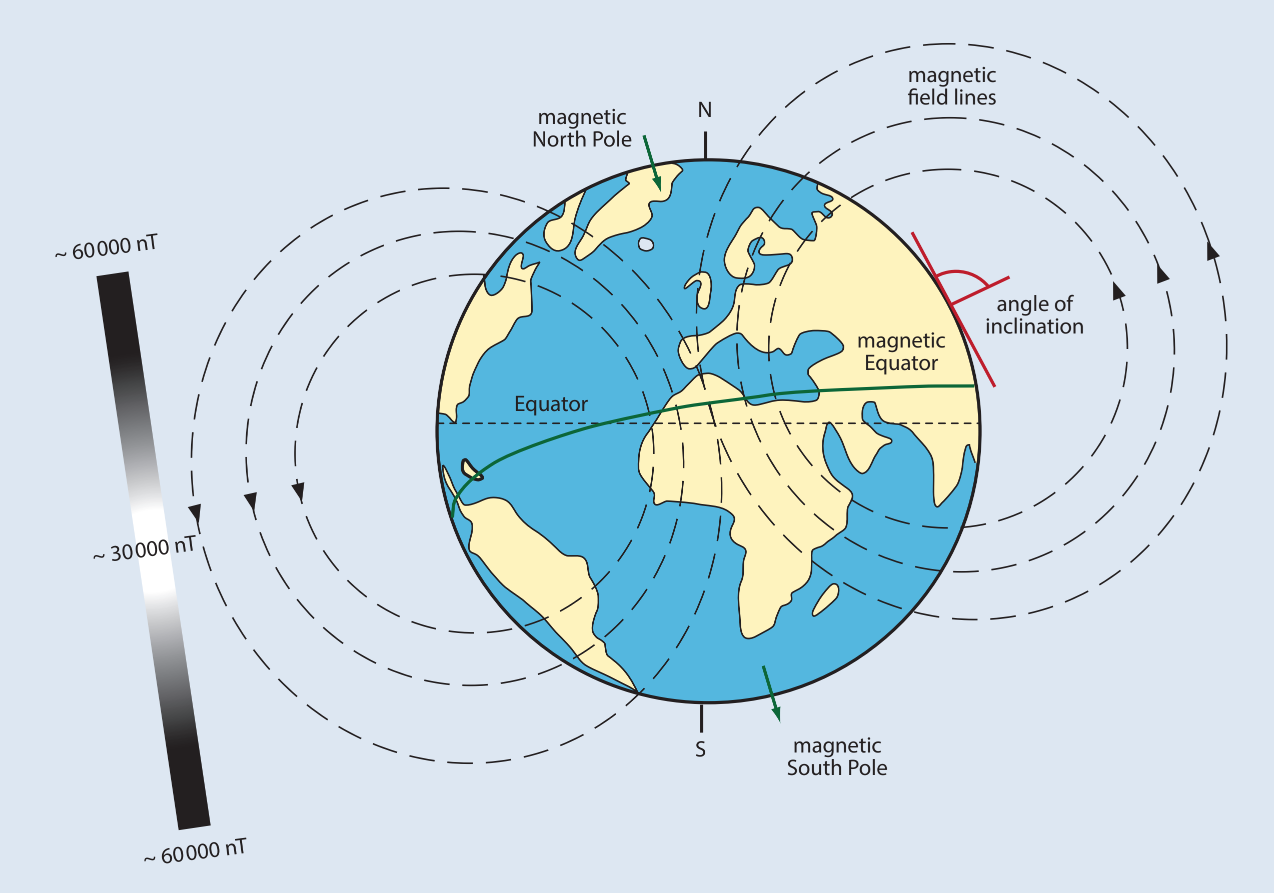
Migratory birds cover thousands of kilometres around the globe, apparently effortlessly and equipped only with their own senses. In contrast, for us humans, in times before the development of modern aids,navigation was as tricky as it was risky. How do birds – with their 'birdbrains' – manage to navigate with so little effort?

After more than 60 years' of intensive research it is now known that birds have several reference systems (compasses) that work simultaneously, and often combine information from several cues to find their way to the desired destination. Whether a pigeon wants to return to its loft, a Robin flies to winter in Spain, or an Arctic Tern circumnavigates the globe, they can all make use of the sun, the stars, and the Earth's magnetic field as navigation aids. Additionally, some species can also navigate using landmarks such as large rivers, mountains, or even motorways, as well as odours and perhaps even ultrasonics.

» Innate direction

Before we take a closer look at the individual navigation systems, the question arises as to how a bird knows at all when it must begin migration and to where. Information on this was provided by studies on warblers in the 1970s and 1980s. Young warblers, which had never migrated themselves, were kept in captivity. Their spontaneous choice of migration direction was studied in cages, and it turned out that they spontaneously jumped and fluttered in the direction that they would have selected in the wild. Cross-breeding experiments with Blackcaps demonstrated the heritability of this innate directional behaviour. If birds from populations that migrate to the west of the Alps were crossbred with those that take an easterly migration route, their offspring selected a southerly migration direction exactly between the migratory directions of the two parental populations. If birds from non-migratory populations were crossbred with long-distance migrant populations of the same species, the

Together with the bird's inner clock, the sun is used by day migrants as the most important compass reference. Information received at sunset can also play an important role for nocturnal migrants, e.g. to calibrate the magnetic compass. Photo: H. Glader.



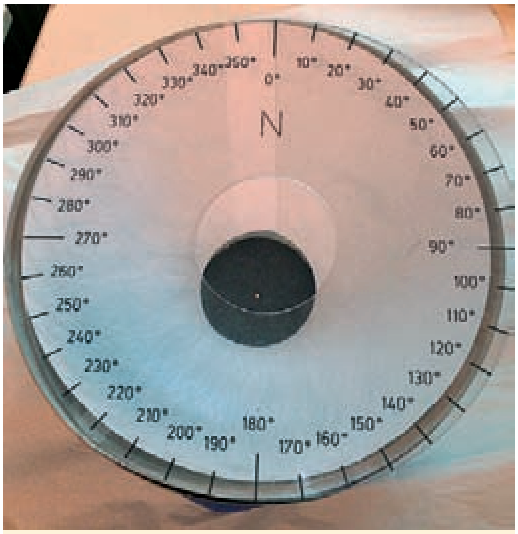
Schematic depiction of the Earth's magnetic field. The Earth's magnetic field is strongest at the magnetic North and South Poles (c. 60,000 nanotesla) and the field lines there are perpendicular to the Earth's surface. When one moves towards the magnetic Equator, the strength of the magnetic field, and the angle between the magnetic field lines and the Earth's surface, decrease successively. The angle of inclination and the strength of the magnetic field can thereby be used to determine the rough north-south position and, because the magnetic field lines always point to the magnetic north, the Earth's magnetic field can also be used as a compass.

offspring became middle-distance migrants.

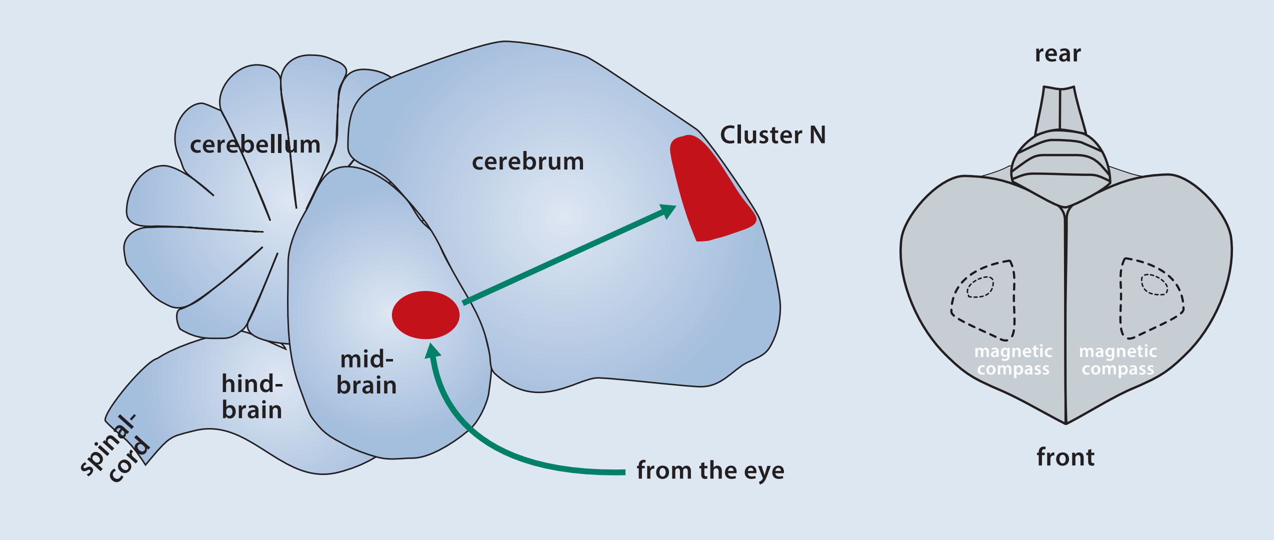
» How migratory birds navigate

Because migrant birds kept in captivity attempt to migrate in their species-specific migration direction during the natural migration season, this behaviour can be used to discover what information the bird requires for orientation. Gustav Kramer, a contemporary of Karl von Frisch, used mirrors to demonstrate that Common Starlings can use the sun for orientation. It was later discovered that the determining factor was not the sun's height above the horizon, but rather the azimuth (the sun's angle as projected on the horizon). It was also discovered that orientation using the sun is learnt in an early imprinting phase and has to be synchronised with the circadian rhythm, i.e. the bird's inner clock. The possible role of polarised light should also not be left unmentioned, since some bird species appear to calibrate their magnetic compass by the polarisation pattern of the setting sun.

But what happens when the sun cannot be used as a reference system,e.g. at night? Do birds have a sextant in their brains and orientate themselves on the Pole Star as seamen have for centuries? Emlen&Emlen tested night-migratory birds in a planetarium and demonstrated that they can use information from the starry sky as a compass and that a functional star compass requires learning of the starry sky's centre of rotation. When Emlen&Emlen exposed hand-reared young birds to a 'false' centre of rotation in the planetarium the birds later orientated themselves on this. In other words, the strategy of young birds manifests as a search



During the migratory season, the orientation behaviour of birds is tested in so-called Emlen funnels. Their migration urge is so strong that they jump in the preferred direction, thereby leaving scratches on the paper lining of the funnel for later analysis.

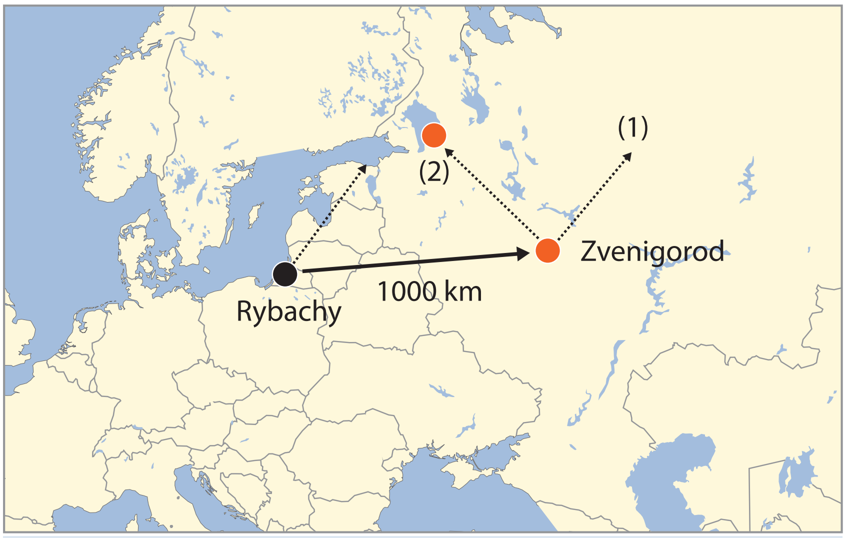


Schematic depiction of a Robin's brain. We know at present that magnetic compass information is processed in the areas marked in red. (Cluster N in the forebrain and part of the visual area of the thalamus in the midbrain).

Modified version of Mouritsen et al. 2005: Night Vision Brain Area in Migratory Songbirds. PNAS 102, 8339-8344..

for rotating points of light in the sky and interpreting the centre of rotation as north.

Likewise, what happens on overcast days? In order to answer this question, researchers have investigated the most difficult to understand and yet most fascinating orientation system – the magnetic sense. Wolfgang Wiltschko was the first to show that migratory birds use the Earth's magnetic field for orientation. How exactly do birds sense the Earth's magnetic field? Here we arrive at a question that is considered to be one of the last remaining fundamental riddles in sensory biology.



Eurasian Reed Warblers were relocated from Rybachy to Zveningorod in Russia, a distance of ca. 1,000 km. Birds that cannot transfer magnetic information through the trigeminal nerve (1) do not notice the relocation. Untreated birds can however compensate for the relocation (2)

» Magnetic sense

The Earth's magnetic field is defined by three parameters: direction, intensity and inclination. The direction of the magnetic field always points to the magnetic North Pole. The intensity or strength of the magnetic field can almost be read like a map. It is relatively linear from 30 000 nT (nanotesla: unit of measurement for the strength of the magnetic field) at the magnetic Equator and increases to 60 000 nT at the magnetic poles. It thus provides a potentially usable pattern, although anomalies do occur worldwide. The magnetic inclination is the angle between the Earth's surface and the magnetic field lines, i.e. the inclination angle of the Earth's magnetic field to the horizontal. It has a value of 0° (horizontal to the Earth's surface) at the magnetic Equator, ca. 65° in Central Europe and 90° (perpendicular to the Earth's surface) at the magnetic poles. In this way, the Earth's magnetic field potentially provides a bird with a useful map as well as compass information. But how can this information be perceived and processed in a 'birdbrain'?

At present there are three hypotheses on the perception of the magnetic field. The first and oldest hypothesis assumes that small structures similar to a compass needle exist in birds' bodies. These could be in the form of small iron oxide (Fe_3O_4 - magnetite) crystals. The second hypothesis proposes that the magnetic field is perceived by the bird's eye, in which there are molecules whose photosensitivity are dependent on the alignment of the magnetic field relative to the molecule, and could therefore enable the bird to 'see' the Earth's magnetic field. The third hypothesis proposes that the lagena, part of the sense of balance in the inner ear, is responsible for the perception of the magnetic field. But which hypothesis(es) is/are correct? At present it appears that birds have a magnetic compass in the eyes and a magnetic map sense in their upper mandible.

Contents

The possibility of a magnetic compass in birds' eyes was first concluded when Robins tested in Emlen funnels for their migratory behaviour were discovered to be capable of using only light with specific wavelengths (colours) for compass orientation. The birds could orient well in blue and green light but became disorientated in yellow and red light. This would be difficult to explain if the eyes were not in some way involved in the perception of the magnetic field.

A theoretical model was then developed as a potential explanation, suggesting that absorption of short wavelength light by molecules present in the eye creates radical pairs (unpaired electrons) that are sensitive to the magnetic field. These molecules can exist in two different quantum conditions following a quantum chemical light reaction. Depending on how the molecule is arranged relative to the Earth's magnetic field, both components have a different yield. As these molecules appear to be distributed equally across the whole of the hemispherical retina, the result is probably a sort of pattern that can be understood as a visual impression of the magnetic field, and this could provide birds with compass information as a kind of heads-up display. But does the eye contain such molecules?

In 2004, the sole class of receptor molecules that seem to meet all requirements, the cryptochromes, were proven to exist in the retina of migratory birds. In addition, it was demonstrated that the expression, i.e. the production, of cryptochrome significantly increases in the cells of the retina of migratory birds such as the Garden Warbler or Robin at night when they display migratory behaviour. It was also shown that Garden Warbler cryptochromes form very long-lived radical pairs when they are exposed to light.

The related processing areas in the bird's brain have also been identified. A small part of the thalamofugal pathway in the bird's brain is responsible for processing magnetic compass information. It is therefore relatively certain to date that the magnetic compass of migratory songbirds is located in the eye and that birds have a visual perception of magnetic field lines.

» Compass and map

In order for true navigation to take place, a map is required in addition to a compass. It is therefore possible that birds receive magnetic map information with the help of other magnetic sensors. Indeed,scientists believethey discovered iron mineral structures associated with nerve tissue in the upper mandible that were suspected to act as magnetic sensors for map information. Closer examination however, revealed that the iron mineral structures were actually cells of the immune system. Nonetheless, experiments since have shown that the nerve that transfers information from the upper mandible to the brain perceives magnetic information. In Robins, the two brain areas receiving information through the ophthalmic branch of the trigeminal nerve contain a large number of neurons, which are activated by magnetic field changes. Furthermore, Eurasian Reed Warblers indigenous to Russia lacking intact trigeminal nerves, were unable to compensate for an east-west relocation during spring migration; and pigeons with cut trigeminal nerves, trained to recognise a specific magnetic field, could no longer solve this task. The upper mandible therefore appears to play a part in the perception of magnetic map information. The primary receptors however remain undiscovered.

The third hypothesis involving the lagena has only been proposed recently. American scientists discovered that the parts of the bird's brain that receive information from the lagena react to magnetic field impulses. It still has to be clarified what implication this has for the magnetic field orientation of birds. It should be stressed that at the current point in time, none of these theories exclude each other in any way and a combination of the individual hypotheses is quite conceivable.

Despite all efforts by man to understand the fascinating navigation capabilities of migratory birds, there are still many unsolved riddles that we want to decode in the coming decades. It is likely that the discovered mechanisms will provide inspiration for new man-made navigation devices and even for the development of quantum computers.

Nele Lefeldt, Susanne Schwarze, Henrik Mouritsen

Institute for Biology and Environmental Sciences, Oldenburg University

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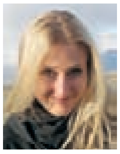

Nele Lefeldt is a graduate student in Prof Dr Mouritsen's working group ‚Animal Navigation' on the orientation of migratory birds using the earth's magnetic field. Her current project is concerned with the role of the lagena in magnetic field orientation.
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Susanne Schwarze is also a graduate student in Prof Dr Mouritsen's working group. She works on the influence of electromagnetic interference frequencies on the orientation behaviour of nocturnal migratory birds.

Prof Dr Henrik Mouritsen has directed the ‚Neurosensory/Animal Navigation' working group at Oldenburg University since 2002. He is primarily interested in understanding the orientation mechanisms of migratory birds and how they sense the Earth's magnetic field.

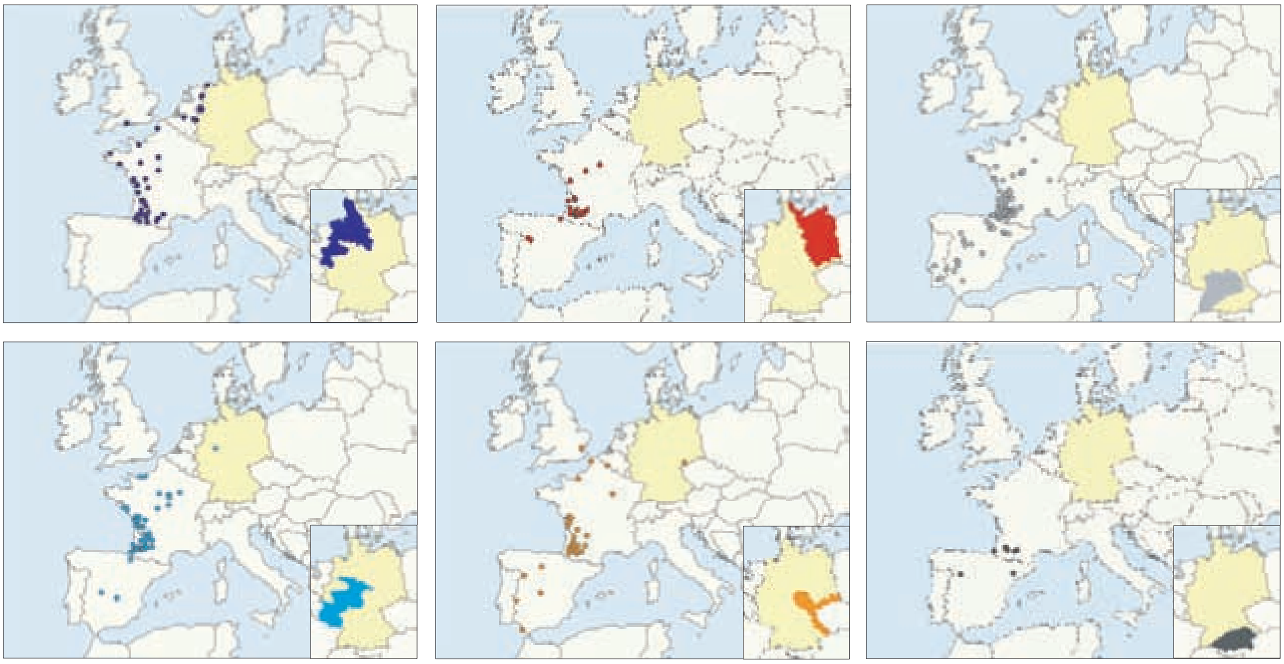
Contents

Cartographic presentation of ringing data:

German ring recovery atlas

Birds have been fitted with rings in Germany and Europe for over 100 years. The results of this scientific bird ringing have been included in numerous publications on bird migration, but a comprehensive presentation of the ring recoveries for the whole of Germany has been lacking to date- this gap will now be filled.

The introduction of scientific bird ringing more than 100 years ago revolutionised avian research. For the first time it became possible to establish the location of individual birds outside their breeding areas, as well as their migration routes and wintering areas. The first ring recovery atlas published by Schüz & Weigold in 1931 brought sensational information, for instance, the wintering of European Barn Swallows 10,000 km distant in South Africa. Since then some 20 million birds have been ringed in Germany with more than a million ring recovery reports. In addition there have also been some 150,000 ring recoveries in Germany of birds ringed abroad. A German ring recovery atlas was therefore overdue, especially because various



Winter recoveries of ringed Stock Doves breeding in Germany are reported primarily from South-western Europe. Some breeding birds of the North-western German Plain (above left) winter however in the Benelux states. The inset maps show the major natural regions in Germany from which the recovered birds originate. Photo: J. Dierschke.

other national ring recovery atlases have been published recently - as in the Czech Republic, Denmark, Finland, Italy, Norway, Sweden, and the United Kingdom.

» A long way

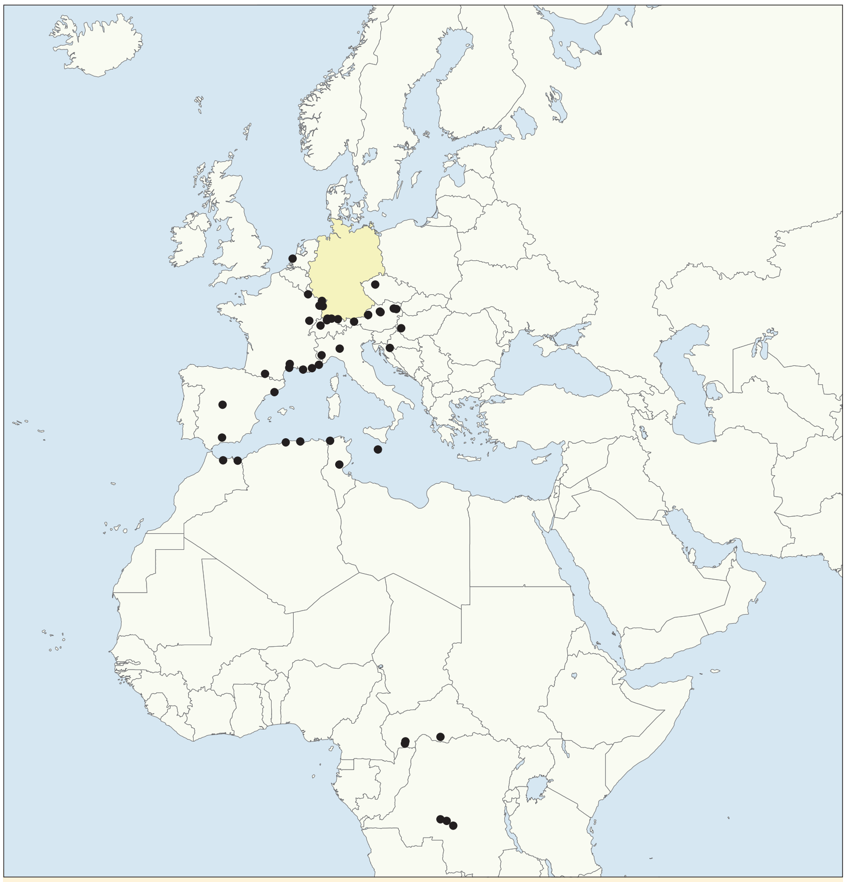
Evaluation of the movement of breeding birds, on stopover or wintering in Germany, began several years ago. For historical reasons, there are three ringing centres in Germany (Helgoland, Hiddensee and Radolfzell) each with its own data system and data structure. Before a common ring recovery atlas could be produced, several details thus needed to be addressed. First, the different databases had to be combined. Second, a comprehensive check for errors in the data had to be completed. The database also had to be extended to include undigitaliseddata, data on recoveries in Germany of birds ringed abroad listed in the EURING database, and data from colour ring projects. As these projects are mostly organised by ringers themselves, consultation with their coordinators was necessary to acquire the data.

More specialised tracking data from satellite telemetry, GPS telemetry, or geolocation (see pp. 20 to 25) were not included in the combined database. However, they were used in the species notes if they augmented the ring recovery data and were published or freely available (e.g. in MoveBank https://www.movebank.org/).

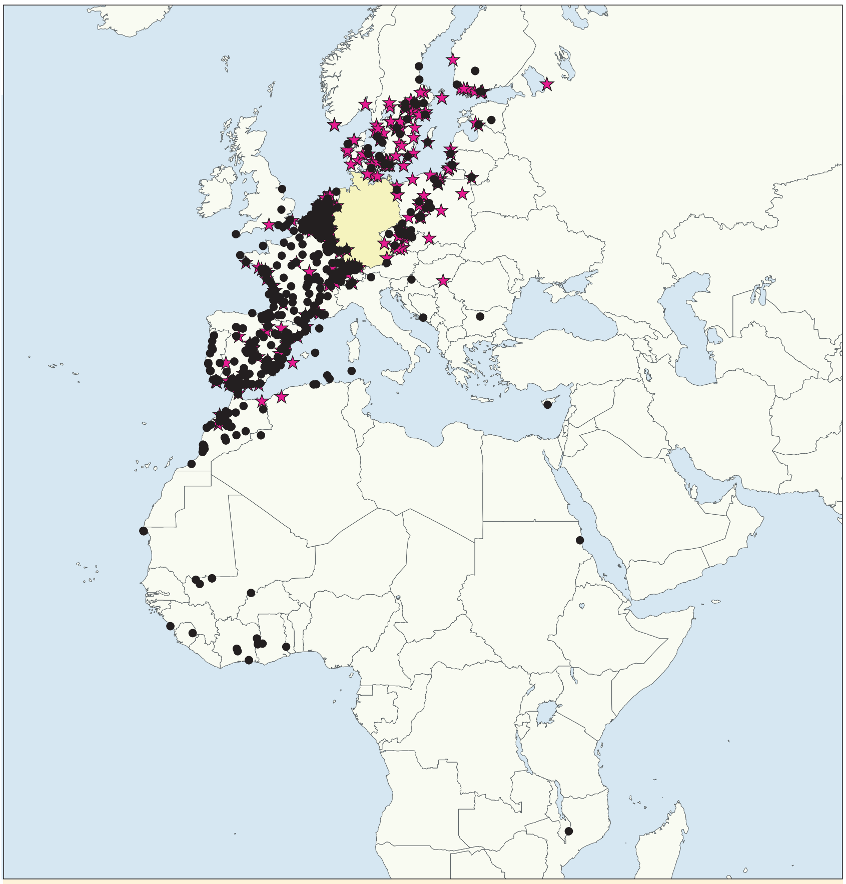
» Many questions

Ringing recoveries can throw light on a number of scientific issues. However, in orderto produce a compact, single volume work, it became evident that a German ring recovery atlas must be restricted to just a few questions. The scope of the atlas is therefore limited to the following questions:

- How large is the distribution range of birds occurring in Germany?
- Which migration routes do birds occurring in Germany take?
- Where do birds that breed in Germany spend the winter?



The autumn migration of the Common Swift is in a southerly or south-westerly direction. The few ring recoveries from south of the Sahara indicate a possible wintering area in Central Africa. Photo: C. Moning.



Most ring recoveries of Reed Warblers have been made on a north-east to south-west axis. There are however, some recoveries in a south-easterly direction, indeed as far as South-east Africa and therefore considerably further south than those on the south-westerly route. Dots: ring recoveries, stars: ringing locations of birds with a foreign ring recovered in Germany. Photo: C. Moning.

- Where are the breeding grounds of birds that winter in Germany?

» Evaluation

The number of ringing recoveries differs considerably between species. In some cases very few recoveries have been received, even for common species like the Turtle Dove and Woodlark. For others, the database is almost overflowing with recoveries, e.g. Barn Owl, White Stork, and Starling. It was therefore decided not to treat all species equally but to present species with large numbers of ring recoveries on two or four pages, species with few recoveries on a single page, and species with only single recoveries in a short text or in tabular form.

Only those ring recoveries with a distance of more than 10 km between ringing and recovery locations were considered. In order to highlight geographical differences in migratory behaviour of birds ringed in Germany, the recoveries are depicted with a colour-coded relationship indicating their area of origin. This is based on the major natural regions of Germany (see http://en.wikipedia.org/wiki/Natural_regions_of_Germany). This makes it easy to determine, for instance, whether birds of Eastern Germany spend the winter in different areas to those of Western Germany.

» First results

Data for some species has been evaluated and presented in cartographic form. Here are a few examples:

- Stock Doves throughout Germany migrate in a south-westerly direction to winter in Portugal and south-west Spain. Birds that winter in the Benelux states, however, come exclusively from North-west Germany. An exception was a Stock Dove ringed on 28.7.1984 in Northern Württemberg that was shot in January 1985 in Turkey.
- Most Common Swifts migrate in a south to south-westerly direction. There have only been very few ring recoveries south of the Sahara, but these indicate that the species' wintering area is in Central Africa.

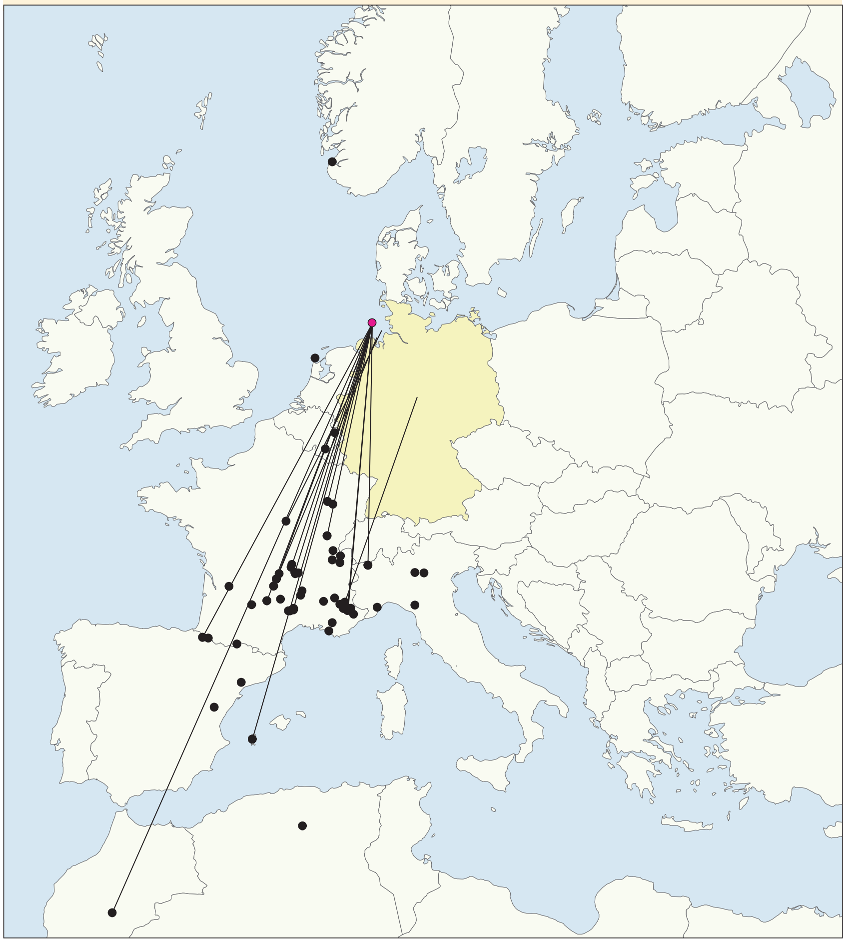
- The majority of Reed Warblers ringed in Germany migrate in a south-westerly direction to winter in West Africa between Guinea and Nigeria. A number of birds, however, migrate to the south-east and southwards as far as South-east Africa.

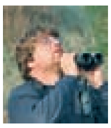
» Outlook

This first ever evaluation of the complete ring recovery data from the whole of Germany will provide a great deal of information, some of it new and surprising. A number of matters cannot, however, be presented in such a compact atlas. These will require more special treatment that we explicitly wish to encourage. On the other hand it will become evident for which species we have little or no information about their migration routes. For instance, although there are quite a few ringing recoveries of Scandinavian Ring Ouzels in Germany, we have no data on the migration routes and wintering areas of Ring Ouzels breeding in Germany, as there have been to date no recoveries of the very few German breeding birds that have been ringed. It would therefore pay off to ring more birds of this species. By exposing such gaps in our knowledge we hope to encourage our numerous voluntary ringers to fill these gaps wherever ringing makes this possible. Finally, we would like to thank the countless voluntary ringers who have ringed birds over the past 100 years, tirelessly and often with a high level of personal commitment, thereby making an invaluable contribution to migratory bird research.

Jochen Dierschke,
in cooperation with Volker Dierschke, Wolfgang Fiedler, Olaf Geiter, Kathrin Hüppop, Ulrich Köppen, Volker Salewski and Franz Bairlein.

Autumn migration of the Ring Ouzel through Germany. There are a few recoveries of Scandinavian birds on passage but none however, from the German breeding population. The unbroken lines denote ring recoveries in the months immediately following ringing. Red dot: Helgoland. Photo: J. Dierschke.





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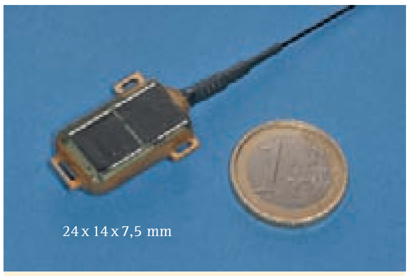
On the way to new methods:

A lifetime of round the clock monitoring

Bird migration has been studied both by visual observation and by ringing studies. This has enabled the general location of breeding, stopover and wintering areas of many species to be identified. As a rule, ringing studies determine only two points, the ringing and the recovery point. The introduction of satellite telemetry in the mid-1980s permitted a more or less continuous tracking of individuals for the first time and thereby provided an analysis of all regions visited in the course of a year. Because of transmitter size, the use of this technology was for a long time restricted to a few large bird species. Today a variety of further methods are available that also permit the tracking of small birds, as well as the parallel recording of different behaviour forms and environmental parameters in high spatial and temporal definition. In future, the combination of established and newly developed methods will enable birds of almost all sizes to be studied during their complete lifespan.

Satellite telemetry has revolutionised the research of bird migration. Comprehensive individual-based analyses of habitats throughout the year became possible for the first time, often for several years in succession. Regular fixes permit not only the direct following of a bird's journey, they also provide information on where and for how long it stops over, where it winters, and whether it wanders around or is tied to a specific area in the wintering period.

For the first time in 1984 a Bald Eagle was fitted with a satellite transmitter, weighing at that time 170 g, a so-called PTT (Platform Transmitter Terminal). Since that time satellite telemetry has developed rapidly. Whereas transmitters in the mid-1980s still weighed over 150 g and could only be worn by a few bird species, such as large birds of prey,



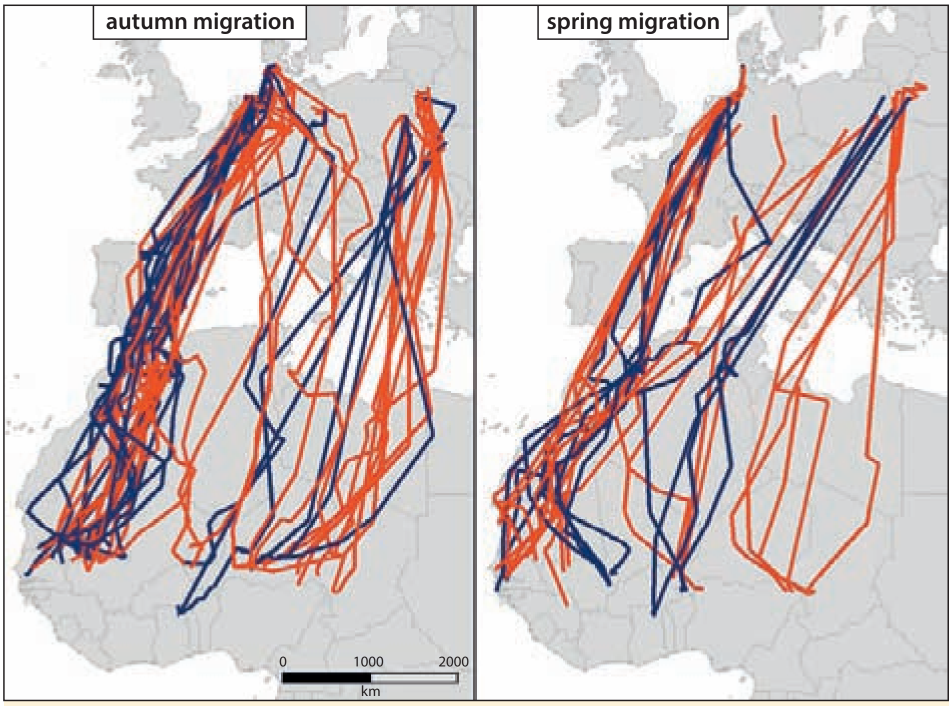
One of the lightest currently available standard solar-powered satellite transmitters weighing only five grams. Photo: R. Nagel, IfV.

The migration routes of the male Montagu's Harrier, 'Franz' – born 2001 in Reiderland and fitted with a satellite transmitter in 2006 – were recorded for over five years. The bird wintered regularly in South Mauretania/North Mali. Photo: T. van Kooten.

storks, geese, and swans, by the year 2000 similar transmitters weighed only 18 g. Since 2008 standard solar transmitters weighing only just 5 g are available, so that now species with a body mass of some 150 g can be marked, for instance, the Hobby and Amur Falcon, Cuckoo, or Grey Plover. In spring 2012, Microwave Telemetry System Inc., presented the prototype of a solar PTT weighing only 3.2 g. Solar powered satellite transmitters permit many fixes over a number of years.

In addition to high performance transmitters, ARGOS receivers in satellites are at the core of satellite telemetry. The satellites used by ARGOS (NOAA- und MetOp/ Eumetsat satellites) circle the earth at a height of about 850 km. Until 2001 fixes were obtained exclusively by means of the Doppler Effect and were consequently relatively imprecise. As a rule, an accuracy of more than a few kilometres and often even several dozen kilometres could be achieved. This level of accuracy was adequate for the analysis of migration routes and the regions visited in the course of a year, even though - particularly in Europe - this technology often provided very modest results. Since the turn of the century, solar powered GPS (Global Positioning System) supported satellite transmitters became available. These transmitters provide spatially high-definition three-dimensional data using the GPS system to determine their position and transmitting this data via satellite. The high spatial definition (accurate to < 5 m) permits, for example, the localisation of breeding and stopover sites so that they can be visited for more detailed studies. In addition, GPS transmitters can be fitted with other sensors such as accelerometers, pressure and temperature sensors, or physiological measuring devices, so that a completely new quality is achieved in bird migration study. The lightest of the currently available solar powered GPS transmitters weighs some 20 g.

The great advantage of satellite telemetry is that data on rare species can also be collected in a short space of time even from the most remote regions, including areas from which there are no ring recoveries to date and are unlikely to be in future. Individually based data from all habitats used in the course of a year are not only of paramount importance for an understanding of bird migration but also provide information of immediate relevance to conservation. The disadvantages remaining include the still quite heavy weight of GPS transmitters of some 20 g, the high power consumption necessary to transmit the data in orbits at an altitude of about 850 km, the comparatively low number of possible daily fixes (at best 10 – 20), and the high costs for data transfer and the transmitter compared to the sobering high technical failure rates.



Autumn and spring migration routes of male (blue) and female (red) Montagu's Harriers recorded using satellite telemetry. It is clear that most birds select the same routes for autumn and spring migration. They kept mainly to the first chosen route for many years.

» Long distance transmission via mobile communications (GSM)

At present, less expensive microprocessor-controlled GPS loggers are gaining in importance. These data loggers are capable of storing more than 10,000 fixes and the data can be acquired over several kilometres using the GSM (Global System for Mobile Communication) mobile communications system or UHF/VHF receivers. GSM is the standard for digital mobile communication networks and is known to all mobile phone users. As well as monitoring of persons it can also be used to locate wildlife. When fitted with additional sensors, a number of further parameters as well as three-dimensional location data can be transmitted to the mobile phone of the observer or direct to an Internet database. In contrast to satellite telemetry, it is possible to communicate with the transmitter on the back of the bird, in order to turn it on or off or to alter the data recording rate. The great advantages of the GSM network are its wide coverage and simple use. On the other hand the available devices are still comparatively heavy due to the high power consumption of its necessary powerful buffer battery (GSM / solar GPS 20 – 70 g).

Specific high frequency transceivers permit the use of considerably lighter transmitters weighing only some 6 g, but do not permit use of the mobile network and therefore require the installation of special reception systems or the use of handheld receivers. In dense woodland their range is often less than 300 m while in open countryside up to several kilometres can be achieved.

The fix, accurate to a few metres, can be stored at intervals of seconds provided an adequate power supply and storage capacity is available. The latter is impressively high. Even the smallest logger can store up to 320,000 fixes. This means that, in the case of species with high site fidelity, the data can be read after the return of the birds from winter quarters to breeding site. Because of the great precision and high data density, the new generation of data loggers permit both a detailed analysis of the migration routes and stopovers in various habitats, as well as the localisation of roost and feeding trees and nests, even when these are many thousands of kilometres distant from the observer.

The rapid availability and high precision of the data enable a number of further analyses, e.g. merging with environmental parameters such as the current weather conditions or data on land use. Waypoints can also be transmitted to the autopilot of a small, unmanned aircraft that it can then retrace the routes and photographically record the land use. These loggers enable a data density that was inconceivable only a few decades ago and which makes new demands of methodology on the part of analysts.

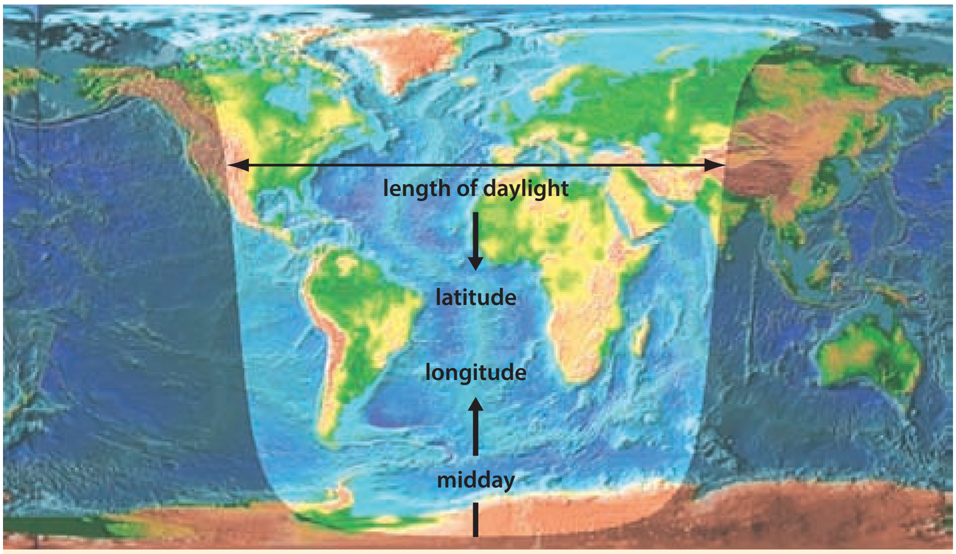
Solar-powered satellite transmitters and GPS loggers permit continuous recording over several years. In Central Europe the comparatively short daylight periods in winter and the weaker irradiation can cause problems. The use of 'intelligent' switching of the logger, which, dependent on the power supply, can temporarily pause certain activities and resume them at the appropriate time, can deal with these problems. Purely nocturnally active birds and bats present these systems with additional but not insoluble problems, as long datasets from Eagle Owls and the first results from fruitbats demonstrate.

» Light-level geolocation

The methods presented above are unsuitable for analysis of the migration routes of birds weighing less than 150 g. This means that up to about 10 years ago no suitable method was available for most species - including all songbirds. The breakthrough occurred with the use of light-level geolocators, which have helped clarify the migration routes of many species, e.g. Blackbirds, Wheatears, Hoopoes, Swifts, and Turnstones. The lightest geolocator at present weighs only 0.6 g, so that birds weighing as little as 12 – 15 g can be fitted with them. The central components are a photocell, a clock generator, a small computer, a memory, and a battery.

The light-level geolocation principle is quite simple and age-old. It was used in the Middle Ages by mariners to determine their position. Using a photocell, geolocators record the intensity of the incident light together with date and time. These data are either stored for a migration season, a year, or very occasionally even longer. In contrast to telemetry the birds are not tracked in real time; they have to be recaptured in order to read the data or to remove the geolocator. The method is therefore suitable in the first instance for species with breeding or birthplace fidelity. After recapture the data are read with the times of midday and midnight providing the geographic longitude, and the length of daylight and hours of darkness providing the geographic latitude. Each day therefore two fixes with an accuracy of some 150 km can be determined. This degree of accuracy is adequate to establish the locations of the migration routes and the winter quarters of mid- and long-distance migrants.

The imprecision in the determination of sunrise and sunset means that for 10 – 14 days either side of the equinoxes it is impossible to reliably determine the exact latitude. Determination of the times of sunrise and sunset, and with them the calculation of the latitude, can be difficult when the species roosts in woodland or reed beds, or even withdraws for the night into a cave or other dark refuge. The screening of the sun causes sunset to appear earlier and sunrise later than is indeed the fact. The logger should therefore be calibrated in advance in the appropriate habitat.



The map of the world shows the division of daylight and darkness and illustrates the determination of latitude and longitude by means of the length of daylight or the midday point.

Source: http://commons.wikimedia.org/wiki/File:Daylight.png,

» ICARUS

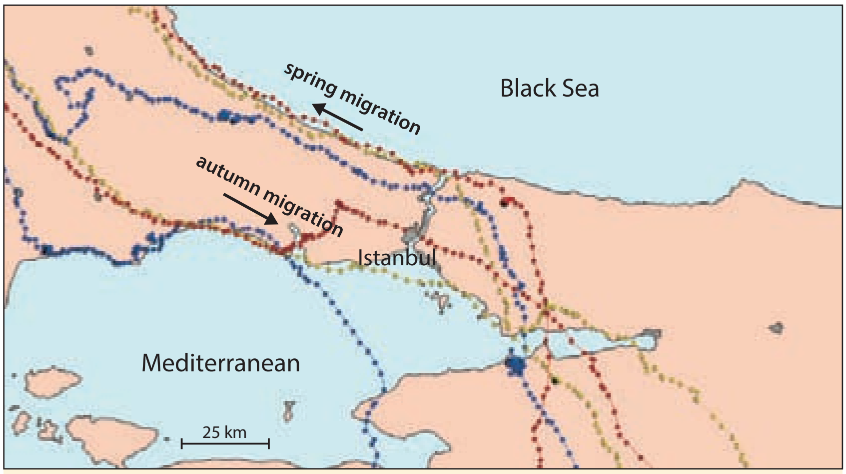
We expect the next revolution in migratory bird and behavioural research to be round-the-clock observation of wildlife from space. The ICARUS project (International Cooperation for Animal Research Using Space – see www.icarusinitiative.org) should make this possible within a few years' time. In the framework of the ICARUS initiative a satellite-supported system is to be developed for permanent observation around the globe of even the smallest of wildlife such as insects. Thanks to support from the German National Aeronautics and Space Research Centre (DLR) and numerous other cooperation partners, the initiative is likely to prove more successful than the attempts at flight by the Greek mythological hero of the same name, who plummeted into the sea with his home-made wings. The first receiver module is expected to be installed on the International Space Station ISS from 2015.

The standard transmitter of the ICARUS system will not weigh more than 5 g and will be further miniaturised in the years following its launch. The transmitters used in the ICARUS framework can be considerably smaller and lighter than satellite transmitters to date because the receivers on the ISS are specifically designed for and adapted to mini-transmitters, and will employ the latest digital communication methods. Additionally, the ISS circumnavigates the Earth at a height of only 400 km, whereas the satellites used by ARGOS orbit at some 850 km and therefore require more power for data transmission.

In addition to high definition three-dimensional data the transmitters, like the GSM loggers described above, contain acceleration sensors. Every movement by the animal and therefore, ultimately every behavioural pattern, leads to a specific spatial movement pattern of the transmitter. Once the sensors have been calibrated they provide information on the behaviour of the individual at a set point in time. Gliding flight, wing beats, swimming, or rest periods can be easily identified nowadays. In addition, the activity budgets of wildlife can be compiled over long periods of time and can be combined with energy budgets - a further novelty in behavioural research.

» New types of sensors

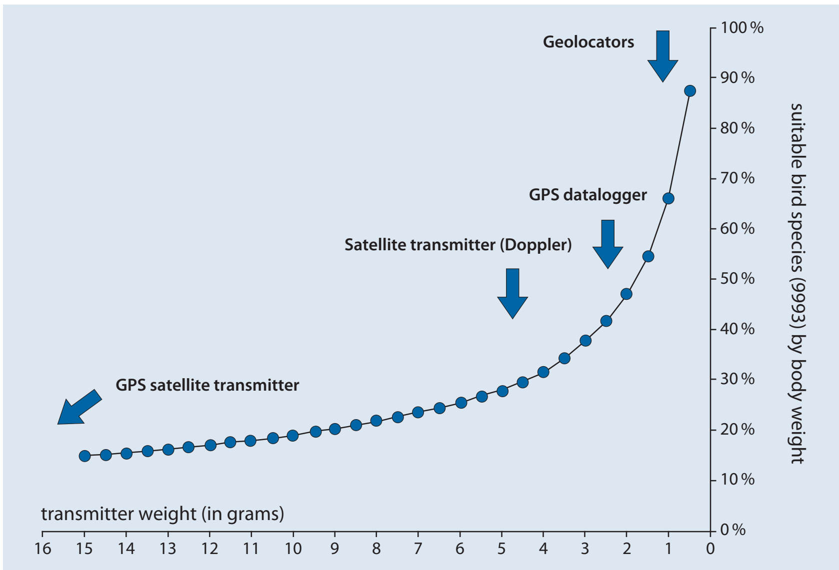
A large number of other sensors are conceivable and in part are already available for heavier logger systems. Additional environmental information can, for instance, through water or air temperature measurement, salt content (e.g. for seabirds), or the ambient light intensity (e.g. for civilisation followers) be recorded and transmitted from the precise location of the bird. In the area of physiology, recording of body temperature and heart rate is already available today in the initial systems and even in the socio-biological context there are first developments such as simple recordings of ambient noise in order to determine the song rates of individuals, or to establish whether an individual is alone or travelling in a flock. Brain activity (EEGs, electroencephalograms) can already be recorded non-invasively on free-flying birds in order to determine, for example, how homing pigeons perceive the landscape or if birds in flight really sleep.



Modern GPS loggers achieve high temporal and spatial definition. Shown here are the flight routes of three White Storks crossing the Bosporus on autumn and spring migration. The dots represent GPS coordinates at 5 minute intervals.

» Movebank

Hundreds of studies using transmitters, loggers and sensors already provide data on migratory movement to a vast extent, and the amount of such data will increase enormously in the near future. Bird ringing with its ringing centre framework has demonstrated how, with central and standardised data storage, a merging of the results of individual studies can result in a huge database (see pp. 34–35). Today ring recovery data are available not just for analysis within the respective study for which they were collected, but also for analyses of many more questions across larger geographic regions and long periods of time. The Internet database www.movebank.org uses this approach to provide for everyone a usable platform for analysis, exchange, and permanent storage of telemetry, geologger, and similar spatially-related data. The study participants can determine how



Possible uses of different technology dependent on the body mass of a bird species. It is assumed that an instrument should not weigh more than 5% of a bird's body mass.

Illustration altered following Bridge et al., BioScience 61, 2011.

Mean route of three Northern Wheatears marked in their breeding grounds in Alaska. The birds migrated across Asia and Arabia to their East African wintering area and used almost the same route in autumn and spring.

Illustration following Bairlein et al. 2012.

A lightlevel geolocator on the back of a Northern Wheatear shortly after fitting. Only a few hours after release only the spike with the light sensor jutted out of the plumage.

Foto: H. Schmaljohann, IfV.

much detail of their study only they themselves, their cooperation partners, or the general public can access, and who can download their data. As is usual in the scientific community, they conduct their own evaluations under their own name, whereby in Movebank they are assisted by numerous instruments and previously prepared additional data, i.e. climate information. They are able to standardise their data in Movebank, and store them in an understandable and usable form for others – including future generations – thus increasing the value of the studies. In view of the possible additional strain that is expected of the wildlife fitted with miniature transmitters and loggers, the high costs of such studies, and the urgency with which such movement data is required to understand wildlife migration and for species protection, the use of Movebank should be taken for granted for all forms of telemetry studies.

Technology available for the analysis of movement patterns (altered following Robinson et al. 2010). Methods in bold type are commented on in the text.

Method	Employment	Limitations
Passive Integrated Transponder) (PIT) (RFID – Radio Frequency Identification)	Identification of individuals using a mobile antenna at frequently used locations, e.g. Breeding site, bird table; local	Range < 1 m
VHF Telemetry (radio tracking)	Analysis of home ranges, activity patterns, survival rates of young birds, partly including transmission of physiological parameters. Seldom bird migration, following in aircraft; mostly local	For ground stations mostly up to a few kilometres only; battery life in small transmitters a few days or weeks
Satellite telemetry	Migration routes and home ranges; worldwide	Limited to species weighing > 150 g Doppler locating: Low spatial definition, GPS locating only for species weighing > 400 g
Mobile communications/ GSM logger	Home ranges, migration routes, height and speed, physiological parameters, environmental factors; worldwide	Limited to species weighing > 200 g dependent on system: worldwide up to a few kilometres
Geolocation	Migration routes; worldwide	Birds must be re-caught, low spatial definition: some 150 km
Radar	Migration routes, direction, height and speed, forecast of risk of aircraft collision, environmental impact studies; local	Low-flying species often not recorded
Acoustic acquisition	Migration phenology; local	Mostly only a few 100 m
Isotope	Localisation of moult areas; worldwide	Low spatial definition
Genetic marker (DNA)	Allocation of individuals to populations; worldwide	For many species low genetic differentiation

» Other methods

In addition to the described direct methods of tracking the migration routes of individual birds there is also a series of other indirect methods (see Table), of which only one will be described here as it can be used harmlessly for even the smallest species. It involves the identification of a chemical fingerprint - the stable isotopes - of feathers. Many migratory bird species moult at least part of their plumage in winter quarters (see pp. 48 to 52). The developed feather mirrors the chemical signature of the location where it grew. In this respect, it is advantageous that the Earth's surface is chemically not uniform. A freshly grown feather carries until the next moult a site-typical chemical fingerprint. If the isotope composition of a feather grown in winter quarters is examined in the breeding area, the location of the wintering area can be determined. It has been shown, for example, that south Swedish Willow Warblers winter in West Africa, whereas those from north Sweden winter in East Africa. This is information that could only be speculated on based solely on the few ring recoveries.

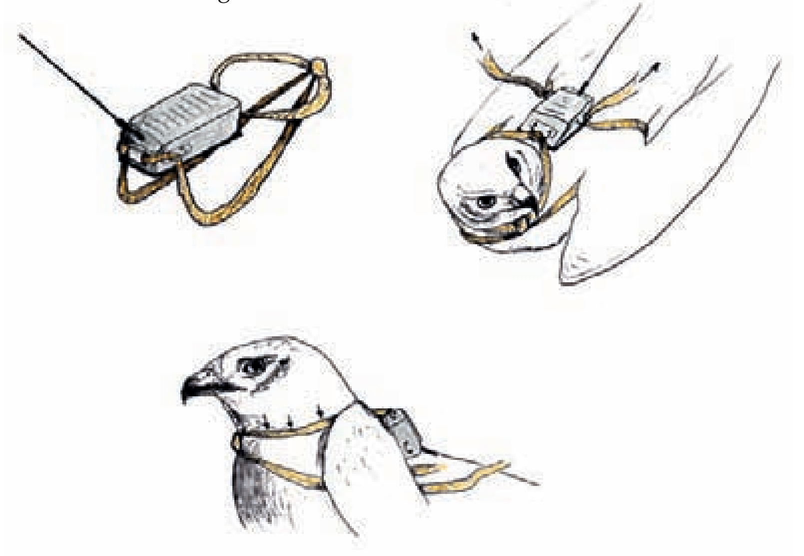
» Outlook

The methods available at present, or in the near future, permit answers to be found to a large number of long unanswered questions that have become ever more pressing against a background of increasing environmental pollution. On cost grounds alone, but also for animal welfare reasons, detailed telemetry studies will always have to be restricted to a relatively small number of individuals. Even with the use of ICARUS this could be just a couple of hundred individuals of a population at any one time. Systematic bird ringing remains essential, whereby the biological study of populations, such as the integrated monitoring of songbirds, will be more in the foreground than the analysis of migration routes. Radar devices also offer a means of analysis of mass bird movement, as well as in the framework of environmental impact studies, and ultimately there are areas where the species specialist with his or her binoculars remains as before indispensable for collection of data on bird migration. Indeed it is these ornithologists, often volunteers, who will necessarily still be required to trap birds for fitting with markings in order to record the large amount of necessary background data (population trends, breeding success etc.) and provide information from the surrounding environment of marked birds. Nowadays a 'toolbox' is available for all those involved in bird migration research and other branches of ornithology of which previous generations could only dream. It is our responsibility to use it in a fitting manner.

Klaus-Michael Exo, Wolfgang Fiedler, Martin Wikelski

Fitting, size and weight of transmitters and loggers

A transmitter or data logger should essentially not weigh more than 3 – 5 % of a bird's body mass. The ergonomic fitting of the transmitter is however, mostly more important than its precise weight. In order to reduce the effects on behaviour, flight, diving, or manoeuvre capabilities to a minimum, the device should be as streamlined as possible. The weights given here for different instruments are net weight, i.e. the weight without fitting material. Whereas this is only a few additional milligrams in the case of a geolocator that is fastened with a ring, for marking with transmitters or data loggers, using a rucksack or leg-loop harness, an additional 0.5 – 2.5 g must be calculated. In addition to a ring or harness bonding material, fixation with fabric tape on the rectrices, or even an implantation, have to be taken into account. The fitting has to be species-specific optimised and should first be tested on birds in aviaries. Harnesses must often be tailored to fit individual birds. Enthusiasm for new technologies must not neglect the fact that the well-being of the bird is of primary importance and it must be guaranteed as far as possible that an individual fitted with a transmitter does not behave differently to an individual without a transmitter. As basically any additional load - even if it is often negligible - represents an impairment, the costs (for the bird) and the use (for science) must be carefully balanced against each other for every study. It must also be pointed out that in many countries the fitting of birds with transmitters or loggers always requires a permit under the animal welfare legislation.



Schematic depiction of the fitting of a rucksack satellite transmitter on a Montagu's Harrier. Graphic: C. Trierweller.

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Prof Dr Martin Wikelski is the Director of the Max Planck Institute for Ornithology in Radolfzell and Professor for the Chair for Ornithology at University of Constanz. His work foci are Animal Tracking and Immune Ecology. In the time frame 2014–2020 the ICARUS Initiative plans the establishment of a novel monitoring system on the ISS that also records very small wildlife worldwide.

Related literature:

Bairlein F, Exo K-M, Schmaljohann H 2012: Eine neue Methode zur Aufklärung der Zugwege wandernder Tierarten: Geolokation. Biologie in unserer Zeit 42: 27 – 33.

Fiedler W, Davidson S 2012: Movebank – eine Internetplattform für Tierwanderungsdaten. Vogelwarte 50:15-20.

Hobson KA, Wassenaar LI 2008: Tracking animal migration with stable isotopes. Elsevier, Amsterdam.

Robinson WE, Bowlin MS, Bisson I, Shamoun-Baranes J, Thorup K, Diehl RH, Kunz TH, Mabey S, Winkler DW 2010: Integrating concepts and technologies to advance the study of bird migration. Frontiers in Ecology and Environment 8: 354-361.

„Out of Africa“:

The evolution of bird migration

Birds breed where they can find optimal food. When these food resources are not available outside the breeding season, for instance, during the winter period, birds migrate to regions that are rich in food. Many insectivores, which exploit the arthropod-rich European summers to rear their offspring, originate in Africa, where they return as long-distance migrants after the breeding season.

Birds can only occur where they can find sufficient and suitable food. Bird species are not free to choose their diet, as a herbivore requires a different gastro-intestinal tract (as well as the necessary digestive enzymes) to a carnivorous species. The mode of nutrition is thus determined both genetically and phylogenetically. If the ancestor of a species were piscivores it is rather unlikely that a direct descendant would become a granivore. These are, of course, trivial facts but they are significant is answering the question as to how the phenomenon of bird migration originated.

Birds were especially successful in evolution because they were able to settle in almost all habitats on the planet, which differ particularly in the available potential dietary resources. One of the preconditions was not only anatomic adaptation such as flight, walking, or diving capabilities, but a specialisation to the available food source. If therefore a region or habitat was rich in fish, species from the guild of piscivores could settle and diversify there. For herbivores on the other hand, such a region or habitat would offer little or no possibilities for development.

The long-distance migrant, the Golden Oriole, utilises the favourable supply of insect-rich food in Central Europe during the breeding season and then migrates south of the Sahara in order to make rich pickings there.

Photo: H. Tuschl, Naturfotoarchiv Willner.

» The influence of the Ice Ages on flora and fauna

The geographical distribution of food resources is not immutable but depends on the climate that over the past million years (in the Miocene and Pleistocene periods) has experienced regular changes of warm and cold periods (a cycle of some 100,000 years). The vegetation in the northern hemisphere today, which we accept as natural, is young in terms of the Earth’s history.

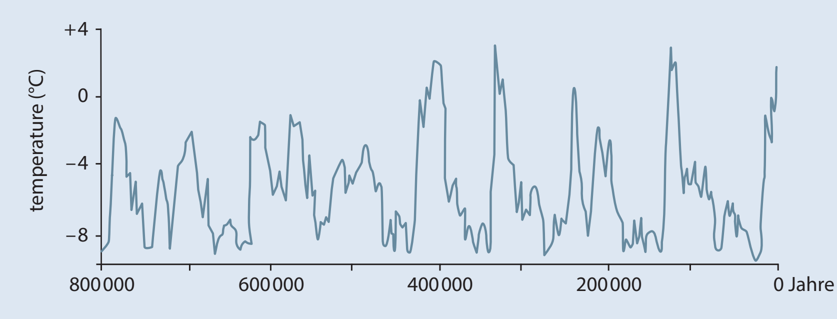
Some 18,000 years ago as the last ice age in Europe reached its furthest geographic extent, a thick layer of ice covered large areas of the continent. The temperatures in the ice-free regions were similar to those in the Arctic today. In wide areas of Europe therefore, there was no deciduous woodland or grassland but rather a steppe-tundra inhabited by reindeer, mammoths, and other arctic animal species. During the ice age, Africa experienced widespread drought with an extensive expansion of the Sahara and a great reduction in the size of the rainforests.

The last ice age ended some 12,000 years ago when the glaciers and ice sheet melted. The released melt water caused a rise in the sea level of some 120-130 m. At that stage, the North Sea as we know it today was formed and the land bridge to Britain was submerged. Deciduous mixed woodland took the place of the tundra-steppe vegetation in Central Europe, which withdrew to Northern Europe. Some 10,000 years ago there was increased rainfall in the Sahara region and for several thousand years (until about some 5,000 years ago towards the end of the height of the Holocene) the Sahara was a green and fertile savannah rich in flora and fauna. Only after this period did the Sahara revert again into the desert and ecological barrier that we know today. Food availability and the distribution and migratory behaviour of bird species are closely related.

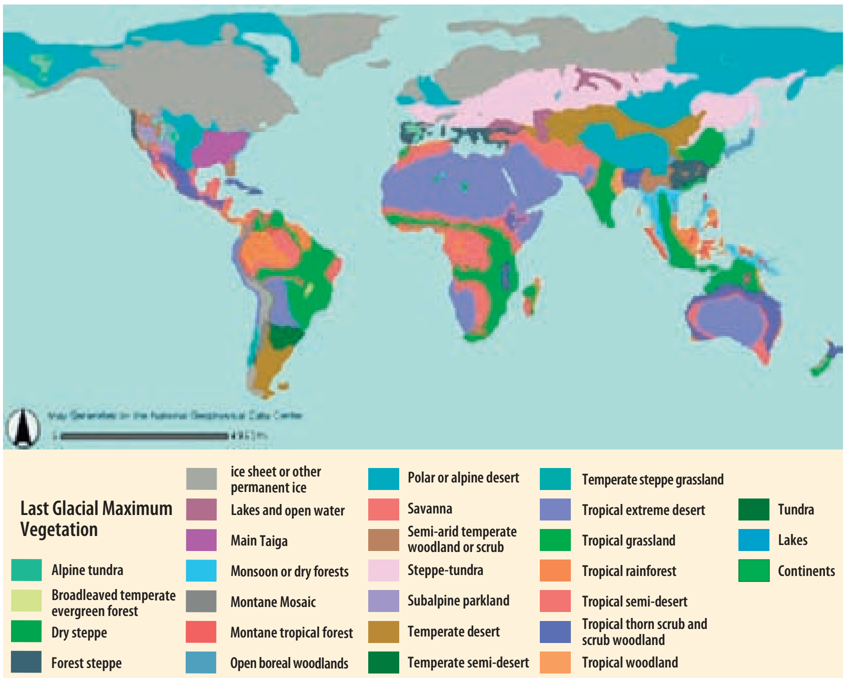
» Herbivores

Although plant biomass is available in large quantities only relatively few groups of birds specialise in this food resource. An animal or bird would have to consume large quantities of low-energy leaves or grasses to become sated and also be capable of metabolising the normally indigestible cell wall components and poisonous secondary metabolites. Among mammals, ruminants and other hoofed animals have evolved into particularly specialised herbivores. The price of this however, was an increase in body size and, in ruminants, the development of a voluminous ruminant stomach with specially adapted microorganisms capable of breaking down cellulose. For birds, whose bodily frame must remain light in order to fly, the development of a ruminant stomach was clearly not a sustainable option.

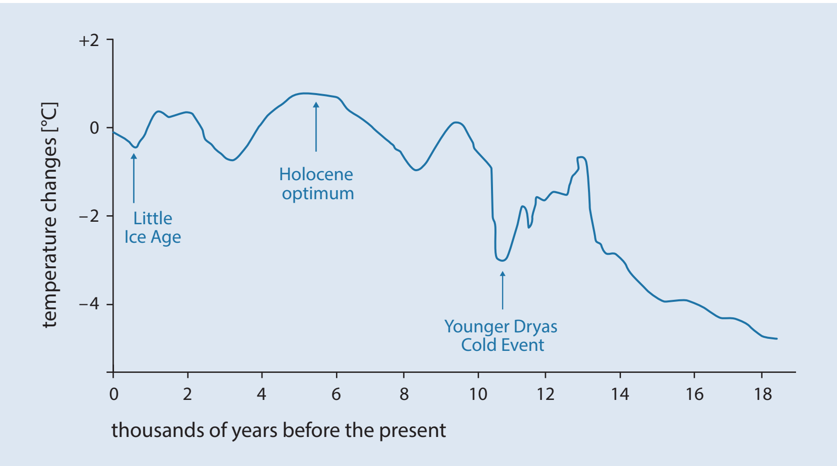
The Palaeognathae, or ratites such as the Ostrich, Emu, and Rhea, which are all herbivores and today have a generous body weight, mark the start of the phylogeny of modern birds. The ratites became flightless at an early stage. Many species of Galloanserae (i.e. swans, geese, ducks, and galliforms – that phylogenetically follow the Palaeognathae) have widely retained their herbivorous diet; only a few species have become piscivores or insectivores. Green plant material is however, also con-



Pleistocene temperature cycles in the past 800,000 years. The minimum temperatures correspond to glacial periods.

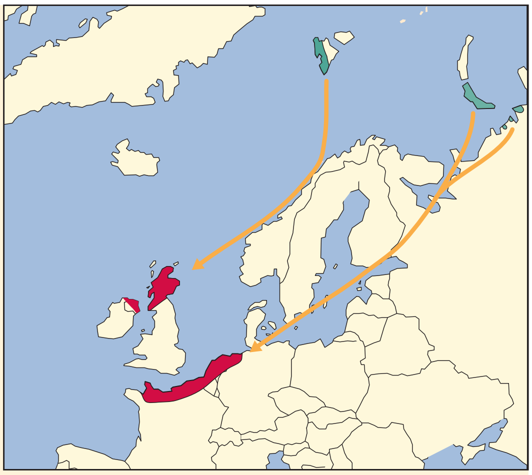


Reconstruction of the vegetation at the height of the last ice age (some 18,000 years ago). Source: Wikimedia Commons.



Temperature changes in the Holocene.

Contents

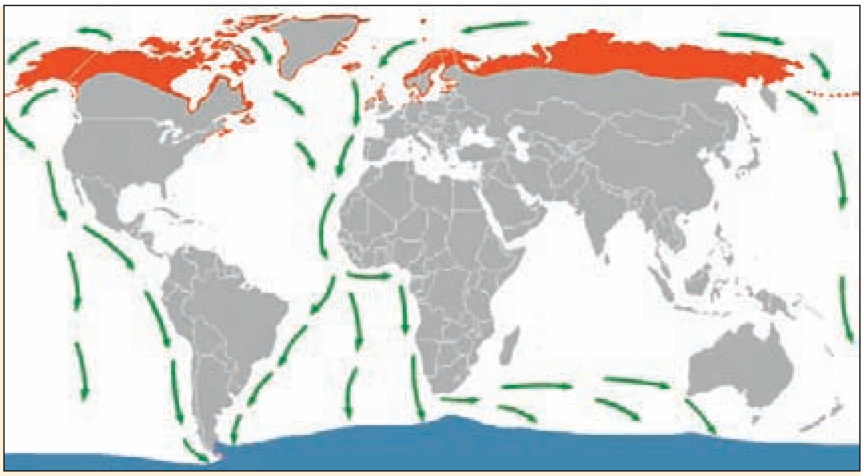


Wintering Barnacle Geese in Eastern Friesland, Germany, and their migration routes and wintering area. Photo: M. Wink.

sumed by representatives of the bustard, crane, and rail (Coot and Moorhen) families. Seeds and fruit, in which some bird families such as grouse, doves, sparrows, many passerines, finches, and buntings have specialised, are significantly richer in energy.

Bird species that have specialised in leaves, needles, and grasses, find food almost the whole year round in Central Europe. It is therefore not surprising that almost all Phasianidae (grouse, partridges, and pheasants) are resident birds in Central Europe.

Arctic-breeding geese and swans find no nourishment in their breeding areas in winter; they migrate southwards and winter on the coasts of the North Sea or the large lakes in Central Asia, where sufficient food is also available in winter. It should not be forgotten however that the arctic breeding grounds became accessible only from about 10,000 years ago, after the end of the last ice age. During the last ice age, insofar as it was not covered in ice, an extensive steppe-tundra existed in Central Europe. The Nordic geese that today settle the Arctic probably bred in this Central European tundra. As the climate in Central Europe changed in the post-glacial period, and with it the vegetation, the geese and swans shifted their breeding grounds more and more northwards. There they found abundant food resources without a great deal of competition. In order to escape the arctic winter, migration evolved from the Arctic into climatically more favourable areas to the south. In Central Europe, plants do not produce seeds all the year round but rather at the end of the vegetation period from late summer until early spring. This food resource is therefore generally not available to granivores throughout the year. Granivores however, also consume animal food (arthropods) that is abundantly available during the summer half-year. Many Central European granivore and insectivore species (woodpeckers, tits, nuthatches, sparrows, finches, and buntings) find food the whole year round and are therefore frequently resident birds. The local populations are however, supplemented by new arrivals from Northern and Eastern Europe when these areas experience periods of heavy frost or heavy snow cover. In these conditions seeds are hard to find. Granivores are seldom long-distance migrants to sub-Sahara Africa.



The Arctic Tern is an exceptionally long-distance migrant, breeding in the Arctic and wintering in the Antarctic, and covering annually up to 40,000 km on its migration flights. Photo: M. Wink; Map: Wikimedia Commons.

Matters are similar for frugivores, as fruit is available from summer until early winter. Fruit is available throughout the year only in the tropics and it is there that the greatest diversity and variety of frugivores species can be found. Of our birds, thrushes, waxwings, and some warbler species are characteristic frugivores that eat fruit temporarily but are otherwise mostly insectivorous. Many species in this group are part-migrants with some warblers, such as the Garden Warbler, even long-distance migrants.

» Carnivorous species

In nature the top trophic level is represented by the carnivorous species. Birds of prey, including falcons and owls, which prey on mammals and other birds, find food throughout the year. Many of them are resident birds. Only the populations in Northern and Eastern Europe suffer from a shortage of food in winter and these therefore migrate, in part, to climatically more favourable areas in Central and Southern Europe as well as to Asia. Insectivorous falcons, such as the Hobby and the Lesser Kestrel that do not find adequate food in our climes in winter, are characteristic migrant species and winter in Africa.

Exceptions to the rule are harriers, kites, and several eagle species that theoretically could also find food in winter in Europe. They are however, all migratory species, probably because the ancestors of these birds of prey evolved in tropical Africa.

Pisciviorous marine bird species (petrels and shearwaters, gannets and auks) are frequently colony breeders that undertake long journeys across the oceans after the breeding period to find the best fishing grounds. Whereas gulls are normally resident or long-distance foragers, migratory behaviour is very pronounced in terns and some species, such as the Arctic Tern, belong to the exceptionally long-distance migratory species.

» Insectivores

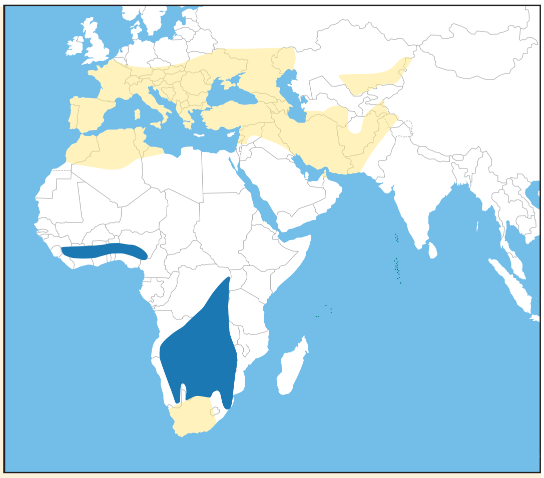
Insectivores, or more correctly arthropod-eaters, belong formally to the carnivorous species, but should be considered separately. In Central and Northern Europe, insects occur in large numbers only in late spring and summer. Many insects die in autumn, or winter in sheltered places where a 'normal' insectivore (unless it is a woodpecker, tit, or tree-creeper) cannot feed on them. The insectivores include a particularly large group of long-distance migratory species that winter south of the Sahara. In this category are the Corncrake, Coraciiformes (Hoopoe, Bee-eater, Roller), cuckoos, nightjars, swifts, Wryneck, swallows, pipits, wagtails, flycatchers, many different warbler species, small thrush species, wheatears, shrikes, Golden Oriole, and Ortolan Bunting.

Some insectivores are quite opportunistic, and species such as Chiffchaff, Blackcap, Dunnock, Pied Wagtail, Stonechat, and Firecrest, are short-distance migrants from Central Europe into the warmer Mediterranean region. It can be speculated that these species previously lived on the Iberian Peninsula, which was not covered by steppe-tundra during the last ice age. Only a few specialist insectivores, such as the Winter Wren, Goldcrest, and Dipper winter here in Central Europe. These are comparatively small species, whose dietary requirements are not as great as, for instance, a Hoopoe.

The question as to why one species migrates as a long-distance migrant to sub-Sahara Africa, and another remains resident or is a short-distance migrant only to the Mediterranean area, can be discussed on several levels:

- Climate and habitat change in the Pleistocene and Holocene
- The phylogenetic status of a species in the framework of phylogeny as a whole

Essentially the trend can be identified that bird species always become migratory when they cannot find food in their breeding area the whole year round. This applies at least to the present day, some 12,000 years after the end of the last ice age. It can be assumed that more than 12,000 year ago all species that we now know also existed then, as phylogenetic DNA analyses have dem-



The Bee-eater is a long-distance migrant that breeds in the warmer parts of Europe, North Africa, and western Asia (yellow) and winters in Africa south of the Sahara (blue). Photo: M. Wink.

Glossary

Holocene - the geological epoch which began at the end of the Pleistocene (at 11,700 calendar years BP) and continues to the present.

Miocene - the first geological epoch of the Neogene Period and extends from about 23 to 5.3 million years ago.

Phylogeny - the history of the evolution of a species, genus, or family etc. Based on their evolutionary origin species are divided into monophyletic taxon, within which all the members have a common ancestor.

Pleistocene - the geological epoch which lasted from about 2.5 million to 11,000 years ago, spanning the world's recent period of repeated glaciations.

Pliocene - the period in the geologic timescale that extends from 5.3 to 2.5 million years before present.

onstrated that most passerine and non-passerine species frequently originated as early as the Miocene and Pliocene and at the latest in the Pleistocene. That means that the species occurring today have successfully survived many cycles of dramatic climatic changes.

At the end of the last ice age the potential distribution range for many of the now trans-Sahara migrants (of which most species are not steppe bird species) was very restricted, as large regions of North and West Europe were covered in ice and Central and Eastern Europe was a treeless steppe-tundra. As the Sahara was also a large desert, the only areas probably remaining for settlement by many species were sub-Saharan Africa or South and South-east Asia. When the Sahara was transformed into a green savannah at the end of the ice age, the settlement area for many insectivores probably expanded to the north and progressively to Europe as well, as the tundra vegetation in the latter region was gradually replaced by woodland. As large amounts of arthropods are available in the short-term in summer in Europe and Asia, some species took the opportunity to settle the new regions with little competition. As the winters at that time were also poor in nutrients for insectivores, bird migration to sub-Saharan Africa or to tropical South-east Asia began, where, during winter in the northern hemisphere, a tropical climate prevails or the summer half-year begins and sufficient food is again available.

To begin with, the Sahara was a green savannah that did not have to be crossed in non-stop flight, but rather in stages. As the Sahara again reverted to desert some 6,000 years ago many species evidently developed the non-stop flight crossing. But even today there is still evidence that a number of species make short stopovers during their crossing of the Sahara, as did their forebears for thousands of years when the Sahara was still green.

If the typical long-distance migrants such as Hoopoe, Bee-eater, Roller, cuckoos, nightjars, swifts, Wryneck, swallows, pipits, wagtails, flycatchers, many different warbler species, small thrush species, wheatears, shrikes, Golden Oriole, and Ortolan Bunting are considered, these are all species whose genus has other representatives in Africa (some in South-east Asia as well) that did not evolve into long-distance migrants. The evolutionary motto for many migratory birds that visit us in the summer half-year (as it is for modern man who emigrated from Africa some 90,000 years ago) is therefore "out of Africa". Where molecular family trees are available (i.e. for swifts, *Acrocephalus*, *Hippolais* and *Locustella* warblers. Wheatears, Stonechats and Whinchats, and swallows) it can be clearly perceived that the European representatives of these groups are descended from African ancestors.

The trait 'migrant' is clearly genetically determined, such that 'zugunruhe', migratory behaviour and direction, and the locations of summer and winter quarters, all exhibit inherited components. The genetic traits are evidently flexible, as it has been proven that some bird species can alter their migration behaviour over the course of only a few generations (e.g. White Stork, Blackcap). This flexibility was probably necessary in the course of evolution as Europe was probably settled "out of Africa" several times in the past periods of climate warming. Today, we cannot determine whether or not the same species became migratory birds in these cycles. The European birds' life in previous warm periods probably looked very different than it does today. As most of our species originated at least one million years ago, they have successfully mastered climatic changes (otherwise they would have become extinct). This flexibility can help us to be optimistic about whether and how our bird world will cope in future with the climate changes forecast by climatologists (see pp. 58–61).

It would seem that both migration in birds and the distribution of species are subject to constant adaption to changing circumstances. If we assume that learned information cannot be passed on, changes in bird habits must be the result of the elimination of those that fail to adapt. As Heraclitus would have put it – everything flows!

Michael Wink

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E-Mail: wink@uni-hd.de

Related literature:

Storch V, Welsch U, Wink M 2013: Evolutionsforschung. 3. Aufl., Springer Spektrum, Heidelberg.

Wink M 2013: Ornithologie für Einsteiger. Springer Spektrum, Heidelberg.

Training and ProRing e. V.:

Support for voluntary bird ringing

The ringing of birds in Germany is to a very large extent in the hands of voluntary ringers. The organisation, provision of rings, and their administration is the responsibility of the ringing centres, but they cannot help with the acquisition of other ringing material. This is where ProRing comes in.

The ringing of birds is an indispensable avian research method. It is in particular dependent on a large number of dedicated voluntary indirect employees of the ringing centres - the ringers. Bird capture and ringing demand not only a great deal of care, security, and skill in the handling of trapping equipment and the birds, but also knowledge of the legal guidelines. The road to becoming a ringer is therefore a long one. Normally, would-be ringers initially do an 'apprenticeship' under an experienced ringer. Depending on the species or task in hand, ringers must get up early in their free time, drive long distances, climb trees or hills, be good cross-country runners, tinker around in the workshop, wade through bogs by night, ward off attacks by adult birds, carry equipment for kilometres, get bitten by mosquitos and scratched by brambles, or 'just' have a very great deal of patience.

If they are still interested after this 'apprenticeship', they have to attend a course at the responsible ringing centre where the background, tasks, and aims of bird ringing; the legal guidelines, implementation and organisation; and capture and marking methods are presented and discussed. This is followed by practical training with birds. Only when all this has been achieved, and the desire to be a ringer is still there, can an application be made for a certificate to conduct bird ringing, in close cooperation with the responsible ringing centre and its planned activities. The ringing centre then provides the now certified ringer with the necessary rings but not trapping equipment and other ringing material. To fill this latter gap ProRing was founded in 2002.

A Great Reed Warbler is measured, weighed and ringed before being released.
Photo: S. Klasan.

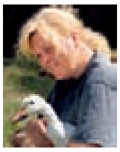
» ProRing e.V.

ProRing (the German association of friends and promoters of scientific bird ringing), with at present some 370 members, supports ringers in their voluntary commitment. Collective orders of ringing material are offered and the association organises the production of large amounts of different ringing aids and passes on the discount directly to its members. ProRing also sponsors ringing projects, assists when problems arise, and conducts the Integrated Grey Heron Monitoring and Colour Marking of Marsh Harriers projects.

ProRing organises conferences and practical seminars as continuation training for ringers, on subjects such as trapping methods, age, and sex determination; or data collection and evaluation. These conferences and seminars are well attended and also offer ringers the opportunity to exchange experience and knowledge.

ProRing supports the evaluation and publication of ringing project data. The association provides information by manning stalls or distributing brochures at various public events such as bird fairs. It also conducts deliberate public relations work aimed at improving the knowledge of and understanding for this research method. ProRing is a registered charity and its work is coordinated with the ringing centres. Further information on scientific bird ringing and ProRing can be found at www.proring.de.

Susanne Homma
ProRing
(German association of friends and
promoters of scientific bird ringing)



Dr Susanne Homma is a biologist working in the field of ornithology. She is an enthusiastic ringer and Chair of ProRing e.V. since 2004.
susanne.homma@web.de

Colour-ringing – it's up to all of us

As early as 1937, the publisher of the magazine 'Vogelzug' (bird migration) wrote, "*The more random long distance recoveries on ringed birds fades into the background, the greater will be our demands for identification of ringed birds in the wild*". In addition to marking birds with metal rings, coloured and a variety of 'form' rings were introduced in order to enable identification of individual birds in the field without recapture. Today, this is a very widespread method used in population and behavioural biology, but in times of excellent optical equipment and digiscoping it gains increasingly in importance in bird migration research.

Fitting birds with individual marks readable from a distance, in addition to metal leg rings, is also widespread. Besides combinations of uncoded colour-rings, colour-rings with an individual code that can be read directly are also used especially for larger species. Swans and large goose species in particular are also marked with coloured and coded neck collars, and wing-tags are also used on birds of prey and gulls. On the other hand nasal saddles, are often used for ducks. The success of colour-marking is dependent on them being read. The more participants, the faster results are achieved and migration routes and life stories of individual birds can be more precisely determined. This means however, that colour-ring readings must also be properly reported. In contrast to ringing with metal rings, which are exclusively issued and administered by the national ringing schemes, other additional forms of marking include many projects of ringers. It is therefore more important than ever that colour-ring projects are centrally recorded and coordinated. Nothing could be more fatal than using identical colour combinations for different projects. There are therefore central coordinators for individual species such as the Common Crane, or groups of species such as waders or gulls, who monitor the use of colour combinations and also collect the reading reports, maintain the databases, and exchange this information with the ringing centres.

Colour-ringed Spoonbills shortly after ringing on Mellum Island (Lower Saxony).
Photo: B. Metzger.

» Central structures

Since 1995, the European Colour Ring Birding organisation (CR-Birding – www.cr-birding.org) founded by Dirk Raes strives for the central recording of all colour-ring projects, which is now also supported by EURING. CR-Birding is not however, the reporting platform for colour-ring readings, it simply collates information on colour-ringing projects and thereby avoids the duplicate use of colour combinations. Above all CR-Birding provides the point of contact between the colour-ring reader, the individual colour-ring project, and the ringing centres.

All colour as well as metal ring readings should be reported to the regionally responsible ringing centre. The centre then passes on the reports to the project manager. The finder/reader then receives the life history of the bird from either the project manager or the ringing centre. Be patient however – this procedure can take some time, particularly if there are any doubts about the identity of the bird or its marking. If feedback is not received after six months, a request for information can be made to the ringing centre by email. This procedure ensures that recoveries or readings are entered in the official national databases and are then stored for the lifetime of the respective project and made available for evaluation.

Colour-ring readers should take care to note the colour of the ring or rings, and the code if applicable, as well as to which leg the ring is fixed. The exact positioning of each ring is important when a combination of rings is used. For waders in particular, but also Spoonbills where uncoded colour rings with a small flag are used in combination, the positioning is also important. The legs of the bird - right or left - are read from the bird's perspective. When face to face with a bird the leg to your left is therefore the bird's right leg! The same applies to wing-tags.

Olaf Geiter, Franz Bairlein

Related literature:

Boschert M, Fiedler W, Schmidt A 2009: Zug in den Süden – Wohin fliegen Große Brachvögel vom badischen Oberrhein nach der Brutzeit? Osnabrücker Naturwiss. Mitt. 35: 85-90.

Cresswell W, Lind J, Quinn JL, Minderman J, Whitfield DP 2007: Ringing or colour-banding does not increase predation mortality in redshanks *Tringa tetanus*. J. Avian Biol. 38: 309-316.

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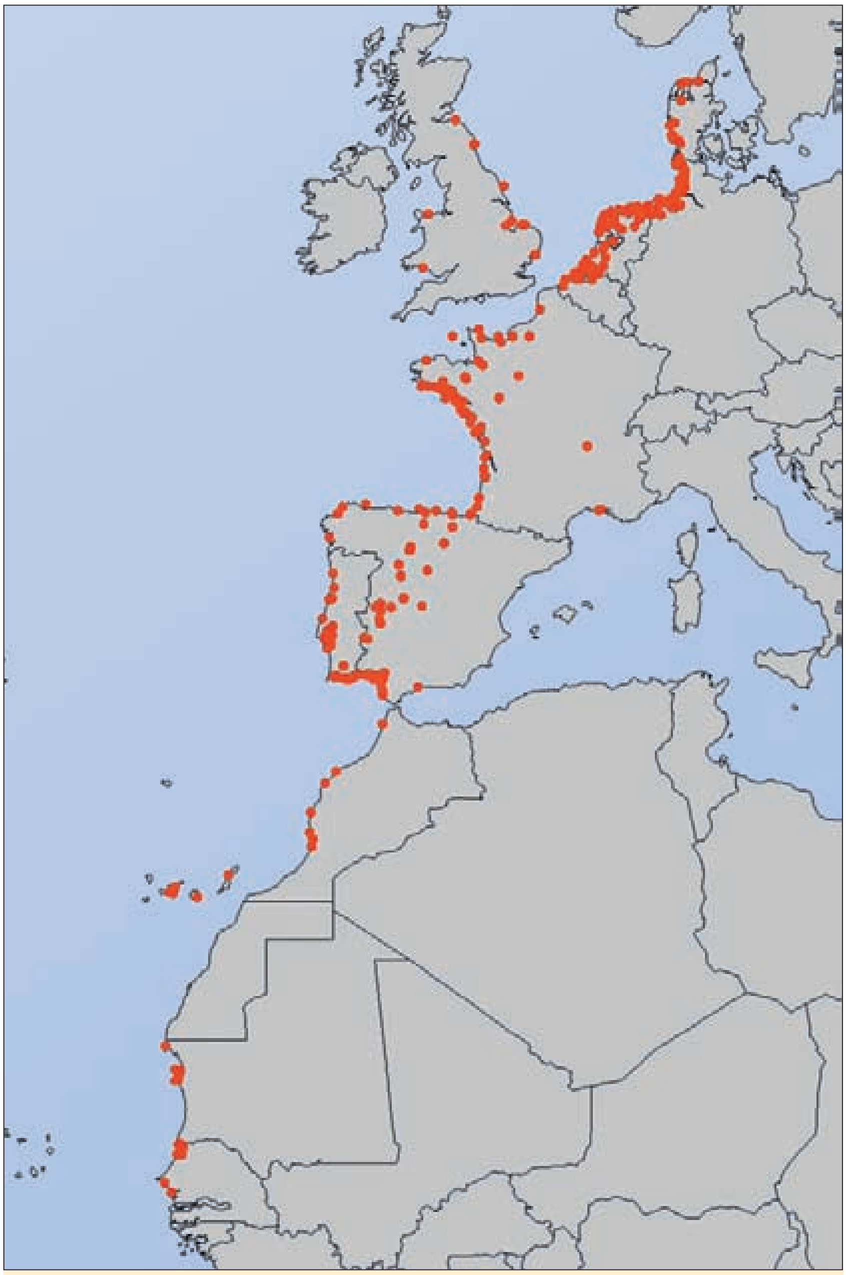
Olaf Geiter is head of the Helgoland ringing centre at the Institute of Avian Research in Wilhelmshaven.
olaf.geiter@ifv-vogelwarte.de



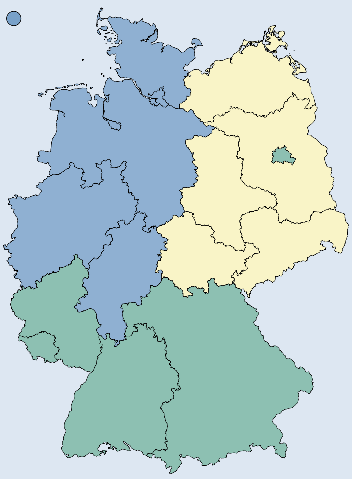
Ring recovery/reading location of Spoonbills ringed in Germany.

Daten: Overdijk/Geiter, 2002-2012

Helgoland Ringing Centre
Institute of Avian Research
An der Vogelwarte 21
D-26386 Wilhelmshaven
ring@ifv-vogelwarte.de
www.ifv-vogelwarte.de

Areas of responsibility of the three German ringing centres

For historical reasons ring recovery/readings from Berlin are handled by the Radolfzell Ornithological Station.



State Agency for Environment, Nature Protection and Geology Mecklenburg-Western Pomerania
Hiddensee Ringing Centre
An der Mühle 4
D-17493 Greifswald-Eldena
beringungszentrale@lung.mv-regierung.de
www.beringungszentrale-hiddensee.de

Max Planck Institute for Ornithology
Radolfzell Ornithological Station
Am Obstberg 1
D-78315 Radolfzell-Möggingen
baer@orn.mpg.de
www.orn.mpg.de

Ringers, ringing centres, EURING and the future

In order to find answers to numerous questions in ornithology it is indispensable to be able to identify birds as individuals. For more than 100 years the method used to achieve this has been ringing, whereas in recent times more and more additional marking and tracking techniques are employed, often of an electronic kind. Nonetheless, whether a small ring, a transponder, a logger, or a satellite transmitter is used, one aspect remains constant - nothing can be achieved without the dedication of volunteers.

Just as it is impossible to imagine ornithology without the classic ringer, the new technologies cannot dispense with the assistance of the numerous amateur volunteers. Volunteers are necessary for the collection of metadata and background information on behaviour, breeding biology, and population trends; as well as the observation of individuals fitted with transmitters, or the search for transmitters fitted to dead birds. A few professionals can conduct the observation and analysis of moving points on digital maps but contribution of substantial new material requires a large number of volunteers.

Migratory birds, whether ringed, fitted with transmitters, or without either, do not stop at man-made borders. International cooperation is therefore essential. Whether it affects the recovery of a ringed bird, clarification of the location of an individual with a transmitter, or the collection of additional data such as assemblies, a network of knowledgeable and cooperative ornithologists is indispensable.

Before an individual marking method can be applied, the bird must first be caught temporarily or taken from a nest. In all cases this requires a permit. In contrast to ringing, the fitting of transmitters or loggers also requires an animal welfare permit. In terms of the capture (and disturbance at the breeding site) the impact of all methods are considered to be the same.

Ring recovery or telemetry data are worthless if not published. Data that is used for one's own research and published is at least useful once, but data that is subsequently available for other, later or wider scale evaluations has wider utility. Whereas this multiple use of ring recovery data via ring recovery databases is common practice, at both national and international level, there is often a reluctance to participate by those engaged in telemetry studies. The provision of presentation and evaluation platforms such as www.movebank.org is already a great step in the right direction. Nonetheless, such databases require a certain degree of supervision, not only as far as the usefulness and completeness of data goes, but also with regard to any questions related to the whereabouts of sensitive species.

Given that the use of mini-transmitters and data loggers will develop as comprehensively as is expected, it is absolutely necessary to co-ordinate and standardise methods and transmission frequencies. In this respect, an intensive discussion on the ethical judgement of telemetry methods is just as necessary as the establishment of the minimum specialist requirements for persons who fit transmitters and loggers to temporarily captured birds.

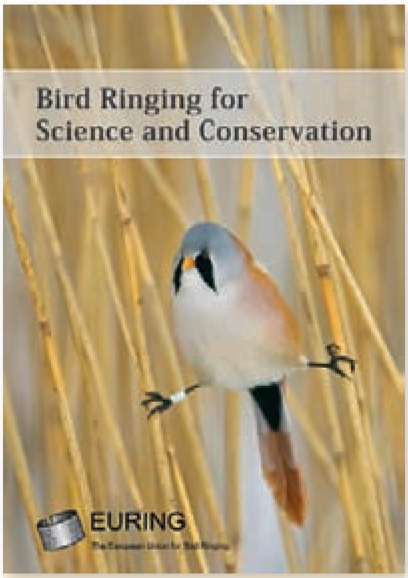
I EURING activities

- Conduct analyses of ringing and ring recovery data at the European level
- Coordination of a network of more than 500 standardised capture projects in the framework of capture-recapture monitoring in Europe
- Initiation of Europe-wide ringing projects with amateur ornithologists
- Promotion of the further development of statistical and computer methods for ring recovery analysis
- Preparation of ringing guidelines and standards
- Provision of a standard code for the entering and exchange of data
- Establishment of the EURING database
- Provision of an Internet platform for communication between ringing centres, ringers, and the interested public.

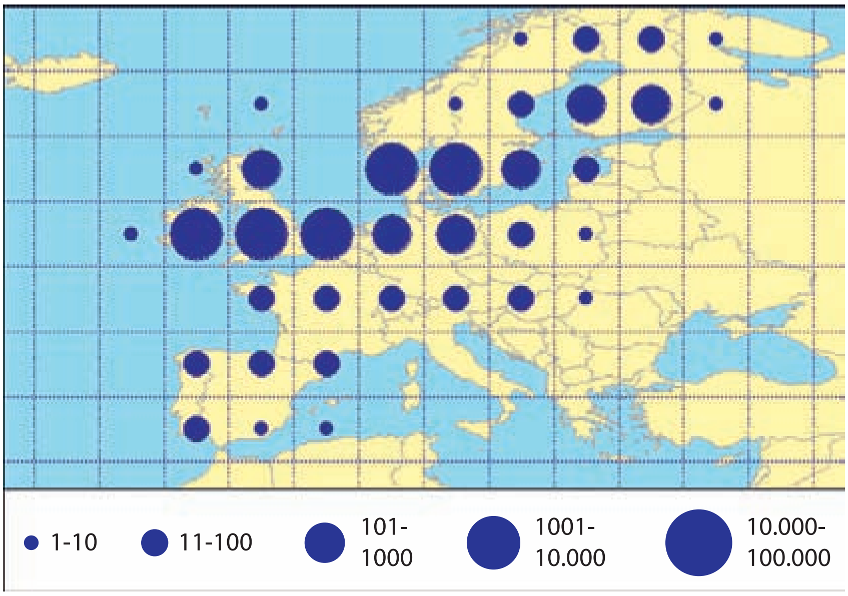
More information at www.euring.org

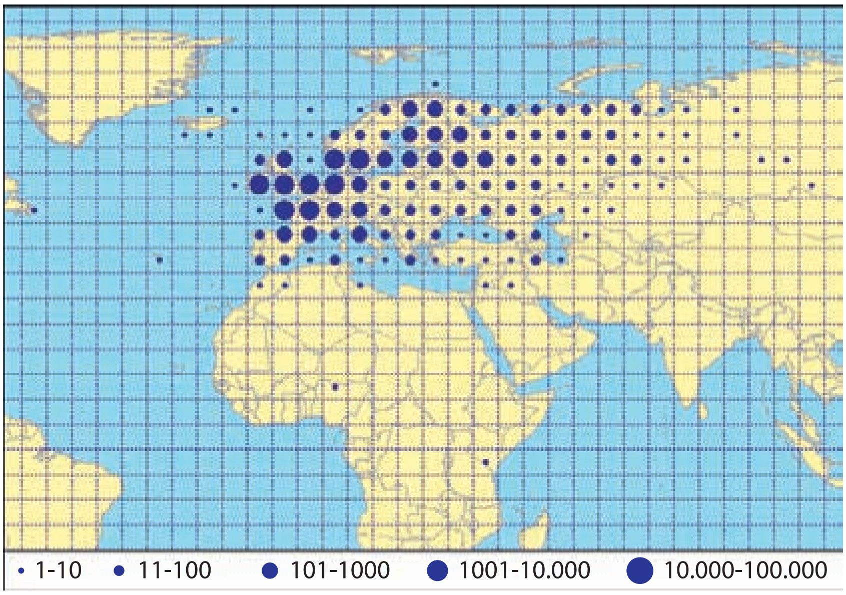
» Europe-wide cooperation

In the European ringing community, sensible procedures and understandings have developed in all these areas. The classical task of the ringing centres is structural development, training, cultivation of contacts, and the guidance and support of volunteers, as well as playing a central role



A brochure printed in several languages provides information on EURING and the many fields of application of bird ringing. It can also be downloaded as a PDF at www.euring.org/about_euring/brochure2007/index.html.





Ringing data (upper map) and data of recoveries of dead ringed Teal (lower map) available in the EURING database. The totals per grid are depicted.

in the licensing system. The maintenance of the standardised databases, the contents of which are international and still understandable after decades, are part of the daily work of these centres. As this would not be possible without international cooperation, standardisation, and agreements, the European Union for Bird Ringing (EURING) was founded in 1963. It is the amalgamation of all 39 European ringing centres and a few others outside Europe. EURING has developed a common code for the processing of ringing and ring recoveries, and set up a central database. With its numerous other activities (see Box 1) EURING is a guarantee for effective European cooperation in avian research and contributes to science and nature protection in many diverse ways. More in the brochure available as PDF in several languages here: http://www.euring.org/about_euring/brochure2007/index.html. The Europe-wide ringing database comprises in the meantime, more than 10 million datasets (see Box 2). It would be ridiculous to drop such proven quality standards and replace them with something new, only because part of the marking material no longer consists of metal rings but mini-computers. On the contrary, these proven national and international structures, established as a result of bird ringing for which they are still required, should also be accepted and used in the field of electronic individual tracking methods with transmitters, loggers, or geolocators.

Wolfgang Fiedler

II Data stock in the EURING database (EDB) for ringing and ring recovery data (As at: start of 2013)

(As at: start of 2013)

Total of all datasets	> 10 Million
Total of all species	485
Number of species with more than 10,000 entries	87
Number of species with 1,000 to 10,000 entries	119
Number of ringing centres providing data	33

Details on the EDB database and the request system for datasets from the EDB can be found at http://www.euring.org/edb. Quick information on the data stock of a species can be found via the EDB index (http://www.euring.org/edb/index.html)

Dr Wolfgang Fiedler is head of the Centre for Animal Marking at the Max Planck Institute for Ornithology in Radolfzell and current chair of the European Union of Bird Ringing (EURING).
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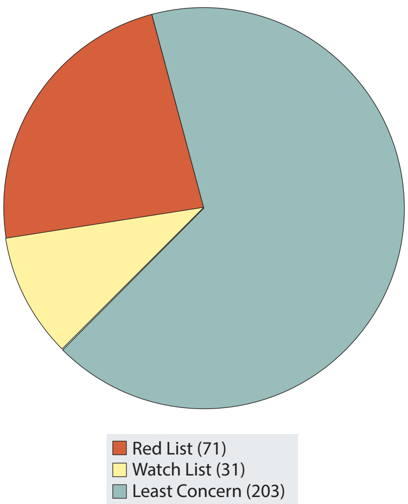
The Red List of migratory bird species

Migratory birds are subject to numerous threats in breeding areas, such as habitat loss and persecution on migration and in wintering areas. National and regional Red Lists of breeding birds have been very important indicators of species and nature conservation at risk for over 40 years. Non-breeding birds that pass through our country or use it for stopover, moult, or wintering, are less easily noted as being in need of conservation measures. This gap has now been closed for the first time at national level by the compilation of a Red List of Migratory Bird Species. In the process, it has become clear how necessary it is to improve our knowledge about bird life outside the breeding season and to carry out more bird census schemes during migration and in winter.

The first Red List of (West) German breeding birds was published in 1971 and as the first national Red List was thereby the forerunner for the development and adaptation of a revolutionary species and nature conservation instrument. Other groups of organisms soon followed, as well as lists for the federal states, which are responsible for nature conservation policy. However, the political breakthrough occurred later in the mid-1980s, after the publication of the 4th edition of the summary of all Red Lists in Germany. Today, Red Lists are in the focus of public nature conservation policy debate, i.e. as a basis for discussion and decision-making. In the meantime Red Lists have even found their way into some legislation. For instance, in the *National Strategy on Biodiversity* introduced by the German federal government in 2007, concrete aims were formulated, orientated on the levels of threat in the Red Lists and which are amended in accordance with their updates.



Threat situation of migratory bird species in Germany (n = 305 species, sub-species, and bio-geographical populations).

» Not only breeding birds

Red Lists of birds were formerly restricted to the breeding season. For a long time the National Red List Committee discussed bringing year-round habitat usage into greater focus. This was because the breeding season is only one of several seasonal aspects and thereby comprises only a part of species-specific threats. Furthermore, many bird species do not occur, or only occur in small numbers, in Germany during the breeding season, whereas during the moult, on migration, or in winter they can play an extremely important role in the community of species. The aim was to develop a structured Red List on the basis of objective criteria, similar to that for breeding birds that would also apply to transitory or wintering species. This Red List would have to be capable of withstanding the critical technical arguments raised by scientists and nature conservation authorities, as well as be receptive to new insights and amendments.

The difficulty experienced in the compilation of a technically robust Red List of migratory birds can be demonstrated by the somewhat trivial question as to what is actually a migratory bird. As all European birds are capable of flight, it is obvious that at different times of their lifespan they travel in one direction or another. Which of these changes of location is however, relevant in terms of a Red List?

In the first instance, the question of the units of analysis needed to

Both the status and the threat level in the new Red List of Migratory Birds are marked with a superscript W to enable a differentiation to the breeding birds list. Under regular migratory bird species for instance (status I^W) the Lesser White-fronted Goose is listed as Category 1^W (threatened with extinction), The Red-crested Pochard in R^W (geographically restricted) and the Northern Lapwing in the Watch List V^W.

be clarified. It became clear in this respect that in addition to those bird species where breeding birds and new arrivals could not be told apart, species exist where different sub-species or indeed bio-geographical populations could, and in terms of the respective endangerment, should be treated separately. From the slightly changed German bird species list of 2005 the Committee obtained a total of 511 species for status assessment.

In the new Red List of Migratory Birds however, only the 279 species that regularly migrate and with *appreciable* migration to, through, or out of Germany were examined more closely (within these species a further differentiation was made of a series of sub-species and bio-geographical populations). In other words all bird species that do not migrate internationally, or are migratory but occur irregularly, as well as non-indigenous bird species (*neozoa*) were not taken into account.

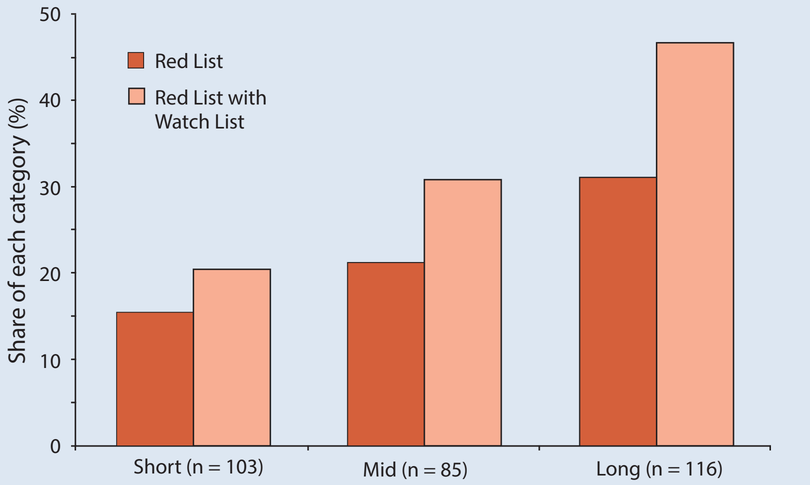
» The threats

For assessment of the level of threat based on the established classification scheme of the breeding bird list, population size, long-term (50-150 years) and short-term (1980-2005) population trends, and risk factors, were taken into account. In contrast to breeding birds, the available data is much sparser and differs greatly in quality. As can be expected, the best available figures are for species that are well recorded by monitoring programmes (Crane, waterfowl etc.). An in-house expert opinion on long-term trends was compiled on the basis of comprehensive research of the relevant literature. It was necessary to employ a multi-stage expert survey (Delphi method) for the identification of short-term trends and for the population size of species. The work with this Red List made it clear once more how essential it is to improve our knowledge about bird life outside the breeding season and to place more emphasis on comprehensive national bird monitoring programmes during migration and in winter.

Of the 305 regular migratory bird species, sub-species, and bio-geographical populations in Germany, 66% are currently classified as of Least Concern and 10% are on the Watch List. Of the 71 (23%) species that were included in the actual Red List, 16 are threatened with extinction ("1" = CR), 26 are Endangered ("2" = EN) and 24 Vulnerable ("3" = VU). Five units are in the category "Extremely Rare" ("R") because their main aggregations are geographically very restricted (e.g. Red-crested Pochard).

It is further evident that, similar to the Red List of breeding birds, long-distance migrants among the migratory bird species are currently threatened to a far greater extent than medium- and short-distance migrants, as are migratory species of the open countryside compared to those of the water bodies and marshlands, urban areas or woodland.

The new Red List of Migratory Bird Species extends our knowledge on the threat to our bird species. Migratory birds are currently particularly exposed to a variety of additional threats outside the breeding season. Red Lists should be more than a list of extinctions. Ideally they should lead to increased conservation concern with the object of



Percentage of endangered species, sub-species, and bio-geographical populations in relation to migration strategy. Left column: Percentage of the 103 short-distance migrants listed in the Red List (red column) or in the Red List with Watch List (blue column); centre column: respective percentage of the 85 medium-distance migrants; right column: respective percentage of the 116 long-distance migrants. A former irruptive species, the Little Bustard, is not included in the diagram.

The National Red List of Birds Committee

The *National Red List of Birds Committee* is an independent organisation instituted by the German Bird Conservation Council to prepare the German Red List of birds. It consists of one representative nominated by each of the following organisations: The German Ornithologists' Society (DO-G), the German Bird Conservation Council (DRV), the Working Group of German Ornithological Institutes, the Federation of German Avifaunists (DDA), the National Agency for Nature Conservation (BfN) and the Association of Federal Bird Conservation Agencies (LAG VSW). The Federation of German Avifaunists, as coordinating agency for the national bird monitoring schemes, is responsible for the compilation of the database. The determination of the risk factors and the assessment of threats is the responsibility of the Red List Committee. The preparation of the Red List of Migratory Birds was undertaken by Hans-Günther Bauer (DRV), Heiko Haupt (BfN), Ommo Hüppop (Working Group of German Ornithological Institutes), Torsten Ryslavy (LAG VSW), Peter Südbeck (DO-G) and Johannes Wahl (DDA).

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enhancing the chances for threatened species. They should lead to substantially improved human interaction with and management of natural resources, both more sustainably and more compatible with nature than they are at present. And the necessary measures should not stop at regional or national borders. Politicians and society must initiate the long known and necessary steps towards an improvement of the situation, which are hopefully feasible without vast expenditure.

Strict protection of nature reserves is not adequate in itself for many migratory species – a much broader approach is required. The Red List of Migratory Bird Species may contribute to paving the way for better environmental and nature conservation policies. In view of the imminent developments in climate change, agriculture, and forestry; destruction of and massive use of chemicals in the countryside; as well as the continuing high bird mortality due to hunting, trapping, collision (glass surfaces, rail and road traffic, and technology), predation (cats, Mink etc.), and many more threat factors; an improvement in the situation is only possible if greater political efforts are made than has been the case to date.

Hans-Günther Bauer
(for the National Red List of Birds Committee)

Related literature:

Hüppop O, Bauer H-G, Haupt H, Ryslavy T, Südbeck P, Wahl J 2013: Rote Liste wandernder Vogelarten Deutschlands, 1. Fassung, 31. Dezember 2012. Ber. Vogelschutz 49/50: 23-83.

Schmitz M 2011: Langfristige Bestandstrends wandernder Vogelarten in Deutschland. Vogelwelt 132: 167–196.

Dr Hans-Günther Bauer is a biologist and works as a scientific researcher at the Max Planck Institute for Ornithology, Vogelwarte Radolfzell. He is a member of the board of the European Bird Census Council (EBCC) and coordinates the *National Red List of Birds Committee*.
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The Red-crested Pochard is classified in the Category R^W because of the concentration of the moult population in very few areas ("geographically restricted").
Photo: F. Derer.

NEW!

Contents

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Ring recoveries of German breeding and visiting birds

Bird ringing is still one of the most important methods of bird migration research. In Germany, birds have been ringed for over a hundred years. More than 20 million birds have yielded over a million recoveries, however until now, there has not been a combined account of those recoveries.
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Migratory bird conservation through international conventions

For many years nature and bird conservationists have encountered difficulties in preserving bird species, even when they spend the whole year in a particular area, or at least within a single country. Often, it is a considerably greater challenge to protect birds that, as migratory species, spend their time in different countries, or even continents, over the course of a year. It is therefore no surprise that migratory bird species show sharper population declines in comparison to resident bird species. For these species, our attention must be directed at areas much larger in geographical scale, and this is where international conventions can help.

Necessary conservation measures for the Aquatic Warbler are summarised in an international agreement under the CMS (Bonn Convention) umbrella. Foto: Z. Morkvenas.

In order to counter the decline of bird populations in Germany and improve the status of endangered species, numerous important bird conservation projects, which include the support of migratory birds, have been initiated using funds from the EU (for instance from the LIFE programme), the federal states, and other public funds from foundations and associations. Nevertheless, many long-distance migrants in particular are still in an unfavourable conservation status (see pp. 54–57). The most likely population-limiting factors operating outside the breeding areas are habitat loss in the stopover and wintering areas and ongoing and widespread human persecution. The species primarily affected are those listed as 'huntable' in Annex II of the EU Bird Directive and which are still hunted in many EU member states despite their unfavourable conservation status throughout Europe. For instance, some 2.5 million Skylarks are still trapped each year in France, Italy, and Malta, although the population of this species in Germany has declined by some 40% over the past 20 years. The 2013 German bird of the year - the Common Snipe - can still be hunted in France, Italy, Spain, Ireland, Denmark, the United Kingdom, and other EU countries despite the population declines recorded in Germany and other EU countries. The annual hunting bags for Common Snipe in the EU total more than half a million birds a year, equal to many times the German breeding population of some 5,500 to 8,500 pairs. Similarly appalling figures apply to Golden Plover (c. 57,000 birds shot annually), Northern Lapwing (c. 500,000), Eurasian Curlew (44,000), Turtle Dove (2.3 million), and Garganey (123,000), as well as many other species. German conservationists are attempting to change this intolerable situation under the umbrella of the German Bird Conservation Council (DRV, www.drv-web.de).

» Convention on Migratory Species (Bonn Convention)

Within the EU, the Birds Directive provides bird conservation with a definite, general, legal, and thereby enforceable foundation. Outside the EU however, migratory birds receive very little protection, except in a few countries such as Switzerland. On migration and in the wintering areas, illegal persecution of birds is often the result of inadequate laws and frequently the relatively poor implementation of national legislation. It is for this reason that international conventions on international nature and environmental conservation are so important.

The first international agreement was the *Convention on Wetlands of International Importance especially as Waterfowl Habitat*, signed in the Iranian city of Ramsar in 1971 and subsequently known as the *Ramsar Convention*.

The most important international treaty for migratory birds is the *Convention on the Conservation of Migratory Species of Wild Animals (CMS)*. This agreement was concluded on 23 June 1979 in Bonn and is therefore also known as the *Bonn Convention*. The Convention's secretariat has its offices in Bonn and is financed by the United Nations Environmental Programme, UNEP. By signing the *Bonn Convention*, 114 member states have committed themselves to the joint and targeted conservation of particularly endangered species. The *Bonn Convention* also creates a framework for other agreements, more specialised in content, from the legally binding *African–Eurasian Migratory Waterbird Agreement (AEWA)* to the *African-Eurasian Memorandum of Understanding on Birds of Prey*, signed by Germany in November 2011. There are also simpler, non-binding *Memoranda of Understanding (MoUs)* for individual species such as the Siberian Crane and the Aquatic Warbler. Some countries have decided not to be a signatory to the *Bonn Convention* for political reasons. Such countries can however, be signatories to affiliated agreements such as the *AEWA* or *Memoranda of Understanding* for the conservation of individual species. BirdLife International and its national partner organisations such as the Naturschutzbund Deutschland (NABU) or the British Royal Society for the Protection of Birds (RSPB) play an important role in the preparation and implementation of these agreements.

» Landbirds Action Plan

Until recently, a large gap existed in the protection of birds through international conventions in respect of landbirds that breed in Europe and winter in Africa. However, in November 2011 a landmark resolution was agreed by the CMS Conference of the Parties (COP) in Bergen, Norway, that should lead to significant improvements in the conservation status of African-Eurasian migratory landbirds. It delivered a mandate for the establishment of a CMS Working Group to develop a flyway action plan for these species for adoption at the next CMS COP in November 2014. This has laid the foundation for more attention to be paid to such species as the Cuckoo, Red-backed Shrike, Common Redstart, Whitethroat, Sedge Warbler, and the Barn Swallow. The Contracting Parties are currently working on the preparation of this action plan. On the German side, the Institute of Avian Research in Wilhelmshaven plays a central role.

Despite the necessity for greater consideration of conservation measures at stopover sites and winter quarters outside Germany and the EU, it should not be forgotten that habitat degradation or destruction in the breeding areas is still the main reason for the decline in many migratory bird species. Additionally, in individual cases it can indeed be possible to compensate for losses on migration or in winter quarters by increasing productivity in the breeding season. It is not therefore, a question of guaranteeing the conservation of our migratory birds in the breeding area *or* stopover and wintering sites, but rather *both* in the breeding areas *and* in stopover and wintering sites. International conventions are an important means for achieving this.

Norbert Schäffer

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Memorandum of Understanding Concerning Conservation Measures for the Siberian Crane (Siberian Crane MoU): www.cms.int/species/siberian_crane/sib_bkrd.htm

Stopover ecology:

What do migratory birds do when they rest en route?

During the migration season we delight in a large number of bird species that, during their wandering, make a stopover in our local area. Although we are used to the regular coming and going of our migrant birds, we know relatively little about why they stopover in a particular area, how long they stay, or why they fly onwards in a particular direction. As migrant birds spend more actual time on stopover than in flight, and the experience at a stopover site influences the choice of the next stage of migration, research into the stopover ecology of a species is important in order to understand their migration strategy.

It was supposed to be one of those days on Helgoland that one never forgets. The weather forecast was ideal. After several days of continuing wide-scale weather conditions of a south-westerly storm combined with heavy rain, the greatly slackening wind was forecast to swing sharply to the south-east with an end to the rainfall. In addition, light drizzle was predicted around Helgoland during the second half of the night. Migration conditions on the mainland would therefore dramatically improve with the weakening winds and cessation of rainfall, so that most of the migrating birds could leave their stopover areas on the mainland in the course of the night. If they took the route across the German Bight, the drizzle beginning during the night would force them to make a stopover on Helgoland. The early morning quiet would be broken by the calls of the Meadow and Tree Pipits and Yellow Wagtails on passage. It looked as though the weather and bird migration forecast would be fulfilled. In the course of the morning the complete extent of this singular event became clear. During the night and the morning, a mass arrival of songbirds took place on Helgoland. The island was blanketed, in the true sense of the word, with trans-Sahara migrants. Hundreds of Common Redstarts, Whinchats and Northern Wheatears turned the open areas on the island into a jumble of red, orange, brown, and white patches of colour and twittering and fluttering birds in flight. Hundreds of Willow Warblers bustled about in the bushes and trees and filled them with life, while the call of an Ortolan Bunting on passage was a reminder that migration was still underway. What a day!

A first-year Northern Wheatear of the *leucorhoa* sub-species that breeds on Iceland, Greenland, or Eastern Canada. A small 0.8 g radio-telemetry transmitter is fitted on its back. The signal strength of the transmitter is so strong that the exact departure time and the departure flight direction for the first 15 km from Helgoland can be determined. The radio-telemetry transmitter was produced by the Swiss Ornithological Institute and the Burgdorf technical college (Switzerland). The elastic loops are fitted around the legs.

But did the onset of drizzle actually force all the birds to land here in the second half of the night? Or were there other reasons for some birds to make a stopover here? And what do they do during their time on the island and how long do they remain? What are the factors that cause one individual to leave earlier than another? The trans-Sahara migrants among the songbirds are, with few exceptions (Swallows, Yellow Wagtails and Ortolan Buntings), characteristic night migrants. When do they leave Helgoland – and in which direction? Early or late at night? These questions define the themes encompassed by

A first-year Alaskan Northern Wheatear perched on a dish filled with mealworms set on a weighing scale. Based on the individual colour-ring combination the body weight can be recorded on every visit and its development over the complete stopover period determined.

stopover ecology. They are framed by the decision taken by a migrating bird to break off a flight stage in order to land and the later decision to resume migration. The questions will, inter alia, be answered in the rest of this article, with our nocturnally migrating songbirds that winter south of the Sahara in the foreground.

» Why do migrant birds land?

The aim of the journey of migrant birds is to reach their breeding grounds or their winter quarters. The journey ends on arrival. Dependent on species, migration distance, and strategy, either a large number of stopovers or none are required. One extreme is represented by a few wader species, such as the Bar-tailed Godwit, which tops up its energy reserves close to its breeding site in order to make a non-stop flight to its winter quarters without a single stopover on the long journey. The other extreme is represented by a number of songbird species that can only master their journey of several thousand kilometres in nocturnal flights and therefore need to rest every day. There are four known reasons for a bird to end a flight stage on migration:

- **Energy reserves:** If the energy reserves for flight are almost used up, the bird ends its flight stage ('emergency landing'). During the subsequent rest phase the energy reserves are restocked.
- **Stopover sites:** If during a flight phase migratory birds reach a good and/or traditional stopover site, the flight phase is ended independent of the currently available energy reserves. For many wader species of the Palearctic-African migration system, the Wadden Sea and West Africa represent such stopover areas. These are essential in order that energy reserves for the rest of the migration route can be stored and are therefore considered to be obligatory 'intermediate goals' of their seasonal journey. Songbirds refuel with the amounts of energy for the required distance to be covered before crossing an ecological barrier (sea or desert). An example from the group of birds of prey is the Montagu's Harrier, which regularly seeks out stopover sites in Northern Morocco.
- **Migration strategy:** Nocturnal migrants land, as a rule, before sunrise. It is very probable that, with the help of visual and/or acoustic information, they seek stopover sites in the second half of the night in particular, and that they end the flight stage as soon as one is found. With favourable wind conditions, songbirds extend their flight phase into the morning hours, whereas land birds migrating over the sea have to fly on until the next stopover site is reached. On the other hand there are the daytime migrants. These are gliding flyers dependent on thermals,

A first-year Northern Wheatear at a stopover site on the Bering Straits in Alaska.

Radio-telemetry work at night on Helgoland. The radio antenna, together with a compass, is fastened to a pole so that the antenna does not need to be held all night long with outstretched arm; but also so that it can be held over the cliff edge to better locate the sleeping Northern Wheatears.

as well as birds of prey that use flapping flight, and also many short-distance migrants and swallows. Swifts are an exception as they rest in flight.

- Weather: Departure from a stopover site usually takes place in favourable weather conditions (no rain, weak winds). If the conditions deteriorate as a result of approaching rain or storm the flight stage is broken off and birds land.

» The importance of the stopover for migratory birds

The behaviour of a migratory bird at a stopover site is influenced by the decision as to why the previous flight stage was ended. If this is because of unfavourable weather conditions, or the end of the night or day, many of these birds can continue their journey when better migration conditions set in, as they were not forced to end their flight phase due to energy shortage. If they find good feeding conditions however, it is possible that they will make a longer stopover in order to make best use of the good food supply. Birds that have broken off the flight phase as a result of energy shortage, or the arrival at an important stopover site, will then rest as long as is necessary to refuel the energy reserves for the onward journey.

As restocking with energy during stopover is slower than energy consumption during flight, migratory birds spend more time on their long journeys on the ground than in the air. According to theoretical calculations, migrant birds spend seven times more time on the ground than in flight. This was confirmed in the field by Alaskan Northern Wheatears wintering in East Africa tracked by light-level geolocators. In autumn, the ratio of flight time to time on the ground was 1:6. As spring migration of the Alaskan Northern Wheatear is markedly faster than autumn migration (by a factor of 1.4), the temporal ratio (flight:ground) was only 1:3. Although the energy costs per unit of time are higher for flight than for rest, the long periods on the ground have the consequence that the energy ratio between flight and rest is around 1:2. These figures should not however, be interpreted to show that stopovers are a loss-making factor for migratory birds in terms of energy. The significance of stopover for migratory birds lies in the storing of energy reserves that are consumed during later flight. This can only occur when more energy than required is stored during stopover.

How quickly and how much energy a migratory bird is able to store during stopover is dependent on food supply and its availability. Greater intra- and interspecific competition pressure can have the consequence that some individuals can feed adequately, while others are prevented access to the common food resource. Additionally, the presence of predators influences feeding behaviour. The higher the predator pressure the less nourishment is consumed. Overriding these factors is the weather that has, for insectivores in particular, an influence on the fuel deposition rate of migrant birds, as low temperatures and rainfall limit the availability of insects.

» The decision to leave the stopover site

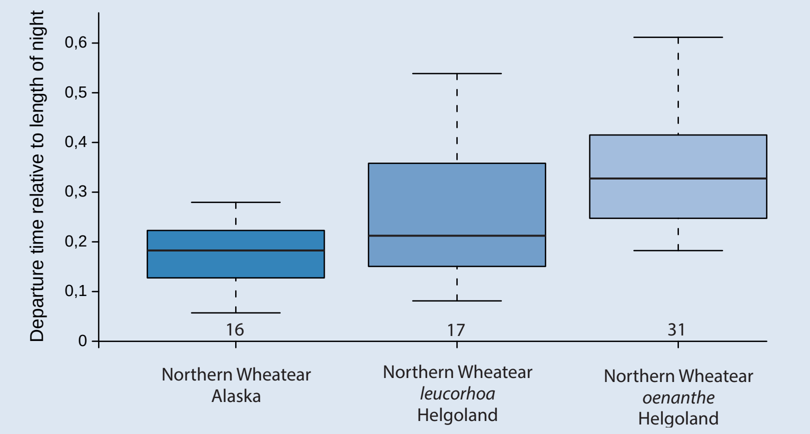
The decision to leave a stopover site is closely related to the reason why a bird ended its previous flight stage and the conditions experienced by the bird during stopover. Migratory birds that did not need to replenish energy reserves will continue migration at the next opportunity, whereby bad weather conditions will delay departure. The decision to depart the stopover site for birds that ended the previous flight stage to rest, i.e. to refuel with energy, appears to be influenced by the amount of energy stored combined with favourable wind conditions. This is particularly marked in birds that do not require crossing an ecological barrier. The 'Scandinavian' Northern Wheatears (Oenanthe oenanthe) depart Helgoland in spring with less fuel reserves and in less favourable weather conditions than the leucorhoa subspecies, which has to fly the 1,400 to 4,000 km across the North Sea and North Atlantic to reach their breeding grounds on Iceland, Greenland, or in Eastern Canada. Individuals at a stopover site that are subservient or inferior to conspecifics and other competitors, or can scarcely feed because of unfavourable food availability, will leave the site and seek better stopover conditions in close proximity. These birds will often backtrack on their migration route (reverse migration). Based on previous experience, they will most probably find a more favourable stopover site than if they continued their flight in the direction of their migratory goal. More reasons explaining the departure decisions of migratory birds from a stopover site are discussed in an earlier FALKE article in German (FALKE 57: 144-149).

» Decision to depart during the night

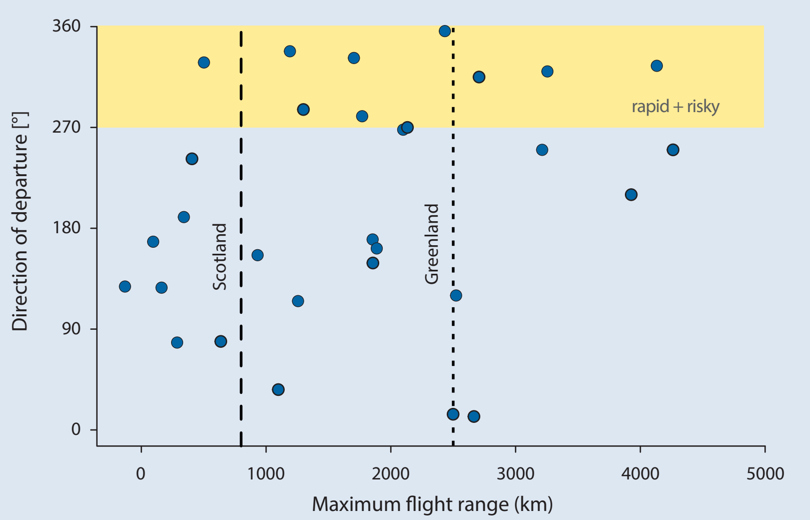
The conditions affecting the departure decision by a bird on a particular day are well known. In the case of nocturnal migrants however, the question arises as to what time during the night migration resumes. Before departure migratory birds calibrate their compass systems. The necessary atmospheric calibration tool (polarisation pattern) can best be seen during twilight. It is therefore predicted that nocturnal migrants depart shortly after twilight. This is consistent with the result of radar research, which describes an exodus one to two hours after sunset. Radio-telemetry studies of Reed Warblers demonstrate however, that the departure time at night varies considerably, although the responsible explanatory factors remain unknown.

During spring migration, Northern Wheatears of both sub-species (*oenanthe* and *leucorhoa*) departed from Helgoland a considerable time after the end of civil twilight - the latest departure was 5.5 hours after sunset - whereby the *leucorhoa* Northern Wheatears began their onward journey earlier than the *oenanthe* Northern Wheatears. Interestingly, Northern Wheatears left a stopover site on the Bering Straits in Alaska in autumn comparatively earlier than their relatives on Helgoland in spring. As migration to the breeding grounds is faster than that to winter quarters, it could be expected that migratory birds in spring are under greater pressure than those in autumn, and therefore depart earlier at night. The Alaskan Northern Wheatears must however, master a much longer migration route (c. 14,500 km) than the *oenanthe* (4,000 - 6,000 km) and *leucorhoa* Northern Wheatears (6,000 - 8,000 km) that pass through Helgoland. The potential flight duration of nocturnal migrants is determined by the length of the night. An earlier start at night therefore maximises the potential flight duration and distance. For Alaskan Northern Wheatears therefore, an early start at night in autumn appears necessary in order to cover an average of 330 km per night. The departure time at night is probably controlled endogenously and differs between the different Northern Wheatear populations according to flight distance.

In addition, energy reserves influence the nightly departure time. The more energy reserves a Northern Wheatear possesses, the earlier its departure at night. It is believed that high-energy reserves equate to a high motivation to migrate. A nocturnal migrant optimises its flight stage through earlier departure at night. Lean birds leaving a stopover site have less motivation to migrate and will only fly a relatively short distance because of the lacking



Departure times relative to length of night for the Northern Wheatear during autumn migration in Alaska and during spring migration on Helgoland, shown separately for *leucorhoa* and *oenanthe* Wheatears. The departure times are shown in boxplot form. The median is shown as a bold line, the box around the median contains 50% of the respective data, and the 'antennae' show the minimum and maximum values. The number under the boxes denotes the sample size. The *oenanthe* Northern Wheatears migrate significantly later at night than the other two groups.



The direction of departure across the maximum flight range of *leucorhoa* Northern Wheatears when leaving Helgoland in spring. The direction of departure is established by radio-telemetry. The maximum flight range is estimated taking account of the amount of energy on departure and the prevailing wind conditions. The grey area comprises the directions in which *leucorhoa* Northern Wheatears flew a long (risky) stretch across the sea, but reached their breeding grounds relatively rapidly.

Diagram following Schmaljohann & Naef-Daenzer (2011).

A female northern wheatear is carrying a light-level geolocator on its back. The light sensor sticks out of the feathers just a few millimeters.

An Alaskan northern wheatear is calling. A unique combination of color-rings is used to identify individual birds.

energy reserves. For these birds, the nightly departure time plays no significant role, as with a later start at night they will still be able to reach their next goal, namely a stopover site in close proximity. The conclusion from these considerations is that nocturnal migrants with the potential to fly long distances will depart early at night whereas those without such potential will leave at some time during the night.

» Direction of departure

Not only the nightly departure time, but also the direction of departure is influenced by the bird's body condition and prevailing wind conditions. This is made clear by the example of the *leucorhoa* Northern Wheatears on passage through Helgoland. Arriving from their African winter quarters they alter their migration direction at some stage from north to north-west or even west. The most direct and therefore quickest route to the breeding grounds from Helgoland is in a north-westerly direction. That would take them some 1,700 to 4,000 km across the North Sea and North Atlantic if they did not make a stopover in Scotland. Songbirds are capable of such flight performances, but would require adequately large energy reserves. Because of the unpredictable weather conditions and the lack of stopover sites en route, this option is risky. A more time-consuming but safer alternative, if the energy reserves for a trans-oceanic flight are inadequate, would be to circumvent the ecological barrier. Which route do the *leucorhoa* Northern Wheatears select when leaving Helgoland after a stopover? Birds with larger energy reserves flew increasingly in a north-westerly direction, whereas 'weaker' birds, and those faced with unfavourable wind conditions for crossing the North Sea left the island in a southerly and easterly direction. This indicates that the birds without large energy reserves and wind support circumvent the ecological barrier in order to refuel somewhere else. If they find a suitable stopover site to refuel their energy reserves, they then attempt the 'leap' from there across the Atlantic. The maximum flight range derived from energy reserves and wind conditions, together with a nightly departure time, is of central significance for the interpretation of the departure direction from a stopover site. From this we can conclude whether or not a bird continues migration with a long flight stage, or 'only' leaves the stopover site in order to seek a better feeding place. Only when we are in possession of these facts will we be able to properly interpret the behaviour of a migratory bird at a stopover site.

Heiko Schmaljohann

Two Northern Wheatears and a Bluethroat at a mealworm feeder in Alaska.

Photos: H. Schmaljohann.

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Migratory birds in Africa

Migratory birds spend only a few months of the year in their Palaearctic breeding grounds and begin the long journey to Africa in autumn, to stay there during the northern winter. Common Swifts for instance spend only three and a half months in our towns and cities but up to six months in their Central African winter quarters. Pied Flycatchers occupy territories in West Africa for half of the year. The ecology and population dynamics of migratory birds can therefore be understood only when the living conditions in Africa are known.

Studies on the wintering of European migratory birds in Africa are still few and far between. Research focused previously on the location of wintering areas and the ecological niche occupied by migratory birds in the African avifauna and habitats; today attention is focused on the individual consequences of migratory behaviour. This article will attempt to summarise the available information on the wintering ecology of European long-distance migrants in Africa, identify the gaps in our knowledge, and discuss which perspectives can be gained through the use of new methods. The discussion will be limited to sub-Saharan regions and will concentrate primarily on songbirds.

» Precipitation determines the environmental conditions

In tropical Africa, significant seasonal climatic differences are expressed not through fluctuations in temperature but rather through the change between the dry and rainy seasons. Their timing is caused by the north-south movement of the inter-tropical convergence zone (ITCZ) between approximately 20°N and 20°S. During the European summer the ITCZ wanders from the Equator northwards as far as the southern fringe of the Sahara and reaches its northernmost point in July. Subsequently, it moves back southwards, crosses the Equator and reaches its southernmost point in January. As the ITCZ is accompanied by precipitation, this falls primarily north of the Equator during the European summer and in Southern Africa during our winter months. The rainy season begins later, lasts for a shorter time, and there is less precipitation the farther it is away from the Equator.

These conditions have an enormous significance for the wintering ecology of European migratory birds. In autumn, after crossing the Sahara, they reach savannahs, which have just experienced the peak of the rainy season. The development of the vegetation and the amount of insect diet available has reached its maximum. These conditions soon alter with the rapid progression of the dry season. In contrast, dry habitats await those birds arriving during European autumn, south of the Equator. The rainy season begins in October and food availability therefore reaches its maximum in the middle of the European winter.

» Non-stop or stopover?

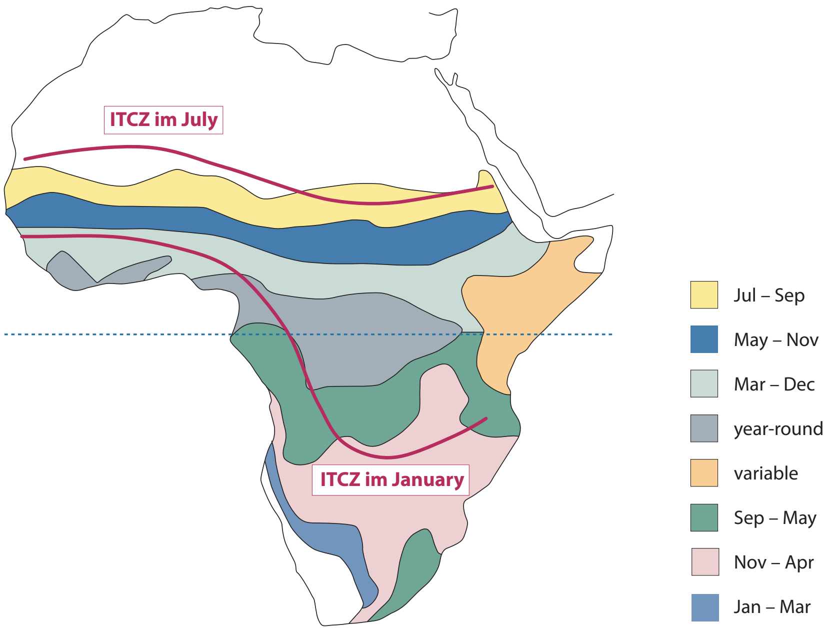
Many migratory bird species undertake extensive wanderings between different regions of Africa during the European winter – a behaviour

Bonelli's Warbler, here foraging in an acacia, belongs to the species that winter in the Sahel zone immediately south of the Sahara.

described by Reg Moreau as 'itinerancy'. In West Africa, a large number of arriving birds remain at first in the Sahel zone immediately south of the Sahara. Whereas Common Redstart, Chiffchaff, Bonelli's Warbler and Common Whitethroat spend their entire stay in Africa here; Nightingale, Great Reed Warbler, Garden Warbler or Willow Warbler follow the precipitation southwards. Most migratory birds remain however, north of the Equator.

Birds that migrate via the Nile Valley or the Arabian Peninsula to East Africa pursue a different strategy. As soon as they have reached the northern savannahs they spend two or three months there to exploit the abundant food supply available after the rainy season and often to moult as well. In November and December they begin again to build up fat reserves for a long journey. In a second stage of their migration they fly on to Southern Africa where the rainy season is just beginning, creating favourable conditions for wintering. As a study using geolocators has demonstrated, the Thrush Nightingale additionally makes a second stopover of several weeks in Kenya on its way from Northern to Southern Africa.

After wintering, spring migration takes place directly and relatively rapidly. While the autumn migration can last up to four months, spring migration lasts only some six to eight weeks. The Pied Flycatcher, which follows the longer coastal route to West Africa in autumn, flies back in spring using the direct route across the Sahara and the Mediterranean to Europe. In Eastern Africa, a generally further eastern migration route is assumed for spring than for autumn. For the Red-backed Shrike this was recently confirmed through the use of geolocators. For storks and birds of prey, satellite telemetry resulted in a different picture. White and Black Storks demonstrated no such seasonal loop migration. On the other hand, Swedish Ospreys and Marsh Harriers that winter in West Africa, cross the Sahara in spring on a more westerly route than in autumn.



The location of the Inner Tropical Convergence Zone (ITCZ) determines the rainy season in Africa (According to Jones 1995; with friendly approval of the author).

» A sedentary or nomadic life in winter?

Some migratory bird species spend the entire time in Africa in a relatively small area. In the Northern Ivory Coast, Pied Flycatchers arrive in September and occupy territories. These are defended against conspecifics in battles lasting at times for hours. A colour-ringed Pied Flycatcher that remained in a territory just one hectare in size for at least 188 days holds the record stay. The Marsh Warbler, Whinchat, Red-backed Shrike, or Whitethroat also winter in relatively small territories. Migrating Northern and Isabelline Wheatears defend their territories in East Africa not only against conspe-

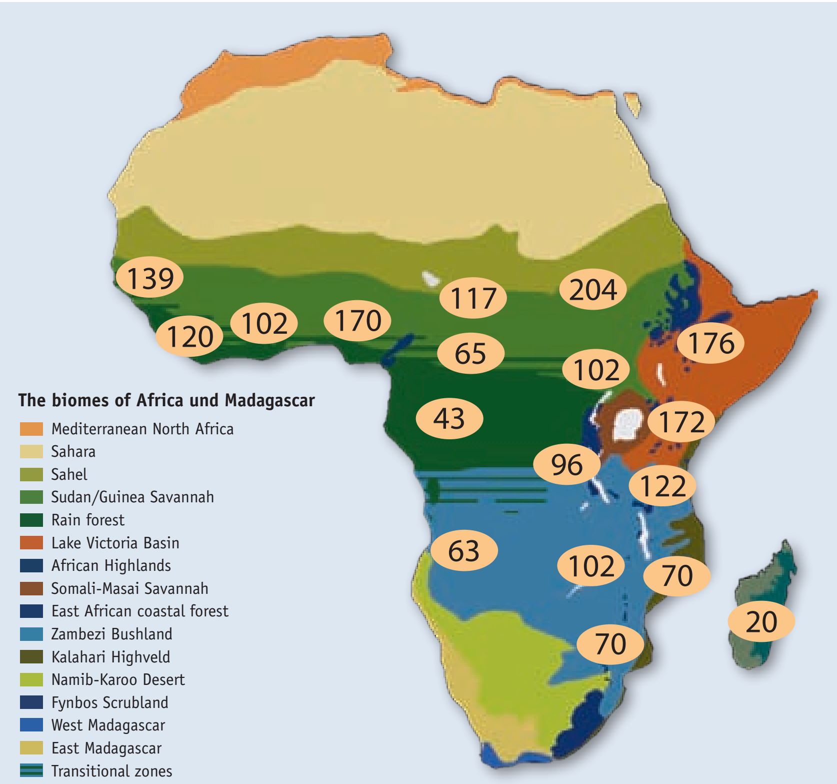
The highest density of Palaearctic migratory birds is to be found in the savannahs of the Sahel zone.

A Spotted Flycatcher rests in an oasis in the Sahara on migration.

cifics but also against other Wheatear species. Such interspecific territorial behaviour is however rare.

Once occupied, a territory is often sought out again in the following winters. In Nigeria, Yellow Wagtails were recorded in the same territory seven years in succession. Individual Pied Flycatchers and Red-backed Shrikes remained in the same territories for up to four consecutive winters. Territorial site fidelity by some waders and birds of prey has also been confirmed by satellite telemetry. Successful wintering in a location probably means that the conditions will also be favourable in later years. Site fidelity thus reduces the costs of searching for suitable winter quarters.

Species that do not establish a winter territory may spend the winter wandering about in flocks. The Willow Warbler mostly appears in flocks, often together with African species with a similar ecology. Aggressive behaviour is seldom seen in these flocks. The advantages of flock behaviour are obvious - many eyes see more than two. Members of a flock may be quicker to spot an approaching predator and also be able to pool their knowledge of available food.



Palaearctic migratory birds are not distributed equally across Africa. They winter primarily on the northern and south-eastern savannahs. Map after Fishpool & Evans 2001.

» A wide choice with restricted use

Africa, a continent three times the size of Europe, offers a large number of different habitats. These range from deserts in the north and south to equatorial rain forest with a series of steppe and savannah zones in between. The habitats are not, however, equally used. It is hardly surprising that migratory birds attempt to cross the Sahara in the north as rapidly as possible and avoid the southern Namib and Kalahari Deserts. This also applies, however, to the habitat that is in general the synonym for overflowing richness of life - the tropical rain forest. Wulf Gatter was able to demonstrate that the habitat, and not the geographic region, was avoided. After logging of the rain forest in West Africa, Yellow Wagtails frequented the clear-felled areas. The greatest density of Palaearctic migratory birds is found in the seasonally dry savannahs, especially those directly south of the Sahara, where they may indeed outnumber the indigenous insectivorous songbirds.

Moreau was the first to point out the astounding fact that the greatest concentration of migratory birds is to be found in the habitat that, after the deserts, seems the most unsuitable to accommodate such a large number

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of them: the Sahel. In West Africa in particular, an extension of the birds' migration route by only a few hundred kilometres would take them to the moister Guinea savannahs, which presumably offer a greater food supply. Additionally, immediately before the start of spring migration, millions of birds in the Sahel zone restock the necessary fat reserves for crossing the desert at the end of the dry season, when food is at a premium. This contradiction is called Moreau's Paradox. It is however pointed out that this paradox must be more apparent than real. One explanation is that, precisely in the dry season, some of the most widespread trees and shrubs in the Sahel zone are in full bloom. The consequent oversupply of nectar attracts insects that then serve as food for the birds. The observation that many birds regularly drink the nectar is however relatively new. The Saltbush or Toothbrush Tree, *Salvadora persica*, widespread on the southern fringe of the Sahara, is also of great importance. At the start of spring migration from Africa it bears berries that, for *Sylvia* warblers in particular, play a great role in the building up of fat reserves.

Although most migratory birds are found in the seasonal savannah, among them are a few downright specialists. One of these is the Aquatic Warbler, which winters primarily in the *Scirpus/Sporobolus* marshes of the flood plains of the Senegal and Niger rivers in West Africa. The Ortolan Bunting winters in another, only partially occurring habitat in Africa, preferring highlands above 1,000 m.

» Avifauna in Africa – competition with migrant species?

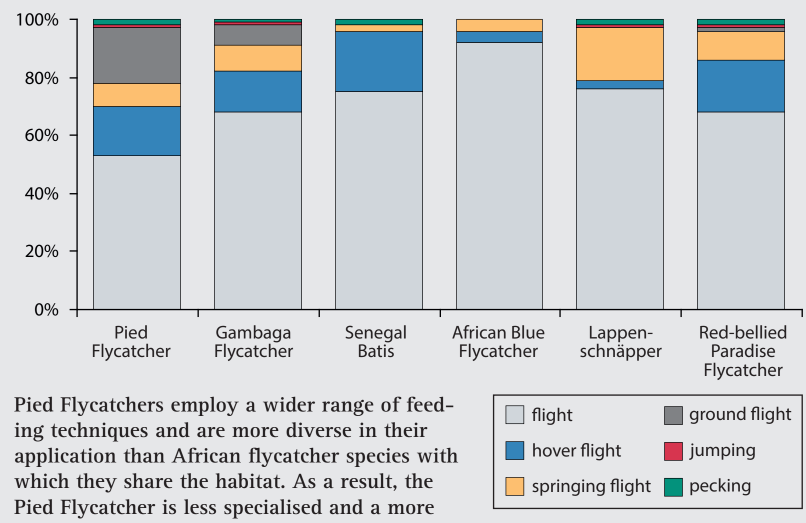
A few decades ago the predominant view held was that competition is the driving force behind the ecology of species and the dynamics of communities. For a long time the question was therefore posed as to how Palaearctic migratory birds could find sufficient resources to winter in Africa as these, according to the niche theory, were already used up by local species. Migratory birds would as a result only occur in habitats where a temporary surplus was unused by African species. Critics of this theory pointed out that African species and migratory birds often occur side by side, that aggression or interspecific territoriality rarely takes place, and that some African species breed in the dry season at the same time as the habitats are used by high numbers of migratory birds. This all pointed to the fact that birds with different migratory behaviour did not compete for resources.

Potential competition is no longer considered to be the only possible reason for the spatial distribution of migratory and indigenous birds in Africa. Newer theories mention the relationship between eco-morphological aspects and habitat selection. Long pointed wings lend the long-distance migration energy-saving advantages, but are however unsuitable for mobility in densely-grown habitats. Another theory proposes that most migratory birds are 'niche followers', i.e. they use similar habitats in Africa to those in the breeding areas. As most of them breed in open habitats they tend to also winter in open habitats.

One characteristic of migratory birds is their flexibility in choice of habitat in comparison to native African species. Willow Warblers in Zimbabwe were the only species in their guild that occurred in all three habitats that were the subject of a study, whereas two resident African species with similar ecological preferences were confined to one or two of the available habitats.

Many migratory birds, such as this Olivaceous Warbler, also sing in Africa.

It was assumed that insectivorous migratory species, in comparison to ecologically similar African species, feed on the higher shrub and tree areas that lie more on the fringe of a given habitat. Explicit studies of Pied Flycatcher, Willow Warbler and Red-backed Shrike could not however confirm this. Migratory birds are more flexible in their feeding habits. Pied Flycatcher and Willow Warbler



Pied Flycatchers employ a wider range of feeding techniques and are more diverse in their application than African flycatcher species with which they share the habitat. As a result, the Pied Flycatcher is less specialised and a more diverse diet is probably available to the species.

Sand Martins winter in large numbers in the Djoudj National Park in Senegal …

… and suffer high losses after several consecutive days of unfavourable weather with precipitation and strong winds.

demonstrate a greater variety of feeding techniques than African flycatchers and *Sylvia* species, which implies that a wider spectrum of diet is available to them. It cannot however, be concluded from these observations that migratory birds are either more or less successful than resident species or that competition determines their cohabitation. Migratory birds are considered today to be an integral part of the Afrotropical avifauna.

» Connectivity und carry-over effects

In the past few decades migratory bird research has made enormous progress in the fields of orientation, physiology, and various theoretical aspects. The initial questions posed by the bird migration researcher concerning the when and where in Africa can also be answered at the species level. At the population and individual level the issue is more significant. Here the key word in the focus of interest is 'connectivity'. Connectivity describes the degree of connection between breeding and wintering areas of individual populations. Connectivity is high when birds from a single breeding area winter in a specific region and low when breeding populations mix together in the wintering area. Knowledge of connectivity helps to explain some of the reasons for differing fluctuations in population, and there are many approaches to the study of connectivity (see pp. 20 to 25).

Though the catchword is new, pointers to the role of connectivity have existed for some time. After the drought in the West African Sahel zone at the end of the 1960s, populations of some long-distance migrants in Western Europe collapsed. Eastern populations, which do not winter in the areas most affected by the drought, were much less affected.

In future, one of the most important research goals will be the understanding of the relationship between ecological conditions in the African wintering area and individual reproductive success in the breeding area. Carry-over effects describe non-fatal, individually experienced conditions in one season that affect the survival and reproductive success in another season. Italian ornithologists have discovered that a presumed good food supply for Barn Swallows in their winter quarters leads to an earlier arrival in the breeding grounds. This in its turn increases the chance of second broods. Optimal conditions in the wintering area therefore increase the reproductive success in the following breeding period. The mechanisms for this can be different. Food supply need not be the measure of all things for a suitable wintering area. An analysis of stable isotopes has shown that Great Reed Warblers that moult in different habitats exhibit different levels of infection with bird malaria. This

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In the Sahel zone and the Southern Sahara nectar from the blossoms of the Maerua crassifolia ...

... and the berries of the Saltbush are important basic food resources for migratory birds prior to spring migration.

Photos: V. Salewski.

could prove to be a disadvantage in the next breeding season. An applied aspect of this study could lead to the identification and protection of particularly suitable wintering areas because, as in Europe, the pressure on habitats used by migratory birds in Africa is steadily increasing.

The potential consequence of climate change is a further field with which bird migration research is occupied (see pp. 58 to 61). Over the past decades great progress has been made in understanding the wintering ecology of Palaearctic songbirds in Africa but ever new challenges and questions arise that can be tackled with technical innovations. We can therefore expect further exciting results in future, but also that new questions will emerge.

Volker Salewski

Moult – different strategies for an optimal flight features

Breeding and migration are only two of the regularly occurring annual events. A third can be added - the moult. Growing new plumage requires high energy expenditure. The moult therefore overlaps very little with other energy-demanding processes such as breeding and migration.

Migratory birds have developed different strategies in order to attune the moult with the necessities of long-distance flight and times of favourable energy supply. Some, such as Pied Flycatcher and Nightingale, moult before autumn migration so that fresh wing feathers are available, but not however for spring migration. For others the time between breeding and migration is too short for a complete moult. They therefore, like the Barred Warbler, interrupt the moult to resume it again in Africa or moult completely in Africa.

A moult south of the Sahara recommends itself from an energy point of view shortly after migration. Great Reed and Melodious Warblers that winter in West Africa adopt this strategy, but then have to begin their spring and autumn migration with worn plumage. In Eastern Africa some species moult during their stopover north of the Equator before they continue their migration to Southern Africa. Only a few species such as the Barn Swallow and Red-backed Shrike moult in Southern Africa. The Willow Warbler is a special case. It moults completely before autumn migration and a second time in the winter quarters, thereby always migrating with fresh plumage. Other species like the Chiffchaff, and a few *Sylvia* warbler species, moult only the outer flight feathers – the most worn out – in the winter quarters. Despite fundamentally species-specific moult strategies, individual deviations always occur.

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Long-distance migrants live more dangerously:

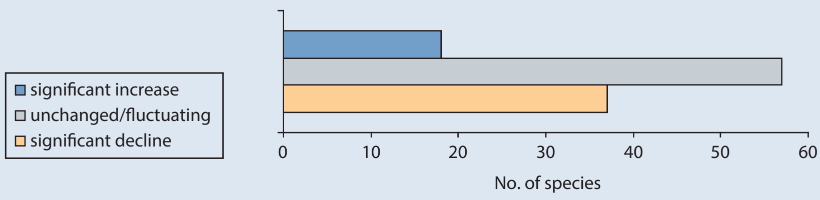
Population trends of German migratory birds

The monitoring programmes of the Federation of German Avifaunists (DDA) have provided information on the population development of common breeding bird species since at least 1991.

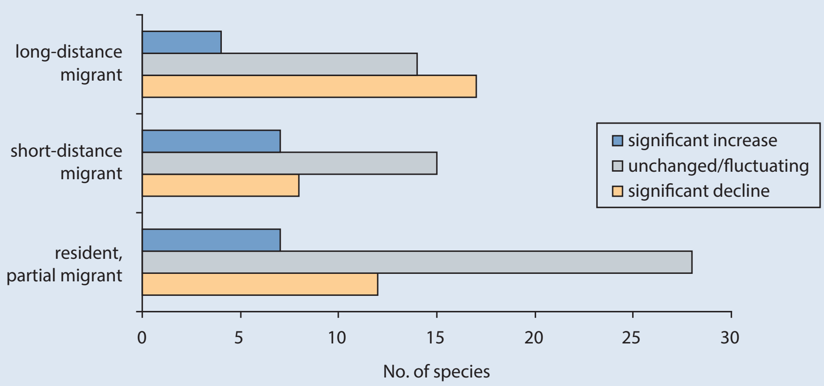
The Sedge Warbler is a trans-Saharan migrant that winters primarily in the Western Sahel. Because of higher precipitation in its wintering area its population has markedly improved over the past 20 years. Photo: R. Martin.

Whilst it was primarily the typical bird species of farmland and rural villages that declined into the mid-2000s, for several years now the majority of woodland birds have shown a negative population trend as well. Only wetland species show almost balanced trends.

Taking into account only species that clearly increased or declined (i.e. on average more than 1% annually) in the time frame 1991 - 2010, almost twice as many species have declined rather than increased in population size over this period. For almost half the species, population trends remain unchanged. Including all statistically significant trends (i.e. changes in trend of < 1% annually), the overall picture remains the same. Never, since monitoring of common breeding birds began, has the overall balance been so negative.



Number of bird species with a significant trends and average annual population change of >1% between 1991 and 2010. The populations of almost twice as many species have declined than have increased.
Source: DDA Monitoring of Common Breeding Birds (Line transect and point count methods).



Balance of increasing and declining breeding bird species in Germany in the time frame 1991 to 2010, differentiated according to migration strategies. Only those declining and increasing trends that vary by more than 1% annually are taken into account.
Source: DDA Monitoring of Common Breeding Birds (Line transect and point count methods).

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» Long-distance migrants have a problem

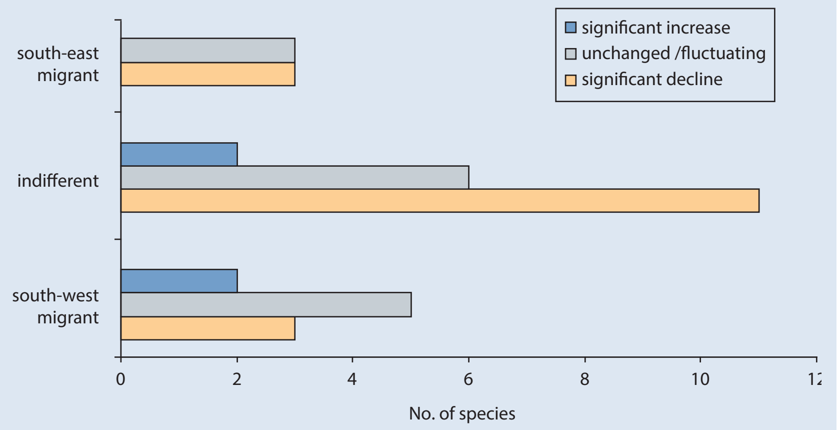
If the migration strategies of the species are studied, it is noticeable that different 'migration types' are very differently affected in terms of population increase and decline. The record of short-distance migrants, i.e. those species that migrate in winter to Western Europe or to the Mediterranean region (Chiffchaff, Blackcap, or Meadow Pipit), is more or less in balance, with seven increasing species compared with eight in decline. The populations of 15 species have not changed fundamentally. There is also practically no change in the majority (28 from 47 species) of resident or partial migrants. Nonetheless the number of declining species (12) is almost double that of species on the increase (7), resulting in an overall negative balance.

The long-distance migrants that winter south of the Sahara or in South-west Asia are however, much harder hit by population declines. The balance here reads 17 clearly declining species as opposed to only four increasing species, a ratio of 4:1 (some 40% of the species show no change > 1% per year). This again confirms what has long been indicated, that long-distance migrants are markedly more threatened than other species. The reasons for this can be very different in nature and in part due to accelerating negative feedback. These are, on the one hand, dangers on the migration route such as massive bird trapping and poaching in the Mediterranean region; on the other, adverse changes in the wintering areas through developments such as intensive farming, including more widespread use of pesticides (e.g. agents such as DDT that has long been banned in Europe), human population growth, increasing over-grazing, destruction of rain forests, and climate change. Often too little is known about which species are affected by which factors and detailed studies on this aspect are required.

However, there are indications that long-distance migrants are also more greatly endangered on their breeding grounds than resident birds because the migration strategy of long-distance migrants is dependent

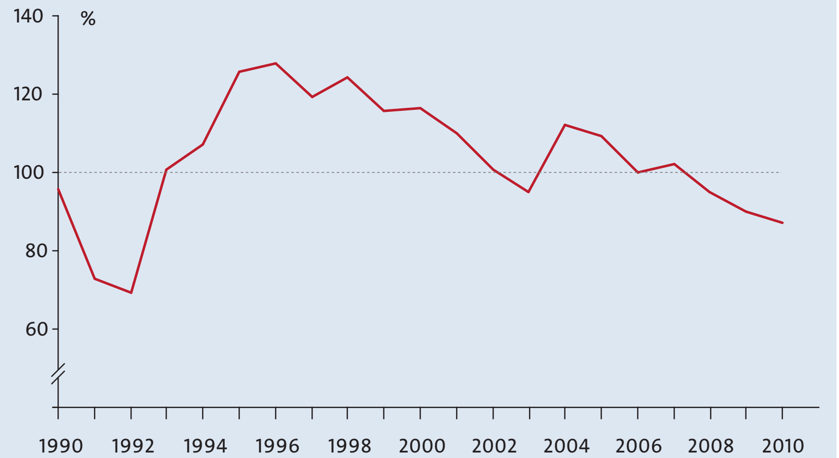
Although the Grasshopper Warbler migrates in a south-westerly direction, and winters primarily in the Western Sahel, its populations have sharply declined since the mid-1990s. Photo: R. Martin.

The Meadow Pipit is a short-distance migrant whose population has strongly and consistently declined over the past 20 years. The reasons for this lie, however, in the breeding rather than the wintering areas. Photo: T. Krüger.



Comparative population trends of long-distance migrants in the time frame 1991 to 2010, differentiated according to main direction of migration.

Source: DDA Monitoring of Common Breeding Birds (Line transect and point count methods).



Population development of the Red-backed Shrike in Germany in the time frame 1990 to 2010. A strong population increase in the mid-1990s was followed by a marked population decline. The overall trend in this period is more or less unchanged.

Source: DDA, combination of the trends from the Monitoring of Common Bird Species (1990-2010) and Common Breeding Bird Survey (2005-2010) (Line transect and point counts). Photo: M. Schäf.

on their feeding strategy. Almost all long-distance migrants are exclusively insectivorous and for this reason they leave their European breeding grounds to winter mainly in Africa. Long-distance migrants are therefore generally more likely to be severely affected by the decline in insect populations in the breeding areas due to use of insecticides and intensive farming methods, than for instance, woodland birds which partially feed on tree seeds or wood-dwelling organisms (e.g. woodpeckers, nuthatches, tree-creepers, tits). The populations of only four long-distance migrant species have markedly increased since 1991, the Common Quail, Yellow Wagtail, Sedge Warbler, and Great Reed Warbler. At least in the case of the Common Quail and both Reed Warblers, the increases represent a recovery after previous dramatic collapses in populations in the 1960s to 1980s. The Sedge Warbler was especially negatively affected by the droughts in the Western Sahel (West Africa on the southern fringe of the Sahara) in the 1960s and 1970s - as has also been recorded for the Whitethroat and many other species. Due to the relatively high precipitation in the Western Sahel after 1990 the populations have since recovered to some extent. The Great Reed Warbler suffered from the partial drying up of its main wintering area, Lake Chad, as a result of climate change and interference with the water balance. Here as well, the situation has improved somewhat since 1990.

» Birds migrating south-west appear to do somewhat better

These examples illustrate that the developments in separate regions of Africa can indeed be very different in character. The division of the trends according to the main direction of migration (mainly south-west, mainly south-east, or indifferent - which means both directions in equal parts or migration on a broad front) clearly demonstrate that, because of the more favourable precipitation conditions over the past 20 years, the south-west migrants (autumn migration over south-west Europe, wintering areas mainly in West Africa)

The Barred Warbler breeds primarily in Eastern Germany and winters in South-east Africa. Its population initially increased in the 1990s but since around 2000 is in sharp decline. Photo: R. Martin.

The Nightingale migrates in a south-westerly direction and its populations have markedly increased over the past 20 years. Photo: S. Pfützke.

are now better placed than the other species groups. Apart from the species with marked population recoveries mentioned above, Reed Warbler, Whitethroat, Common Redstart, and Nightingale all show slightly positive trends (but weaker than % annually) since 1991. In the case of Whitethroat and Common Redstart, this represents a population recovery after severe population declines prior to 1990. Nevertheless, for the (mainly) southwest migrants there are a few markedly declining species such as Common Snipe (due to breeding habitat degradation and excessive hunting in South-west Europe), Grasshopper Warbler, and Northern Wheatear.

The few pronounced south-east migrants (Red-backed Shrike, River Warbler, Sedge Warbler, Barred Warbler, Thrush Nightingale, and Red-breasted Flycatcher) show no positive trends. The populations of these six species have declined particularly sharply since the end of the 1990s. Even in the case of the Red-backed Shrike and Barred Warbler, the populations of which in these two decades have changed to the extent of no more than 1% annually, a closer study shows that these species are in sharp decline since, at the latest, 2000, following a population increase in the 1990s (see diagram for the example of the Red-backed Shrike). The reasons for this especially negative development could be, in addition to intensive bird trapping, the recent relatively widespread droughts in East and South-east Africa, in particular on the Egyptian Mediterranean coast (see FALKE 2013, issue 6). Pesticides also appear to be used more intensively in Eastern Africa than in the Sahel.

Overall, the DDA data on monitoring of breeding birds reveal that, since 1991, long-distance migrants are affected by population declines to a much greater degree than short-distance migrants and resident bird species and that the few species migrating to the south-east show particularly negative trends. The populations of some species that mainly winter in West Africa appear on the other hand, after earlier sharp declines, to have recovered over the past 20 years.

Martin Flade, Johannes Schwarz, Sven Trautmann

Dr Martin Flade coordinated the DDA Monitoring of Common Breeding Birds programme (old) in the time frame 1989 to 2010. Since 2013, he is Head of the Schorfheide-Chorin Biosphere Reserve in Brandenburg. flade@dda-web.de

Johannes Schwarz, together with Martin Flade, steered the DDA breeding birds monitoring programmes from 1989 and until 2010, was particularly responsible for the data input and analyses.

Sven Trautmann is employed by the DDA for the coordination of the Common Breeding Bird (line transect method) conducted since 2004.

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Migratory birds and climate change:

From long- to mid-distance migrant?

Birds are extremely mobile organisms. Depending on their species-specific migratory behaviour, they travel through very different climatic and vegetation zones on their journeys. Correspondingly diverse are the challenges they are faced with on their flight through changing climate and landscape in different geographical regions. Habitat changes due to climate change still have to match the temporal course of migration, breeding, and moult. This applies especially to long-distance migrants that winter south of the Sahara. They must cope with a particularly wide spectrum of habitats and climatic zones and are probably especially affected by climate change.

Climate change, especially in the form of changes in temperature and precipitation, can have an effect on very different aspects of bird migration. Particularly noticeable are changes in migration timing and influences on condition and breeding success, as well as shifts in passage and wintering areas. An increase in migration speed in Central and Western Europe is also likely, perhaps supported by the more favourable wind conditions that occur as a result of climate change.

» Changes in spring migration timings

Over the past decades, temperatures have risen most noticeably in winter and spring, and the 'phenological spring', i.e. vegetation development, starts increasingly earlier. As a result the resources for migratory birds in their stopover areas and breeding grounds are available ever earlier in the year. Together with the shift in the vegetation periods, the distribution range of wildlife and plants also shifts closer towards the pole, albeit with great species-specific and geographical differences. For Central and North European birds, a mean of roughly one kilometre annually can probably be assumed.

Early arrival secures the best territories and is particularly applicable to birds returning in spring. A bird that cannot cope with an ever earlier start of spring is at a disadvantage in both intra- and interspecific comparison because it gets only an inferior territory or mate, if any at all. It probably also arrives too late for the optimum food supply for rearing of offspring. The consequence of a delayed arrival can therefore be few or no offspring at all.

The vast majority of migratory birds apparently attempts to cope with the earlier onset of spring, as spring passage and arrival of the majority of bird species is also considerably earlier. Changes in phenology (the seasonal occurrence) can be confirmed very well by the trapping statistics on Helgoland. Most of the species trapped on Helgoland, in the trapping garden of the island station of the Institute for Avian Research, do not breed on the tiny island in the south-eastern North Sea. One is therefore not dependent on the evaluation of the first arrival, but can calculate the statistically more robust

One of the three tunnel traps in the Helgoland trapping garden used for capturing small birds on stopover. Photo: K. Hüppop.

mean annual value of all individuals within one species trapped during a migration period. Within the past 50 years the spring migration time on Helgoland of 20 out of 23 small bird species has actually shifted forwards by up to 19 days (on average by 10 days). There was no change in the case of only three species.

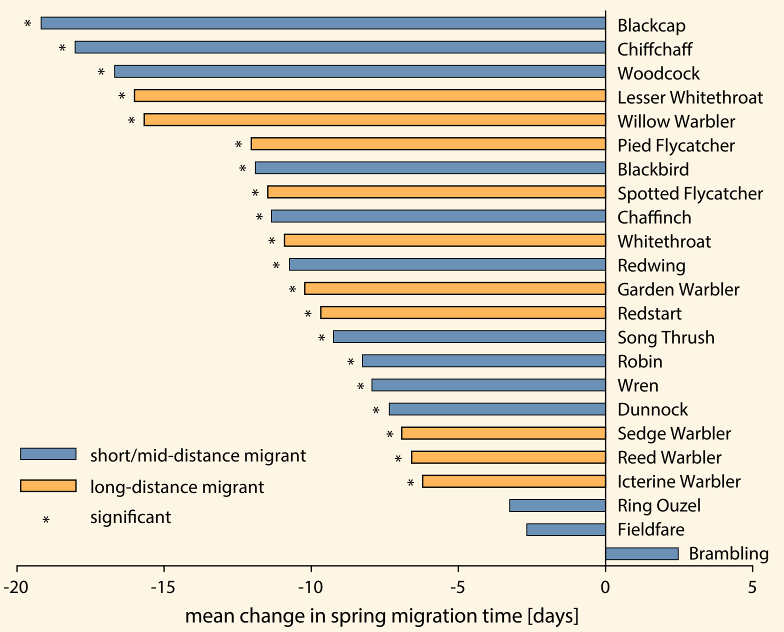
The long-term data from Helgoland represent a particularly impressive record of changes in spring migration phenology. In the meantime, countless datasets from many other locations have been analysed which confirm without doubt a clear trend towards earliness in spring for most species across wide areas of Europe; and also for many other parts of the planet, even when they are based only on statistically much less robust first arrival data.

Migratory birds can achieve earlier arrival by departing earlier from their stopover and wintering areas, by higher flight speed, or a shortening of their migration routes. It is clear that for many short- and mid-distance migrants, similar wide-scale weather systems determine the climatic conditions in both wintering and breeding areas. The birds therefore sense whether the vegetation development in a particular year begins earlier or later, and begin migration to their breeding grounds correspondingly. The situation is different for long-distance migrants. South of the Sahara they are cut off from the weather development in their breeding grounds. They have no way of knowing when spring begins in Europe. As the start of their migration is probably to a great extent genetically determined, it is often suspected that long-distant migrants will 'miss the bus', and could be consequently disadvantaged in comparison to short- and mid-distance migrants. This belief is supported by the, in part, severe collapses in the populations of trans-Saharan migrants. The available data on migration phenology is, however, contradictory. Although the vast majority of studies indicated that the very variable first records of short- and mid-distance migrants had become considerably earlier than those of long-distance migrants, the difference in mean passage dates was much less. On Helgoland we found no difference at all between the two groups. We therefore conclude that long-distance migrants are able to increase their flight speed as soon as they arrive in Southern Europe and find vegetation that is already well developed.

The Blackcap holds the record for earliness in spring migration time on Helgoland. Photo: H. Jaschhof.

» Consequences of earlier spring migration

With constant timing of autumn migration earlier migration in spring means a longer stay in the breeding grounds, and thereby additional time for more or replacement broods. As a result, the 'annual production' of young can increase, and there is evidence that this is indeed the case. On Helgoland we observed that several species showed an increase in the proportion of young birds on autumn migration. On the other hand, the number of second broods by tit species, for instance, has decreased, and the breeding period of trans-Saharan



Changes in mean spring migration times over the past 50 years for 23 species on Helgoland based on trapping figures. A few northern European Blackcaps and Chiffchaffs are long-distance migrants wintering in Africa south of the Sahara.

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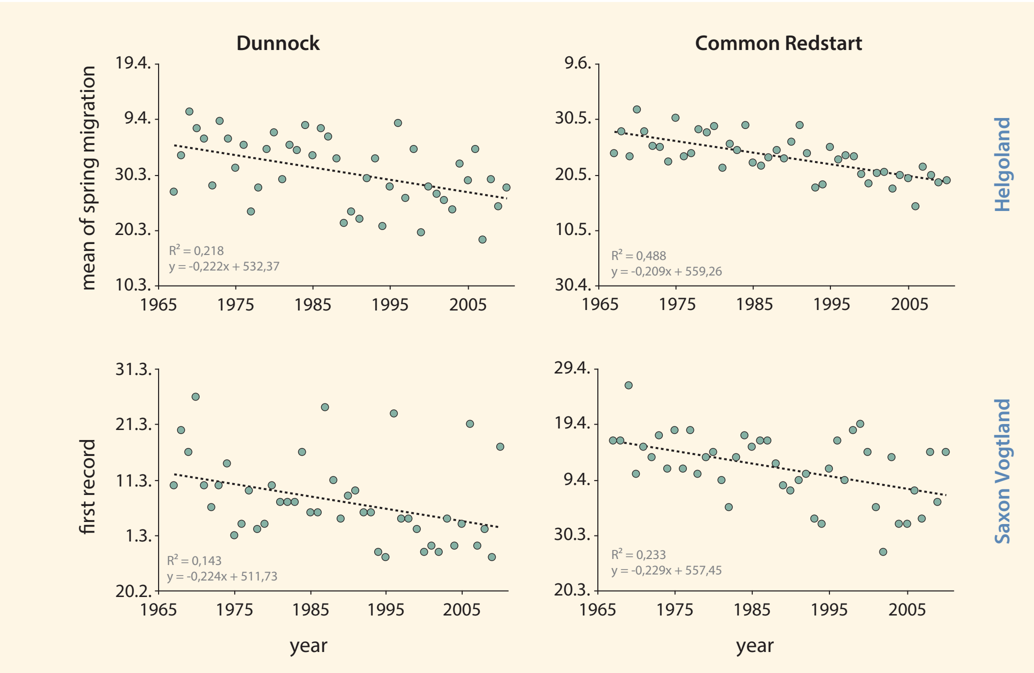

Two examples of long-term changes in spring migration times of a long-distance migrant (Common Redstart) and a mid-distance migrant (Dunnock) in Saxony (data from Stephan Ernst) and on Helgoland (own data). The datasets have been reduced to the same time frame (1967 to 2010).

migrants has not lengthened as was expected.

With Pied Flycatchers, and possibly other species, a temporal decoupling of food supply and requirement has apparently led to population declines. In terrestrial habitats plants react in their phenology more rapidly to climate change than invertebrates, and these again faster than vertebrates. Birds consequently react more sluggishly than their prey. Despite the earlier spring migration times some bird species arrive too late and miss out on the best prey supply for the rearing of their young. Nonetheless, for many species the dramatic habitat changes in the stopover and wintering areas, especially south of the Sahara, are the main reason for the decline in their populations.

» Changes in autumn migration timings

In the case of autumn migration the picture is considerably less uniform than that of spring migration. Although temperatures in summer and autumn have also risen, the rise is not as great as in winter and spring. As a result, the timing of autumn migration has hardly changed at all, and the few cases of earliness and delay on Helgoland balance each other out. The reasons for this different behaviour are unclear, although the demands of autumn migration are different to those in spring. As a rule, birds have more time during autumn migration. They can wait for good migration weather and stopover longer on migration where food is in good supply.

» Shifts in passage and wintering areas

Many short- and mid-distance migrants do not migrate these days as far as they did previously. According to figures from North America the wintering areas of more than 250 species shifted to the north by 0.5 to 1.5 kilometres annually. Ring recoveries have revealed shifts of the same order of magnitude for Europe. In addition to Black-headed Gull, Blackbird and other species that have shortened their migration routes, other typical migratory birds such as Chiffchaff, Blackcap, Song Thrush, and Dunnock, also attempt to winter in our climes. Species that winter south of the Sahara cannot shorten their migration routes step-by-step because of the ecological barrier. Instead they must undertake a big leap in order to winter north of the Sahara; that is to change from long-distance to mid-distance migrants in one fell swoop. Indeed, in more recent times Barn Swallows

Barn Swallows winter in increasing numbers in the Mediterranean region. Photo: F. Sigg.

The migration routes of European Black-headed Gulls considerably shortened as a result of climate change. Photo: S. Pfützke.

and House Martins in particular, but also individual Pied Flycatchers and Common Redstarts, already winter in the Mediterranean region.

» 'Import' and 'export' of the effects of climate change

The size of bird populations is regulated principally by the annual breeding success and the conditions in, and mortality outside, the breeding area, i.e. during migration or in stopover or wintering areas. The important regulatory factors are therefore not only the climatic conditions during the breeding season but also those in the stopover and wintering areas. There are indications that the amount of precipitation in the Mediterranean region, which influences the state of the vegetation long before the migrant birds arrive, decisively affects the supply of insects during stopover or wintering.

In the meantime it is known from several species that the precipitation conditions in the Sahel have influence over how many birds return to their European breeding grounds the following year, and whether or not they breed successfully. For many species, extreme events such as persistent drought in Africa are particularly decisive. There, in conditions thousands of kilometres distant, changed climatic circumstances are noticeable as a delayed reaction in 'our' breeding birds. The White Stork is a case in point. Thanks to decades of ringing we are well aware of the factors that play a role with this species. Its population size in Europe is essentially determined by effects both in the breeding area (temperature and precipitation) and also outside it (precipitation and primary production in the Sahel).

Climatic conditions in our latitude can also have a corresponding effect on birds that breed farther to the north. Mild winters which result in a decrease in the energetic quality of the mussels in the Wadden Sea, apparently lead to an undersupply for the Eider ducks from the Baltic region and Eastern Russia that winter there, and are possibly the reason for the observed decline in mussel-eating wintering birds in the Wadden Sea. Studies of Arctic geese lead us to expect deterioration in the food quality in the Central European stopover and wintering areas that are an indispensable precondition for successful breeding and rearing in the far north.

Ommo Hüppop, Kathrin Hüppop

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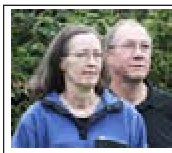

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Offshore wind energy turbines:

Possible effects of offshore wind energy turbines on bird migration

Offshore wind farms are an important building block of Germany's new energy policy. Dozens of wind farms are planned, particularly in the German Exclusive Economic Zone in the North Sea. In future expansion phases, several thousand huge rotors could be in operation within a few years. To these will come converter platforms, numerous supply and service vessels, and helicopter traffic. At night the structures are illuminated by marine navigation and aviation obstruction lights. Could these massive changes cause problems for migratory birds?

The licensing procedure for offshore wind farms sees the 'Threat to Bird Migration' as a ground for refusal. At present however, our knowledge of the effects of offshore wind turbines (WT) on bird migration is still inadequate. For this reason several research projects have and are being conducted concerning the possible effects of WT on bird migration. What have they achieved so far and what questions still remain open?

On the research platforms FINO1 and FINO3, several remote sensing methods to record bird migration are permanently in operation the whole year round. These include vertically and horizontally rotating marine radars, microphones to record the flight calls of birds on migration, and video and thermal imaging cameras. In this way, complete migration periods are covered whereby the randomly collected data from environmental impact studies can also be included.

Offshore bird migration is extremely variable. Due mainly to the constantly changing weather, the species spectrum, intensity of migration, and height and direction of flight fluctuate greatly. Causal relationships between a change in a single aspect of bird migration and the operation of an offshore wind farm are difficult to establish by classical before-and-after studies on the basis of a given number of study days. Even by day it is difficult to identify a possible barrier effect or an increase in mortality as a result of collisions with the structures.

Nonetheless, visual observers carrying out standardised migration counts by day from set locations can provide important data. In this way, it was established that for various duck, and a few other bird species, avoidance behaviour plays a major role. Video and additional radar records show the nature of species-specific avoidance behaviour. This at times differs greatly between species, but can also vary from day to day within a species. Strong winds can, for instance, force Kittiwakes (which as a rule avoid WT) to go near them. The possible effects of forced diversions can be enormous in the case of large wind farms. Extended migration routes demand additional energy expenditure, which can affect not only the bird's own survival, but also subsequent breeding success. The study of avoidance behaviour is therefore of critical importance for impact assessments and for judging the relevance of a measure. Pink-footed Geese from Spitsbergen, for example, of which

A view of the alpha ventus offshore test field from FINO 1. The microphone for the automated recording of migratory bird calls can be seen in the foreground.

almost the complete population cross the German Bight several times a year, are very sensitive to offshore WTs and take wide-ranging avoidance measures. They are only unaffected by the presence of wind farms when there is considerable free space to avoid them. Regional or spatial planning is essential. The farther out to sea the wind farms are located, the more favourable it is for migrating birds, as many species migrate close to the coast, especially by day.

» In the dark of night

A great part of bird migration takes place at night. With the use of radar we are able to make migration visible and record its intensity; allocation to species is however only possible in exceptional cases. The recording of flight calls, directly or with an automatic microphone system, can be of assistance. This method does not work at great distances, is only of use for calling species, and it is difficult to quantify the data. Nonetheless, it is at present the only method available to record the species spectrum at night and in poor visibility. It has been established that, at night, mainly songbirds such as thrushes migrate across the German Bight.

» Collisions

The species spectrum identified by flight calls is consistent with the dead birds found on research platforms. The reason for these collisions is probably the attraction of the birds to the obstruction lights. To date, four mass incidents have been registered on FINO1, with between 88 and 199 birds, whereby the number of corpses scavenged by gulls or blown off the platform by the wind cannot be accounted for. Model calculations demonstrate however, that the actual number of birds suffering collisions is likely to be a multiple of those found, depending on wind direction and strength. Although nocturnal migration over the sea generally takes place at a lower altitude than over land, in favourable migration conditions most birds fly above the WTs. In bad visibility, however, they reduce their flight height and fly deliberately towards light sources.

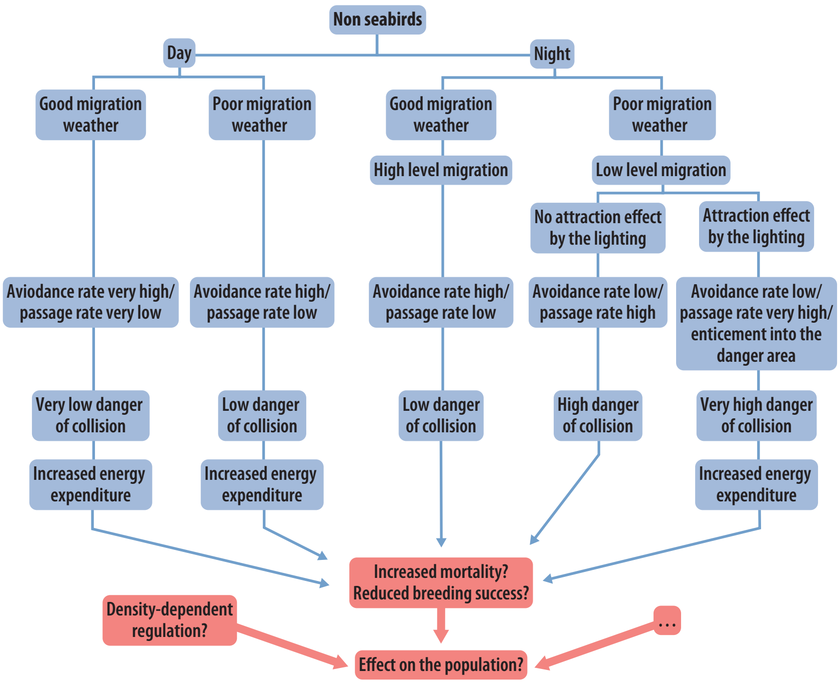

Diagram of possible effects of offshore wind farms on non-seabirds. The red boxes indicate population-relevant influences. In addition to those shown here, many other large-scale influences such as climate change or habitat loss have an effect on the population.

This can lead to a higher number of victims. Although such figures make one sit up and take notice, they have a blemish - the quantitative backdrop remains unclear. Even using the most modern research methods, it is still not possible to quantify the nocturnal migratory activity at the species level. This makes impact assessments difficult, as mortality caused by offshore structures cannot at present be put in relation to population size. Nevertheless, the numbers of collisions need to be minimised and new solutions, such as the use of flashing lights instead of permanent lighting, or need-based use of obstruction lights, are very promising. An automatic recording of the calling rate could help in this instance. If bird calls are recorded on a massive scale within the danger area of illuminated offshore structures, switching off the lights, and possibly the rotors of WTs as well, could reduce the collision potential.

Resting Kittiwakes at FINO 1.

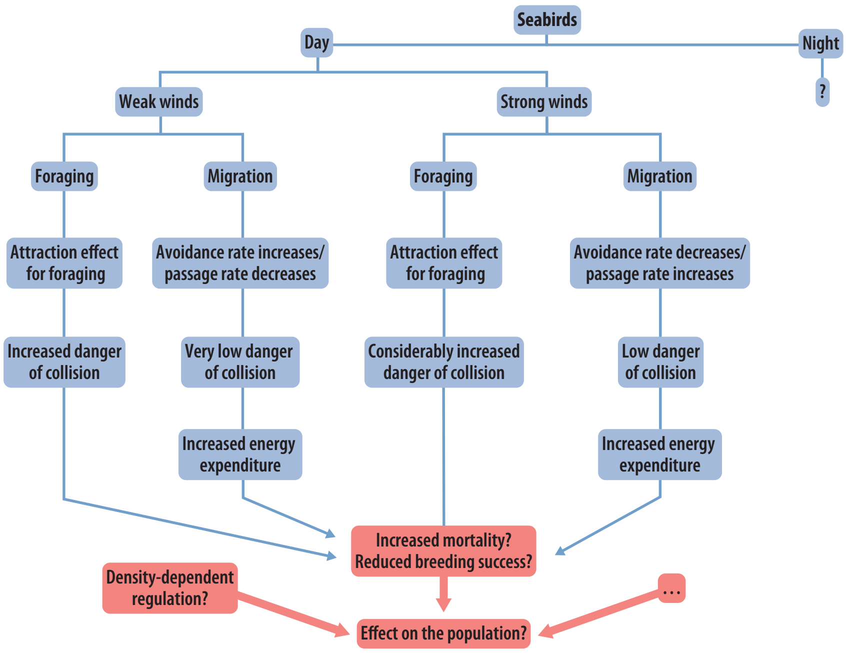

Diagram of possible effects of offshore wind farms on seabirds. The red boxes indicate population-relevant influences. In addtion to those shown here, may other large-scale influences such as climate change or habitat loss have an effect on the population.

» Where do we stand?

The possible influences of offshore wind energy facilities on bird migration are complex and there are still many gaps in scientific knowledge. An initial and sensible step would be, for species that migrate regularly over the sea, to differentiate between seabirds and non-seabirds in the widest sense. Seabirds, with their flight and swimming abilities, are better prepared to cope with the challenges of the frequently extreme weather conditions than many non-seabirds. Of the latter, many migrate by day; frequently at a low altitude, and in good weather conditions are able to make a wide detour around offshore structures. This reduces the danger of collision to a great extent but requires higher energy expenditure. If, however, the prevailing weather by day is bad for migration, with strong winds from an unfavourable direction, flights through wind farms are more frequent and the danger of collision increases.

At night on the other hand the situation is different. In good conditions most birds migrate at such high altitudes that the 200 m high structures are unlikely to present a hazard, and avoidance of, or flight through the wind farms, rarely occurs. If the birds run into bad weather, mostly associated with complete cloud cover, rain, and unfavourable winds, they fly much lower, mostly below 200 m above sea level. If the birds are additionally attracted by the illumination of the structures this leads inevitably to a very high danger of collision.

In principle, WTs affect migratory seabirds in a similar way but the specific effects are frequently different.

FINO 1 is occasionally used for rest by noctrunal migrants (here a Redwing).

Vertical rotating marine radar device on FINO 1 for recording the intensity and height of migration.


A selection of dead song birds found and collected after a night of collisions on FINO 1.
Photos: R. Hill.

Especially in strong winds, which limit their manoeuvrability, seabirds migrating at low altitude have great difficulty in avoiding the WTs. During the day, a wind farm can even cause the birds to break off migration to forage for food. The birds then circle around close to the WTs and are in great danger of colliding with them as a result.

Seabirds are long-lived species with comparatively few offspring, so mortality can have a more serious effect than on species that produce a large number of young. Even in the case of seabirds however, there is generally too little information available to assess the consequences of WTs and identify relevant thresholds. What, for example, does an increase in mortality or the energy loss of individual birds mean for the population as a whole? Will breeding success be sustainably less as a result, or do some species balance out the losses by producing more offspring? What role do the WTs play in the light of other changes such as habitat loss or climate change? Without this knowledge a reliable prognosis is impossible.

Ralf Aumüller, Katrin Hill, Reinhold Hill


Marine radar with parabolic dish antenna covered by a radome for recording of migration direction at the offshore test field alpha ventus.


Migration counts are made from FINO 1 in the course of monitoring.

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Ralf Aumüller is an experienced ornithologist, enthusiastic birdwatcher, and scientific assistant with the Avitec Research Company. He is involved in several research projects dealing with the effects of offshore wind farms on bird migration.


Katrin Hill is co-owner of the Avitec Research Company and has been working for several years on various projects concerned with the effects of offshore wind farms on bird migration.


Reinhold Hill is co-owner of the Avitec Research Company. He has been involved for 10 years with the effects of offshore wind farms on bird migration and has cooperated on the development of different automated techniques for recording offshore bird migration.
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Migratory birds and their conservation in the UNESCO – World Heritage Site Wadden Sea

"Biodiversity on a worldwide scale is reliant on the Wadden Sea", according to the official document of the UNESCO World Heritage Convention on its "outstanding universal value" on the occasion of the registration of the German-Dutch Wadden Sea in the World Heritage List (under natural criteria) in 2009. This sentence describes impressively the site's importance in a worldwide context and highlights the responsibility of the Wadden Sea states for a permanent preservation of biodiversity on the planet.

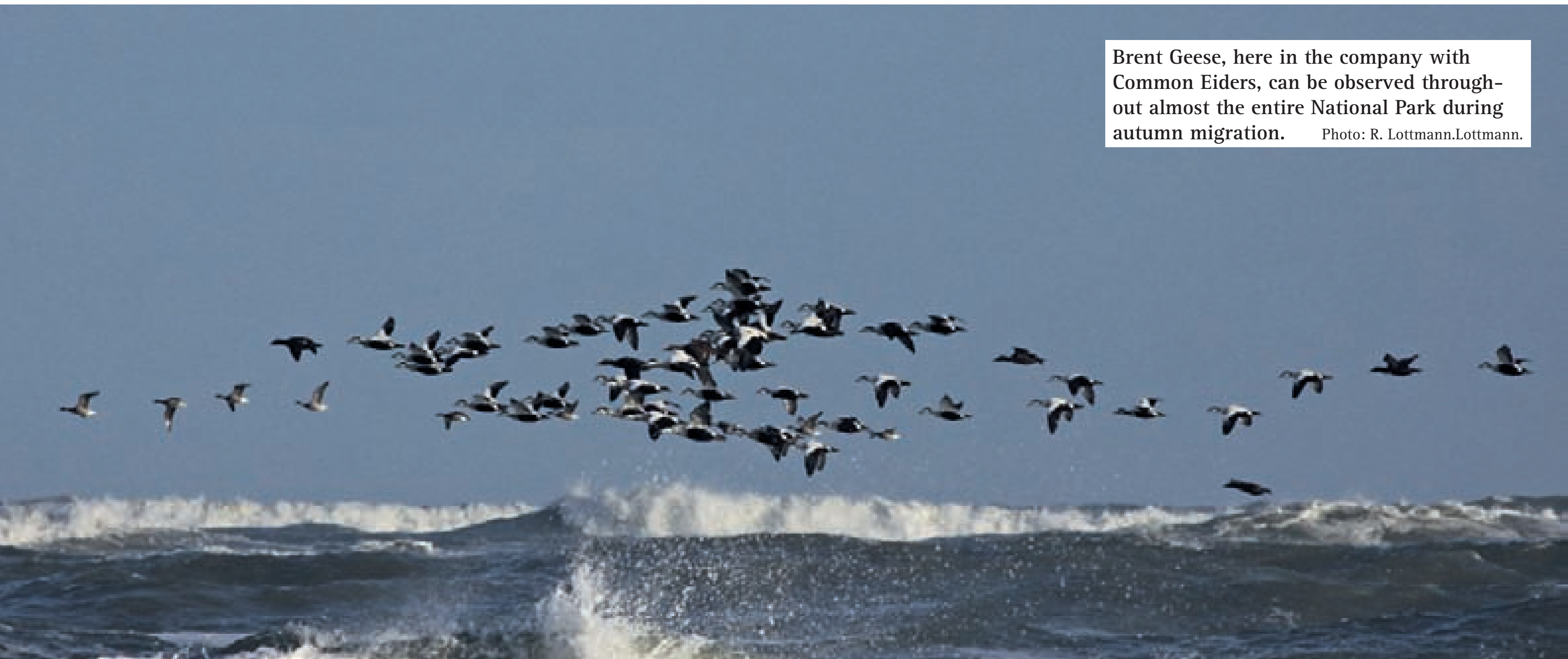
A total 193 natural areas worldwide are listed as World Natural Heritage sites by the UNESCO, as well as 29 further areas that are both natural and cultural sites. The Wadden Sea is on this list, particularly because of the migratory birds. The UNESCO states, "The Wadden Sea is the largest unbroken system of intertidal sand and mud flats in the world, with natural processes undisturbed throughout most of the area. It encompasses a multitude of transitional zones between land, the sea and freshwater environment, and is rich in species specially adapted to the demanding environmental conditions. It is considered one of the most important areas for migratory birds in the world, and is connected to a network of other key sites for migratory birds. Its importance is not only in the context of the East Atlantic Flyway but also in the critical role it plays in the conservation of African-Eurasian migratory waterbirds. In the Wadden Sea, up to 6.1 million birds can be present at the same time and an average of 10-12 million pass through it each year."

» World Heritage Site – also thanks to the birds

The ecological integrity and functionality of the Wadden Sea are essential for permanent preservation of the waterbird species of the Siberian Arctic or Eastern Canada in the north as far as West or South Africa. It was always the migratory birds that fascinated and attracted the coastal dwellers and above all the early conservationists. Otto Leege, the most important initiator of seabird conservation in Lower Saxony and founder of the Memmert seabird sanctuary, wrote the following about the occurrence of Dunlin on the East Frisian Islands in 1905. "This species is the most common of all sandpipers and when autumn migration begins in August, their numbers swell to hundreds of thousands, and at high tide they surge together into huge clouds, restlessly united in elegant swinging over the endless mudflats."

Today, the permanent preservation of the Wadden Sea for migratory birds forms the basis of the conservation objectives of the National Parks. In Lower Saxony, of the 52 individual, strictly protected core zones, 43 alone were designated to include conservation of the significant occurrence of migratory bird species.

The importance of the Wadden Sea for migratory wader and waterbird species can be explained primarily by the abundant and productive benthic life in and on the mud flats, which enables the birds, during both phases

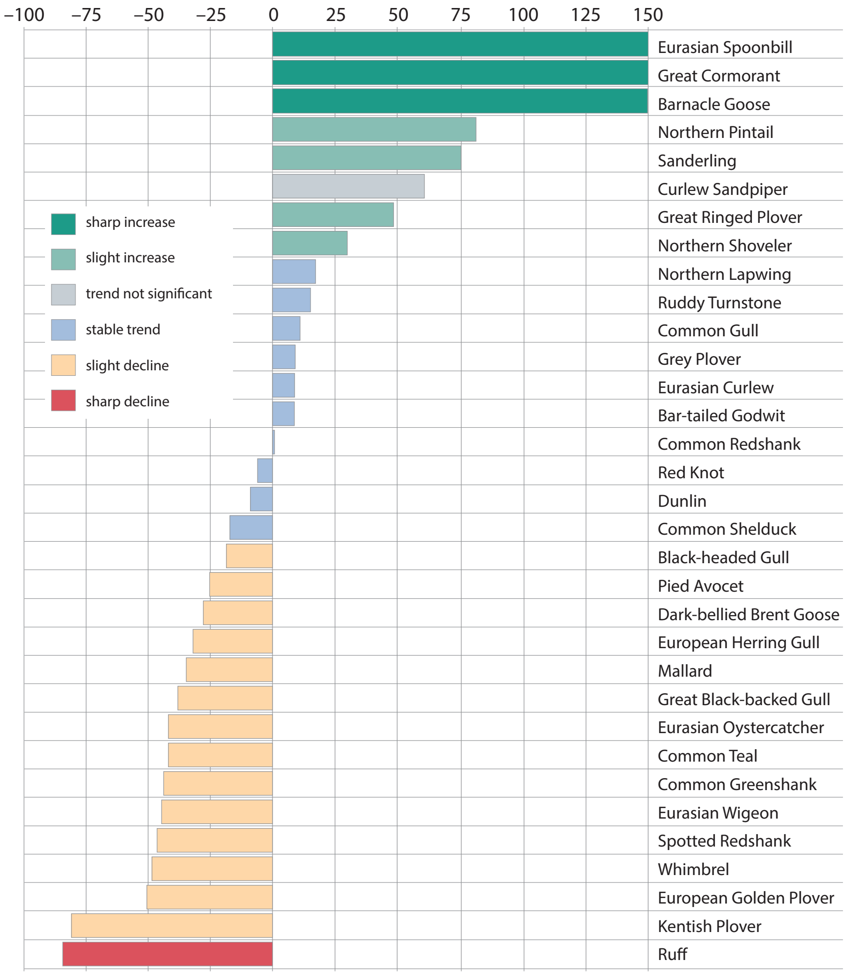


Brent Geese, here in the company with Common Eiders, can be observed throughout almost the entire National Park during autumn migration. Photo: R. Lottmann.Lottmann.

of migration, to refuel and store sufficient energy for the next stage of their journey in a short period of time. The abundant food supply is also important for breeding success in the Arctic, as the bird's condition on departure determines the chances for the coming brood and the probable level of reproductive success on the breeding grounds. In this respect, the Wadden Sea is not only a geographical but also an ecological-functional hub on the East Atlantic flyway, with a special 'fuel station' function.

Changes over a 23 year period (1987/1988 to 2009/2010) in percentages (without Common Eider).

Source: JMMB/CWSS

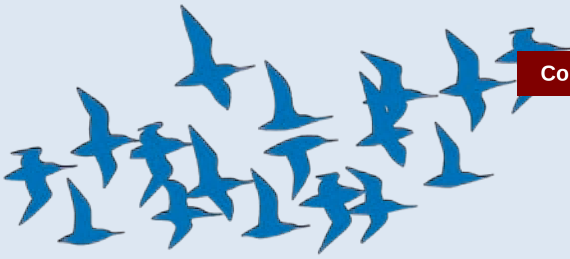


» Population trends are fluctuating to negative

But what is the situation with regard to the populations that use the Wadden Sea? A bird monitoring programme for the whole of the Wadden Sea exists since 1992. All wader and waterbird species are counted synchronously throughout the complete area on fixed dates, as well as in some counting sites every 14 days during spring tides. This not only enables a reliable record to be made of population size and phenology, but more importantly the calculation of population trends along the entire Wadden Sea coastline. Currently, the population developments of the 34 most important bird species (measured as their share of the simultaneously occurring proportion of the population in the Wadden Sea) is very varied, but negative developments predominate. The trend analyses for the past 23 years (1987/88 to 2009/2010) confirm a very sharp decline throughout the Wadden Sea for Ruff and Kentish Plover. In addition, the numbers of 13 typical Wadden Sea migratory species, including six wader, four duck, and three gull species, have significantly declined, albeit to a different degree in this time frame. Species whose populations have increased are piscivores such as Eurasian Spoonbill and Great Cormorant, as well as Barnacle Goose and two wader species of the shore and sandbanks, Great Ringed Plover and Sanderling. The typical mud flat species therefore have stable or declining populations - an altogether gloomy picture. The reasons for these critical population developments are unclear and can, to date, not be explained despite comprehensive analyses. To an extent, substantial regional trends can be identified. In the Netherlands, populations of worm-eating waders tend to increase but these species are somewhat in decline in other areas. It is a moot point whether cockle and mussel harvesting, which is carried out primarily in the Netherlands, has led to the decline in shellfish-eating species such as Red Knot, Eurasian Oystercatcher, European Herring Gull, or Common Eider, whereas worm-eating species have even possibly profited as a result. Increasing populations of the Eurasian Curlew in Denmark are attributed to the suspension of hunting.

» Conservation of migratory birds – only successful in a joint effort

The international Wadden Sea is better protected today than ever before. The German federal state National Parks (Schleswig-Holstein, Hamburg, and Lower Saxony) have reduced bit by bit the negative influences on the ecosystem such as human use, disturbance, and chemical pollution and similar progress can also be claimed by the neighbouring states. The high tide roosting sites for migratory birds are mostly well protected in the core zones of the National Parks and many of them are on the islands well away from the main touristic activities. Nonetheless, the negative population trends indicate emphatically that this policy must be consistently pursued, other potential threat factors must be systematically minimised, and the reasons for the decline studied further. When considering the population trends in the Wadden Sea, its integration as part of the international migration route must also be taken into account. Migratory birds also require favourable survival conditions at all stages of their migration routes. In addition, the quality



185 species in nine days: Migratory Bird Days in the Wadden Sea National Park of Lower Saxony

Every year in autumn the main theme in the Wadden Sea National Park of Lower Saxony is bird migration. In 2013, the 'Migratory Bird Days in the Lower Saxony Wadden Sea National Park' were held from 5 to 13 October for the fifth time. Over a nine day period, between Dollart and Cuxhaven, as well as on the islands, more than 150 events celebrating bird migration were organised, a programme with something for all those interested in ornithology, whether amateur or professional (www.zugvogeltage.de). In 2012, a grand total of 185 bird species were observed.

The most common are wader species, but gulls and terns, ducks and geese provide a characteristic background image, often dominating the whole

landscape. The picture is completed by many birds of prey and songbird species on passage or stopover.

Species such as Brent Goose, Hen Harrier, Dunlin, Bar-tailed Godwit, Common Redshank and Snow Bunting can be seen almost everywhere in the National Park during the migration period.

In addition, rarities such as Great Northern Diver, Red-footed Falcon, Red-breasted Goose, Pallas's Warbler or Black-headed Bunting make guest appearances.

The opportunities for birdwatchers are as varied as the number of bird species that occur.

Every morning a sea-watching workshop is held on the Island of Spiekeroog, under the guidance of the experienced island ornithologist Edgar Schonart, where offshore bird migration can be studied. Ship excursions offer the chance to experience the bird life in the Wadden Sea itself. The cruise takes passengers through the mud flat landscape where typical species such as Common Redshank and Common Greenshank, Ruddy Turnstone, Eurasian Curlew and other wader species can be observed at close range. Flocks of waders can be observed on the high tide roost sites around the islands. A special excursion can be made to the Island of Memmert, which is normally closed to visitors for conservation reasons. Memmert is one of the 'germinal cells' of the National Park and has been afforded strict conservation status for decades.

Bus tours run to the Jade Bight and Dollart and offer impressive geese experiences.

Experienced ornithologists lead all excursions and birdwatchers also have the opportunity to explore the (migratory) bird life of the Wadden Sea on their own. Detailed information is to be found in the local field guide in German 'Vögel beobachten im Nationalpark Niedersächsisches Wattenmeer' (Where to watch birds in the Wadden Sea National Park of Lower Saxony) by J. Dierschke, R. Lottmann and P. Potel.

A speciality is the observation stations that can only be visited during the Migratory Bird Days. One of these is the observation platform at Vareler Hafen in the Rural District of Friesland. An observation tower is erected here especially for the Migratory Bird Days directly on the edge of the mud flats from which, independent of high or low tide, outstanding views of the birds of the Wadden Sea can be experienced throughout the day. The platform is manned by trained National Park employees. Another station is erected on the Kugelbake, which is not only the town of Cuxhaven's landmark, but because of its exposed position, one of the best places on the mainland to observe migratory birds over the mud flats or the sea. The Kugelbake is well known as a good spot to watch birds of the high seas such as Skuas or Sabine's Gulls from the mainland. On several days experienced ornithologists are on hand to assist with observation and identification.

In addition to the ornithological specialist events, including lectures and presentations, there are also lots of other events for children or interested members of the public directly linked to migratory birds. These include art exhibitions, concerts with music from the home countries of the migratory birds, or menus where the different dishes are orientated on the countries of the East Atlantic flyway - often accompanied by a lecture. Where possible, the events are designed to contribute to the sustainability in the region, with regional, organic, or fair trade products. Here as well, the backcloth is provided by the all-encompassing motto of bird migration and migratory bird conservation.

The finale of the Migratory Bird Days is the concluding event - the 'Zugvogelfest' (Migratory Bird Festival) - in Horumersiel. Here visitors have the chance to test the latest optical equipment, obtain information on the National Park, browse through ornithological books and magazines, or attend lectures and presentations. The Migratory Bird Days are an important element of the work of the National Park and contributes to increasing support for bird conservation in the Wadden Sea.

Ring Ouzels use the Wadden Sea for stopover on migration.
Photo: R. Lottmann.

Contents

The Parasitic Jaeger which breeds on the coasts of Northern Europe, also migrates along the Wadden Sea coast above all in September/October. Photo: R. Lottmann.

of one station can have an effect on the condition, survival chances, and potential breeding success at other locations. In this way the individual sites – Arctic breeding area, Wadden Sea stopover, and West African wintering area – are directly dependent on and closely related to each other. These relationships between the individual areas have only very recently been comprehensively understood and they emphasise how global bird migration – very much in the spirit of the world natural heritage – and migratory bird conservation should in fact be understood. Climate change, pressure from human use, hunting, and persecution are only a few of the factors that directly and indirectly affect the living conditions of birds on migration; at different intensity, and often also direction at all locations. Population development at one location therefore always reflects the ecological conditions along the entire migration route. Migratory bird conservation in the Wadden Sea is increasingly being developed internationally and organised trilaterally (Dutch-German-Danish). The UNESCO has encouraged the intensifying of cooperation with the other states along the migration route, in order to improve in this way the conservation of migratory birds. In this context, a research project sponsored by the Federal Agency for Nature Conservation has been initiated by the Institute for Avian Research in cooperation with Oldenburg University, the European White-fronted Goose Research Programme, and the Wadden Sea National Park administration of Lower Saxony, dealing with the study of the migration routes of Arctic breeding birds (primarily Bar-tailed Godwit and Grey Plover) using geolocators and satellite transmitters. The study of carry-over effects between stopover and wintering areas and the Arctic breeding grounds of Geese on Kolguyev Island is also the subject of a research project. Trilaterally, a Wadden Sea Flyway Initiative was initiated (www.waddensea-secretariat.org/management/ projects/flyway-initiative) that is intended to strengthen permanently the cooperation between the individual partners along the migration route. The focus of the initial projects is monitoring activities in West Africa, where our Dutch colleagues are undertaking special efforts to extend the local database. A further German-sponsored project in West Africa serves local capacity building, i.e. the strengthening of awareness and knowledge of migratory birds, and their conservation within the bounds of the East Atlantic migration route as part of a common heritage. Other efforts are necessary in Germany to improve the knowledge of the wider public on migratory birds in general and the importance for them and global biodiversity of the Wadden Sea. In addition to nature conservation and research, education and public relations work are among the core tasks of National Parks. Over the decades, a great deal has been achieved in the various information centres of the National Park. The recognition as part of the World Heritage and the resulting highlighted importance of the Wadden Sea for migratory birds lends greater weight to this work. In addition, a new event format has been developed in Lower Saxony to communicate this issue from various perspectives to a large number of groups and interested persons and sectors of society, so that more and more people are aware and thereby strengthen and actively support migratory bird conservation in the Wadden Sea. Why not join them and come to the coast, for example, during the annual Migratory Bird Days in the Wadden Sea National Park of Lower Saxony held every autumn?

Peter Südbeck, Gundolf Reichert, Petra Potel

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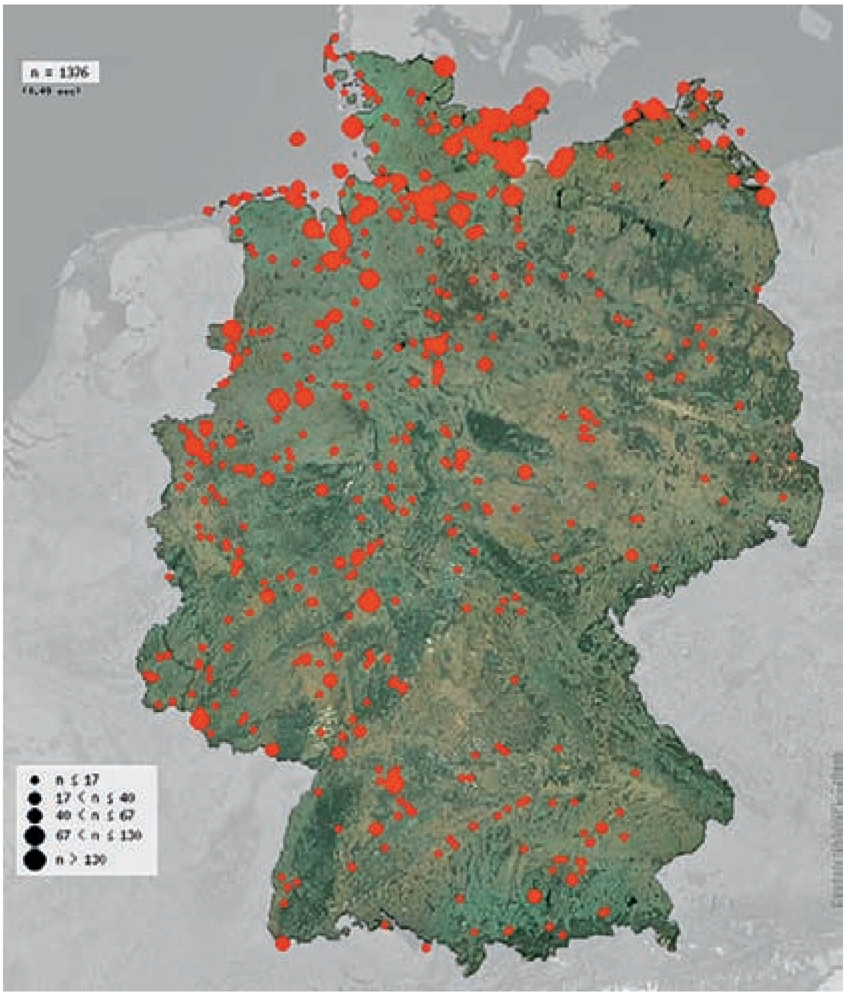
Gundolf Reichert is a qualified landscape conservationist, and as ornithologist in the National Park administration has been responsible for all specialist matters concerning bird species protection, bird research, and monitoring since 2010. He worked previously in a planning office.

Petra Potel is a qualified biologist and has worked in the Sea National Park administration in the field of bird conservation since 1992. She has been responsible for the concept and organisation of Migratory Bird Days in the National Park since 2009.

How can *ornitho.de* contribute to bird migration research?

The start of ornitho.de, an online portal for entering ornithological observations, on 30 October 2011 changed the collecting of avifaunistic data in Germany considerably. By June 2013 over 5 million sightings from more than 6,000 persons had been entered in the portal. In the past, many of these records had gone no further than the individual's field notebook, or were perhaps not noted at all, let alone made available in a central database. It undoubtedly represents a massive wealth of data for migratory bird research, which is growing and increasing in value from day to day. The so-called ad hoc or casual observations that are collated in ornitho.de are not, however, without their pitfalls. On the occasion of the publication of this special edition of Der Falke we intend to follow up the question posed in the title of this article, and examine a little more closely its possibilities and limitations.



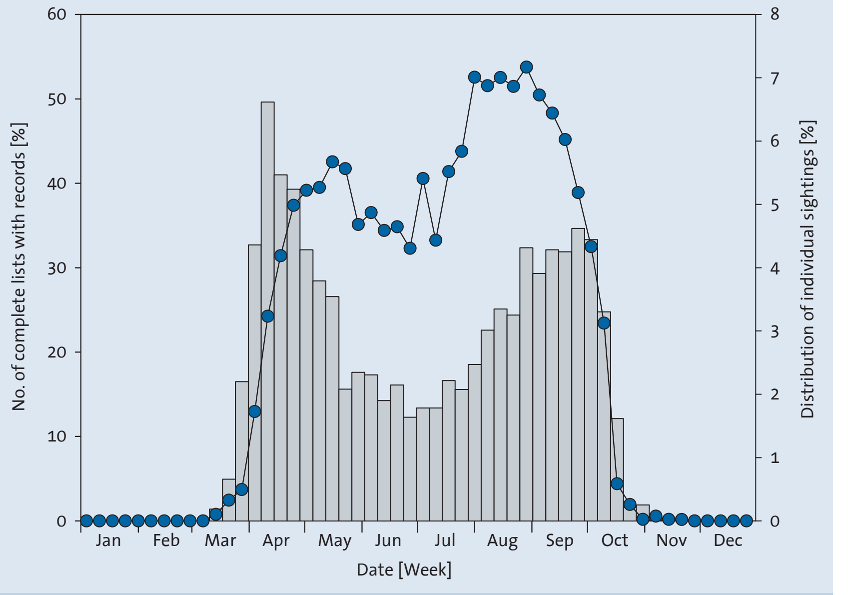
Grey-headed Wagtails *M. thunbergi* breed in Scandinavia and Russia and occur in Central Europe on passage only. Based on the data from *ornitho.de* a marked concentration appears to occur in the Western half of Germany, which supports the sparse information available on a migration route across Western Europe. Random observations can be an important augmentation for research into migration routes of bird species where information from scientific bird ringing is still incomplete. The map shows the total of all individuals reported at a location. Some dots appear larger because of multiple sightings.

If questions are to be answered on a scientific basis, the collection of data is usually strictly standardised and systematic. Sampling effort and recording methods are known and assumptions can thus be made. Data are also comparable and statistically sound analyses can be carried out. In scientific bird ringing, for instance, clear guidelines are laid down for recording wing and beak length, weight or moult score; and in the common breeding bird census the counts are made on statistically representative 1x1 km plots, in predefined time periods, and according to standardised methods. This makes data analysis considerably easier.

There are however, no guidelines for casual observations – that is all observations that are collected in an unsystematic way. If I make an observation that I, for whatever reason, personally find interesting, I submit it to *ornitho.de*. For one observer these are, for instance, all sightings of Red-backed Shrikes during the breeding season. For another, only the first sighting of the species is interesting, and yet another records every Lesser Spotted Woodpecker, or only Red-breasted Goose or similarly rare species. I can therefore decide myself, at any time, what and if I report. This, amongst other things, makes online portals for casual observations attractive.

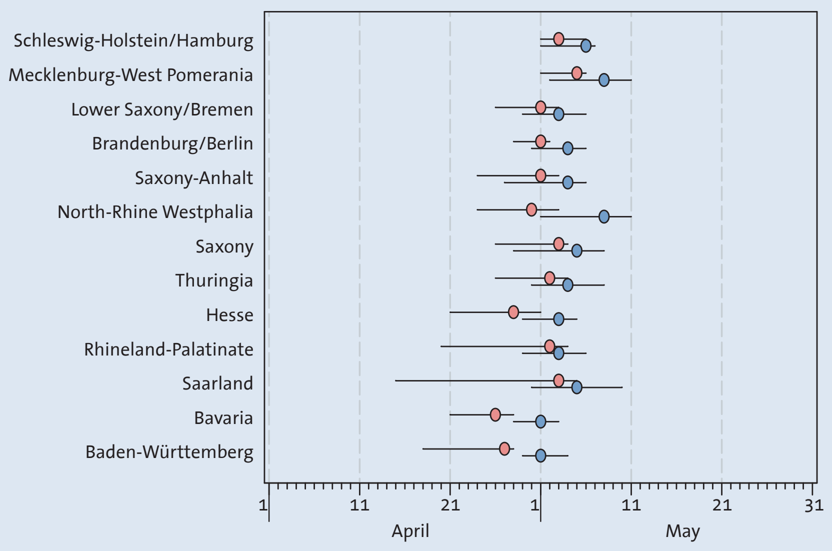
It is clear that this freedom to report observations restricts the possibilities for data analysis. Observations accumulate in well-populated areas and also in the attractive birdwatching sites in these areas. For most of us our free time is generally at the weekend, so a disproportionate number of observations are made on Saturdays and Sundays, and these are in almost all cases positive records of individual species. It therefore remains unknown which other species were present or which species were absent. In general and straightforward terms, it can be said that the more rare or attractive a species or event is (e.g. the arrival of migrants, Common Crane passage), the more complete and therefore more reliable are the casual observations. Or in reverse, the more frequent and common a species is, the more important is a systematic approach to the recording of casual observations.

In *ornitho.de* and other online portals this 'semi-systematic' approach is implemented using complete lists.



Seasonal occurrence of the Barn Swallow in 2012 according to data from *ornitho.de* a) based on individual sightings (columns) as well as b) complete lists (lines; blue – 2012, red – 2013). All species discovered on an excursion are recorded in complete lists. On the basis of the latter, the seasonal occurrence is depicted much more realistically than when based on individual sightings, according to which the pattern resembles that of a migrant breeding at northern latitudes. The reason for this is the dwindling interest of the observer after the arrival of the first individuals in spring. The somewhat later arrival of the Barn Swallow in 2013 cannot be detected because records are summarised by weeks. The percentage of individual sightings and the number of complete lists with Barn Swallow records per week is depicted respectively.

In many places in Germany the males predominate in flocks of wintering Common Pochards. The females move away farther south. Data from ornitho.de data combined with the results of the Waterbird Census should provide sufficient data in order to analyse sex-specific wintering strategies. Photo: C. Moning.



In 2013 (red) the Red-backed Shrike obviously arrived in many locations earlier than in 2012 (blue), especially in Southern Germany. Red-backed Shrikes winter in East Africa and therefore arrive in Germany from a south-easterly direction. In the future data from ornitho.de can contribute to the analysis of the annual variability of the wide-scale arrival of bird species or the differences between individual migration routes. The tenth record is represented by a dot and the first and twentieth record by a line denoting the spread of arrival. Only one record per day and location was used. Source: *ornitho.de.*

In this approach all species seen or heard on an excursion are noted so that during data analysis the conclusion is permissible that all species not noted on the list were not sighted (the strongly varying detectability between individual species or between seasons is a problem that also affects monitoring programmes – but this can be dealt with statistically).

These zero values are essential if answers are to be provided to many questions and – what is often forgotten – these are full-value information. Complete lists also provide information on the time spent and area covered during an excursion. All these factors increase the potential for data analysis to a considerable extent.

» Wide-scale analysis of bird migration phenomena is possible

If one is aware of this background, the random observations from *ornitho.de* can represent an important augmentation for a whole series of questions on the systematic, yet necessarily mainly selective approaches in migratory bird research:

- The arrival of migratory birds in spring captivates us afresh year after year. Most observers therefore report their personal first records for the year, and an increasing number pass on their observations as complete lists. The arrival of many species, as well as the differences between regions and the annual variability, can therefore be precisely described. It was shown in 2013 that short-distance migrants arrived considerably later, but that the late arriving long-distance migrants arrived with us somewhat earlier than in the year before. A long-term comparison provides interesting perspectives in terms of possible trends in the seasonal occurrence of migratory bird species.
- For many species, the differences between the sexes or between adult and young birds can be well distinguished, so that they can often be reported separately. In this way questions on migration strategies and temporal and spatial differences in occurrence can be answered on a broad basis and possible long-terms trends can be analysed. The first examples of such evaluations on the Ring Ouzel, Whooper Swan, and Dotterel have already been published in earlier issues of DER FALKE.
- Above-average breeding success, food shortages, or unfavourable conditions in the main breeding areas are often the trigger for influxes. These can also be well documented by casual observations, as they attract the interest of a wider public. Based on this data, origin and migration movements can also be partially analysed. Examples of this are the arrival of Rough-legged Buzzards in winter 2011/12, the unusually large occurrence of the Black-winged Stilt in May 2012, or the Waxwing invasion in winter 2012/13.

Ornitho.de is not an island unto itself. In almost all countries in Northern or Western Europe there is an online portal for collection of casual data and millions of data are collected annually. If the consolidation on an international level of the data from all these portals can be achieved, a completely new perspective on the migratory movements of birds will be opened – not only for all birdwatchers but also for researchers of migratory birds.

Johannes Wahl, Christopher König, Stefan Stübing

Related literature.

Newton I 2010: Bird Migration. Collins New Naturalists Series 113.

König C, Stübing S, Wahl J 2013: Frühjahr 2013 – Späte Kurzstreckenzieher, frühe Langstreckenzieher. Falke 60: 274–279.

These, and all other publications containing analyses of data from *ornitho.de* are available (in German) and can be downloaded from www.dda-web.de/publikationen.



Dr Johannes Wahl (top) and Christopher König both work for the DDA. Among other topics, they are responsible for *ornitho.de* and dedicate a lot of their time to supporting and running the portal.

Stefan Stübing works as a biologist. He is the DDA's deputy chairman and acts as avifaunistic coordinator of the HGON, the DDA's partner organsiation of the federal state of Hesse.
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