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Defining the key wintering habitats in the Sahel for declining African-Eurasian migrants using expert assessment

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Summary

The Sahel in West Africa is a major wintering area for many western Palearctic migrants. The breeding populations of many of these have declined over the past 50 years. However, there have been few intensive field studies on migrant ecology in the Sahel and these were generally within a very restricted area. Consequently our knowledge of the distribution of species within this extensive area and the habitat associations of these species is limited. Understanding these habitat associations is essential for the effective conservation management of populations. We brought together a group of experts and consulted a wider group by email to assess the main Sahelian habitat types used by 68 African-Eurasian migrant bird species. Those species that showed strongest declines during 1970–1990 were associated with more open habitats than those newly declining during 1990–2000, when declining species were associated with habitats with more shrubs and trees. Populations of species that winter in the Sahel are generally stable or increasing now as rainfall has increased and is now near the long-term average for the Sahel. Those which use the Sahel only as a staging area are, in many cases, in rapid decline at present.

Introduction

Approximately 2.1 billion passerines and near-passerines breeding in Europe migrate to sub-Saharan Africa each year (Hahn *et al.* 2009) and many species concentrate in West Africa in the arid savannas of the sub-Saharan Sahel zone during the non-breeding season. Many of these species have declined in numbers (Sanderson *et al.* 2006, Hewson and Noble 2009, Ockendon *et al.* 2012). Drought in the Sahel has been a major issue for many species but there have also been rapid habitat changes in the European breeding grounds, particularly for species associated with farmland, e.g. Yellow Wagtail *Motacilla flava* (Gilroy *et al.* 2010) and Turtle Dove *Streptopelia turtur* (Browne and Aebischer 2004).

In various studies the annual survival of many migrant species that spend the northern winter in the Sahel has been linked to rainfall in that region during the preceding rainy season (Zwarts *et al.* 2009). However, there are no comparable studies on the effects of land use change on migratory bird survival. The few quantitative studies available show that land cover in the Sahel is changing (Tappan *et al.* 2000, 2004), mostly in response to agricultural intensification and extension of cultivated land. However, understanding of the implications of present and future land use change in the Sahel for African-Eurasian migrant birds is severely limited by insufficient knowledge of the birds' habitat requirements in the Sahel. Some studies have been undertaken on individual or groups of species (e.g. raptors, Anadón *et al.* 2010) and examined how distribution is influenced by spatial aggregation of resources and the birds' response to this (Cortés-Avizanda *et al.* 2011). Understanding the habitat requirements of African-Eurasian migrant birds in the Sahel is important if strategies are to be devised to guide land use change in ways that sustain or restore population levels.

There is therefore considerable potential conservation value in attempting to collate and synthesise currently fragmented data (published and unpublished) alongside field experience and ornithological expertise. In this paper we report the results of a participatory approach to draw together published literature and workshop-derived expert knowledge to quantify the importance of a range of Sahelian habitats for 68 terrestrial migrant bird species that either winter or stage in this region. In doing so we attempt, for the first time, to synthesise knowledge of habitat use for these species, rank these habitats in terms of the number of migrant species they support and their importance for declining species, and thus identify habitats where habitat change might be expected to have the greatest positive or negative impact on migrant birds. We do this by calculating a relative index of habitat usage by declining and non-declining species. Those habitats most associated with species declines (and therefore likely to be those habitats of highest conservation concern) will have higher usage score on average for declining species compared to non-declining species. We then compare the habitat usage indices for all declining and non-declining species between two periods, early (1970–1990) and late (1990–2000), to determine whether there have been any changes in the relative importance of habitats. We further compare the relative index of habitat usage for species present during the northern winter (termed Sahelian winterers) with for those which pass through to spend part of the northern winter further south (termed Sahelian transients) between the early and late periods. If our assumptions that differential habitat use and change in the Sahel are leading to declines are correct, changes in the habitats most associated with declines between the periods should be more pronounced in Sahelian winterers. These habitats may be important targets for conservation expenditure to maintain migratory bird populations.

Methods

The approach we used builds on some of the guiding principles for using participatory exercises to harness and synthesise expert knowledge (Sutherland *et al.* 2011) in relation to (i) defining the project, (ii) organising the participants, (iii) soliciting and managing questions or issues and (iv) disseminating results.

Defining the project

The concept was relatively simple and required three inputs: a definition of the Sahel, a list of relevant bird species and a list of distinct habitat types.

Definition of study area

For the purposes of this study we define the Sahel zone as the region with a long-term (50-year) mean annual rainfall in the range of 200–600 mm. Our focus is on bird species from western Europe that winter in the western part of the Sahel, from Senegal in the west up to and including Niger in the east.

Selection of bird species

The analysis included all species of African-Eurasian migrant landbirds that both breed in western Europe and for which a significant fraction of the population is considered to use the Sahel zone

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of West Africa at some point in the non-breeding season. This classification was determined primarily with reference to standard handbooks (Cramp and co-editors 1978–1994) and Zwarts *et al.* (2009). The classification resulted in a set of 68 species (see full list in the online Supplementary Materials). Species excluded were: those with populations that migrate from temperate North Africa to sub-Saharan Africa, but which do not have a western European breeding population (e.g. Cream-coloured Courser *Cursorius cursor*, Blue-cheeked Bee-eater *Merops persicus*, Eastern Olivaceous Warbler *Hippolais pallida*); species wintering mainly in the Sahel east of Niger; species that only infrequently occur in the western Sahel (e.g. Masked Shrike *Lanius nubicus*, Isabelline Shrike *Lanius isabellinus*); species whose migratory populations are thought mainly to overfly the western Sahel without exploiting resources there (e.g. Alpine Swift *Tachymarptis melba*, Honey Buzzard *Pernis apivorus*), and species whose main wintering grounds lie in the eastern part of Africa (Great Spotted Cuckoo *Clamator glandarius*, European Roller *Coracias garrulus*). Common Kestrel *Falco tinnunculus* was excluded because only a small number of European migrants are thought to enter West Africa and the degree of use made of the Sahel is unknown, due partly to the difficulty in differentiating European migrants from the Afrotropical resident population.

Definition of habitats

The habitat definitions used for this exercise represented a compromise between those that had ecological relevance to birds, and hence could be realistically assigned high, medium or low importance for a given species, and those that could be readily matched with land cover types that could potentially be mapped using low to medium resolution satellite image data, allowing large-scale temporal and spatial change to be assessed in future. Through a process of consultation and discussion with ornithologists with field experience in Africa and experts with knowledge of remotely sensed land cover habitat classifications, we defined 17 habitat categories that cover both a broad structural gradient (from bare soil and open crop and grasslands to wooded savanna) and a wetness gradient (from dry open areas, seasonally flooded wetlands to permanently wet habitats) (Table 1), based on FAO's Land Cover Classification System (Di Gregorio and Jansen 2000). Anthropogenic influence is also included with the inclusion of villages and different types of farmland. Two additional habitat categories, bosquets (areas of dense woody vegetation in dune depressions) and tiger bush (patterned vegetation with parallel zones of dense shrubs and bare areas), were considered to be specific examples of types of woodland and scrub and so were dropped as separate categories.

Organising the participants

From recently published literature, and through personal contacts in universities, research institutes and conservation NGOs, we collated a list of individuals who had undertaken research relating to bird–habitat relationships in the Sahel and invited each of them to attend a one-day workshop. For those living outside of the UK, we offered to cover the cost of international travel. If travel was not possible, we facilitated engagement via email communication. We included in the invitation a spreadsheet containing the list of species and habitats under consideration so that all were able to contribute to the 'habitat scoring process'. The invitation and spreadsheet were circulated to 23 individuals, 17 of whom attended the workshop. The remaining six commented via email. The workshop itself commenced with a short introductory session during which its aims were presented, the scope of the exercise explained (birds, species and region of interest) and the habitat definitions clarified.

Quantifying the importance of each habitat for migrant birds

The central aim of this work was to rank the value/importance of these 17 habitat categories for the 68 selected species of migrant birds, based on best available knowledge from published literature

Table 1. Definitions of the habitats used in this study as modified from Di Gregorio and Jansen (2000).

Rocky Outcrops	Bare rocky outcrops, often associated with inselbergs
Villages	Areas of continuous human habitation
Farmland	Open land dominated by annual or perennial crops, with 0-10% canopy cover of naturally-occurring woody species
Grassland	Dominated by grasses and herbs, with 0-10% canopy cover of woody species
Farm/Shrubs	As farmland but with 10-40% cover of open stands of shrubs or bushes 2-7m tall
Grass/Shrubs	As grassland but with 10-40% cover of open stands of shrubs or bushes 2-7m tall
Shrubland	Open stands of shrubs or bushes 2-7m tall (> 40% cover)
Farmland/trees	As farmland but with a canopy cover of woody plants > 8 m tall of 10-40%
Grassland/trees	As grassland but with a canopy cover of woody plants > 8 m tall of 10-40%
Shrubland/trees	As shrubland but with a canopy cover of woody plants > 8 m tall of 10-40%
Open woodland	An open stand of trees at least 8m tall with a canopy cover of 40% or more, the field layer usually dominated by grasses
Wet woodland	A continuous stand of trees at least 8m tall along seasonal or permanent rivers or lakes, at least 10m tall with interlocking crowns
Irrigated Farm	Areas of farmland that are irrigated for crops such as rice.
Wet Grassland	Areas of damp grassland surrounding open water
Fringing Vegetation	Vegetation < 10m tall fringing areas of open water (permanent or seasonal). Includes woody species such as *Acacia nilotica*
Emergent Vegetation	Vegetation, such as *Phragmites* and *Typha* that requires permanent or semi-permanent inundation
Open Water	Areas of open water which are permanent or seasonal

and through first-hand field experience. This was done in two stages. First, existing knowledge of species-specific habitat use/preferences/requirements was synthesised from the literature and used to derive a preliminary list of habitat importance scores for each species. This information, summarised as a table, was then circulated electronically to the invited experts to solicit their response in terms of the approach in general and the species and habitats selected in particular.

The second stage was for the respondents to use their first-hand field experience to rank these habitats as unimportant or of low, medium or high importance for each species under consideration. We recognised, from the outset, the risk of bias towards areas of field experience and attempted to address this through the 'composition' of experts we engaged in the process. The 23 individuals who participated in the workshop and pre-workshop data-gathering exercise between them had first-hand experience of ornithological fieldwork in the Sahelian zone of each of the six countries that encompass the defined study area (Burkina Faso, Mali, Mauritania, Niger, Nigeria and Senegal), together with a broader expertise in terms of knowledge of the published and grey literature and of fieldwork elsewhere in Africa.

In practice, it was difficult to arrive at clear-cut definitions of low, medium or high importance. A habitat was classed of high importance if it was considered to be used regularly by large numbers of individuals of a species throughout the wintering or staging period and was known, or thought, to provide food or food and roosting areas (but not simply roosting areas). In contrast, habitats were considered of low importance if they were used infrequently, by small numbers of individuals and provided less frequented foraging or roosting sites.

After the workshop, a quantitative ranking of habitat importance was derived by, first, replacing the habitat importance scores of unimportant, low, medium or high importance, for each species-habitat combination, with numerical values of 0, 1, 2 and 3 respectively. These scores were then summed for each species and each species's score for each habitat was divided by the species total so that each species had a total score of 1. These standardised habitat importance scores in effect increased the importance of a habitat when the species was found in fewer habitats and decreased its importance when the species used a wide range of habitats.

We first identified the main habitat association gradients in the bird data using an ordination technique. To identify the key habitats for the group of 68 species selected, a Principal Components Analysis was performed on the standardised habitat importance scores using the PRINCOMP function in SAS. This technique produces a number of composite habitat variables that indicate the main gradients in the species–habitat data. The resulting axes were grouped using a Ward's clustering technique in the CLUSTER and TREE procedures in SAS, and the habitat variables that were significantly correlated with Axis 1 and 2 scores were identified using a Pearson's correlation. This allowed us to identify the key habitats for the suite of migrants selected and provided a graphical way of grouping species together based on their habitat requirements.

To examine any differences in habitat usage between winterers or transients, and declining and non-declining species for the two time periods ('early' 1970–1990 and 'late' 1990–2000), we defined transients as species as those which use not only the Sahel but also habitats further south during the non-breeding season, and Sahel winterers as those that depend totally on resources in the Sahel during the time they spend in sub-Saharan Africa. Declining and non-declining species during the two periods were identified from information in Zwarts *et al.* (2009). See Appendix 1 in online Supplementary Material for classifications and sample sizes.

Determining habitats most associated with declining migrant bird species

We compared the mean standardised habitat importance scores for declining and non-declining species in each habitat and period using a bootstrapping technique. For each subset of the dataset (i.e. individual habitats and period), a total of 10,000 replicate datasets were created using observations from the original dataset selected at random with replacement. The median score and 95% confidence intervals were calculated for each habitat separately for the declining and non-declining species. To determine if the habitat importance scores were significantly different, we calculated the difference in the mean scores for each replicate pair and, if the 95% confidence interval did not span zero, they were said to differ significantly. These standardised habitat importance scores for declining and non-declining species were compared in three ways: (i) all species, in the early period compared with the late period; (ii) all Sahelian winterers, in the early period compared with the late period; and (iii) all transient species in the early period compared with the late period.

Results

Classification of species by habitats

The Principal Components Analysis identified four components that individually explained more than 10% of the variance (PCA1–29.9%, PCA2–23.4%, PCA3–14.0%, PCA4–11.3%, cumulatively accounting for 78.5%). The first two components comprised gradients that could be identified as running from open to structurally more complex habitats and from wet to dry habitats (Figure 1). The cluster analysis of the four main PCA scores (components 1 to 4) identified 7 main groups of birds. These include exclusively wetland species (Group 2) and species that occupy those habitats at the interface of wet and dry habitats (Group 3). For the species that only use dry habitats there was a gradient from open country species to those that inhabit woodland (Groups 5 through 4 to 1). There are two remaining groups: one associated with towns and villages (Group 7) and one where the associations are unclear (Group 6, including only Osprey [open water] and Common Swift [habitat association unclear]).

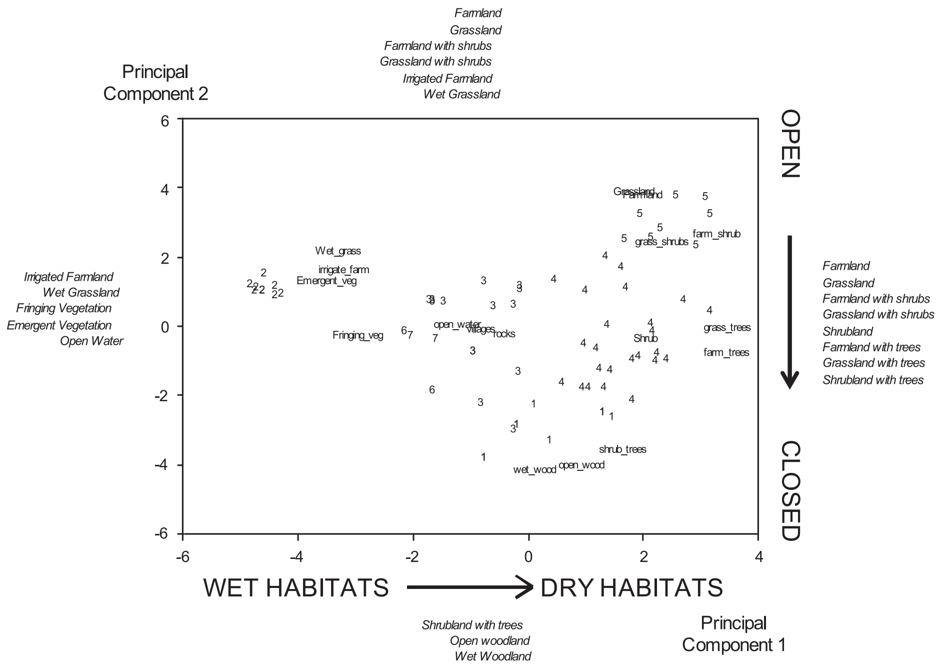

Figure 1. Axis 1 and 2 species and habitat scores derived from a Principal Components Analysis of the standardised habitat importance scores for all migrants considered in this analysis. Numbers refer to the identity of the cluster each species was allocated to (see Table 2). Habitats that are significantly correlated with each axis score are shown in italics.

Habitat associations of declining and non-declining species

During the early 1970–1990 period, the standardised habitat importance scores were significantly higher for declining species than for non-declining species in six habitats, including open (grassland and farmland) and intermediate habitats (grassland with trees, farmland with shrubs and farmland with trees; see Figure 2) This indicates these relatively open habitats were more associated with declining species (Figure 2). Only one habitat, the fringing wetland vegetation, was associated with increasing species.

In the later period (1990–2000), the same habitats were significantly more associated with declining species than with non-declining species as in the earlier period, with one exception: very open habitats (farmland and grassland) were no longer associated with declining species. These open habitats still exhibited slightly higher standardised habitat importance scores for declining compared with non-declining species, but the differences were not significant, and the average scores of these open habitats for species declining during 1990–2000 were much lower than for the species declining during 1970–1990.

Thus, during the 1970–1990 period, population declines in all species were associated with very open and intermediate habitats, whereas during 1990–2000 they were associated with more intermediate habitats.

Habitat associations of transient and wintering species

For Sahelian winterers only, as with all species, grassland had significantly higher standardised habitat importance scores for declining than for non-declining species in the period 1970–1990

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Table 2. Species investigated, grouped according to the habitat types that they are associated with using a combination of Principal Component Analysis and a clustering technique. Scientific names appear in Appendix 1 in the online Supplementary Material. Group numbers refer to groups in Figure 1 and are in no particular order.

Open woodland or shrubland and trees	Exclusively wetland	Associated with both wetlands and dry terrestrial habitats with shrubs and trees	Terrestrial habitats with shrubs and trees	Open country – grassland and farmland	Open water	Rocks / villages
Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Golden Oriole	Great Reed Warbler	Iberian Chiffchaff	Rufous Scrub Robin	Tawny Pipit	Common Swift	Common Rock Thrush
Icterine Warbler	Savi's Warbler	Common Chiffchaff	Garden Warbler	Stone-curlew	Osprey	Pallid Swift
Common Redstart	Grasshopper Warbler	Barn Swallow	Orphean Warbler	Greater Short-toed Lark		
Olivaceous Warbler	European Reed Warbler	Common House Martin	Common Whitethroat	Common Quail		
European Nightjar	Bluethroat	Yellow Wagtail	Black-eared Wheatear	Lesser Kestrel		
Red-necked Nightjar	Common Sand Martin	Red-rumped Swallow	Eurasian Wryneck	Ortolan Bunting		
European Scops Owl	Red-throated Pipit	Black Kite	W. Bonelli's Warbler	Egyptian Vulture		
Common Cuckoo	Aquatic Warbler	European Bee-eater	Melodious Warbler	Isabelline Wheatear		
Pied Flycatcher	Sedge Warbler	Eurasian Marsh Harrier	Pallid Harrier			
		Eurasian Hobby	Whinchat			
		Common Nightingale	Great Spotted Cuckoo			
		Blackcap	Short-toed Snake Eagle			
		Subalpine Warbler	Booted Eagle			
		Spectacled Warbler	Willow Warbler			
			European Turtle Dove			
			Montagu's Harrier			
			Spotted Flycatcher			
			Hoopoe			
			Woodchat Shrike			
			Northern Wheatear			
			Tree Pipit			
			Lesser Whitethroat			
			White Stork			
			Sardinian Warbler			

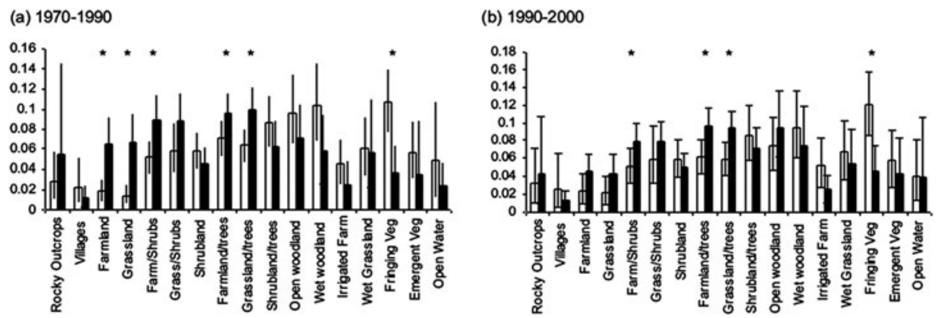

Figure 2. Standardised habitat importance scores (median +/- 95% CIs) for each habitat for all migrant species. Open bars are for stable or increasing species and filled bars for declining species (a) 1970–1990 and (b) 1990–2000. Habitats marked with an asterisk are those for which there is a significant difference in the scores of declining and non-declining species.

(Figure 3). For farmland there was a similar pattern, though not significant, in contrast to the result considering all species pooled. These negative correlations with grassland and farmland may be related to the droughts of the 1970s and 1980s: grass and crop biomass responds to rainfall more immediately than tree and scrub species that are deeper-rooted and can exploit shallow groundwater (Cole 1986). Habitats that were significantly more important for wintering species that did not show a population decline during that period are villages and fringing and emergent vegetation. This is similar to the relationships for all species pooled during 1970–1990.

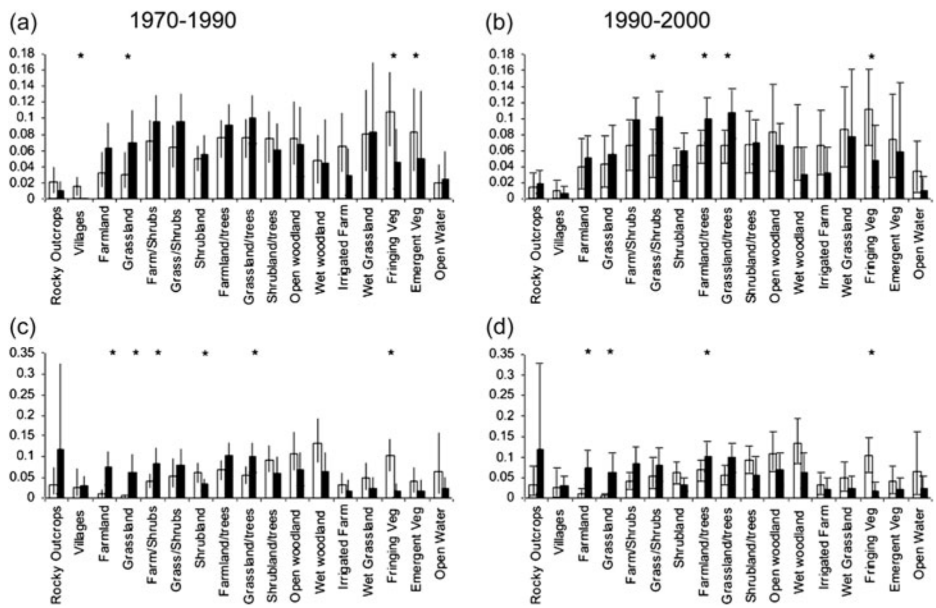

Figure 3. Standardised habitat importance scores (median +/- 95% CIs) for each habitat for Sahelian wintering species (a and b) and transient species (c and d) over the two time periods. Open bars are for stable or increasing species and filled bars for declining species in the two periods. Habitats marked with an asterisk are those for which there is a significant difference in the scores of declining and non-declining species.

For 1990–2000, declining wintering species had a significantly stronger dependence on grassland and farmland with shrubs and with trees than did non-declining transients. Non-declining species had a significantly stronger dependence than declining species on fringing vegetation only. For emergent vegetation the relationship was similar, but not significant.

These patterns and differences were broadly similar for transients. For transient species declining during 1970–1990, grassland, farmland, farmland with shrubs and grassland with trees were significantly more important than for non-declining species. For non-declining transients, shrubland and fringing vegetation were significantly more important.

For 1990–2000, farmland and grassland were again significantly more important for declining than for non-declining transients, joined now by farmland with trees. Fringing vegetation (and emerging vegetation and wetland grassland) was again more important for non-declining transients than for declining ones.

Discussion

The results of this synthesis of expert opinion and published information suggest that African-Eurasian migrants with significant declines between 1970 and 1990 are those particularly associated with open, dry farmland and grassland. In contrast, those species showing significant declines between 1990 and 2000 are associated with more structurally complex habitats, such as tree- and shrub-rich farmland and grassland.

Rainfall patterns and migrants in the Sahel

Prolonged drought in the Sahel has long been associated with declines in migrants wintering there, and there is evidence that rainfall in the Sahel is also important for many species that winter further south, and for which the Sahel is itself a staging area, e.g. Nightingale *Luscinia megarhynchos* (Boano *et al.* 2004) and other species that winter further south in the wetter regions. The pattern of rainfall in the Sahel has been variable, both inter-annually and over the longer term (Grist and Nicholson 2001; Fig. 4). The period 1920–1967 was one of generally above-average rainfall in the Sahel (1900–2001, data from http://jisao.washington.edu/data/sahel/ accessed 10 July 2011), although within the latter part of this period (from c.1953) levels of annual rainfall began to decline. By 1968, the smoothed rainfall index in the Sahel started to fall below the current long-term average and that year was the third-driest in the region since 1900 (the previous two years being 1902 and 1913). The trend in annual rainfall then declined until 1985 but since then it has increased once more and in 2009 and 2010 rainfall levels had, once again, reached or exceeded the long-term average.

The 'early period' of the bird-habitat analyses presented here (1970–1990) coincides with the second half of the prolonged dry period. At this time declining species were associated with open habitats, such as grassland and farmland, to a greater extent than non-declining species. These habitats are dominated by shallow-rooted grasses and forbs that respond rapidly to rainfall decline. More deep-rooted wooded habitats, especially those around temporary watercourses or other water bodies, are to some extent buffered from low rainfall.

The impact of drought in the Sahel on migrant birds was dramatically highlighted in Britain when national breeding bird monitoring schemes reported a 70% crash in numbers of Common Whitethroat *Sylvia communis* in 1969 (Winstanley *et al.* 1974) following the very dry conditions on the wintering grounds in 1968/1969. This very dry year followed a 20-year period of above-average rainfall conditions and the population may well have been elevated given that large areas of the Sahel would have held suitable wintering habitat during these wet conditions. When drought struck, very large areas of formerly suitable habitat would not have been able to sustain wintering Common Whitethroats, whose population increased slowly in subsequent years (Risely *et al.* 2011). The population trend of this species therefore highlights a potential confounding factor in the present analyses as it was classed as an increasing species, reflecting recovery from a

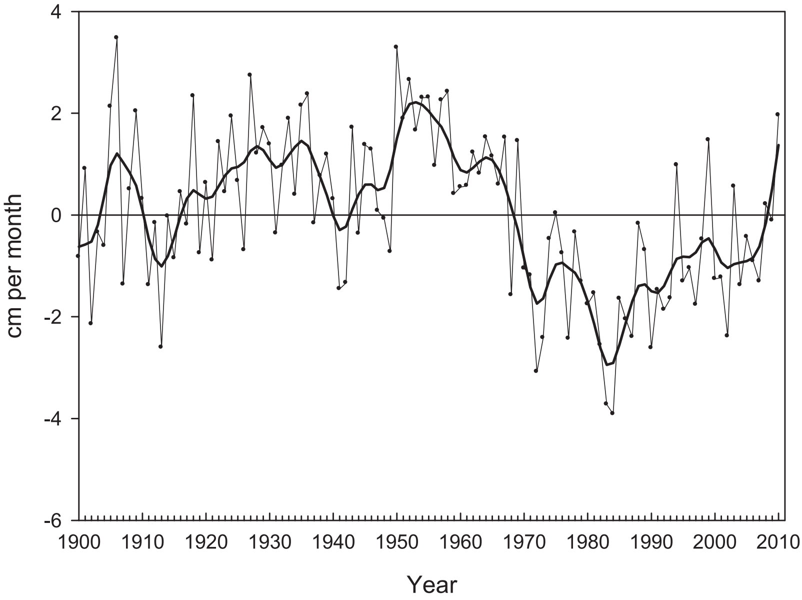

Figure 4. Annual estimates and smoothed trends (cm month-1) of Sahelian rainfall precipitation anomalies 1900–2010 (June to October rainfall; 10N – 20N 20W – 10E). Annual estimates downloaded from http://jisao.washington.edu/data/sahel/

population low, although it has not recovered to former levels. The same may apply to a number of other species but the lack of widely available monitoring data prior to 1970 means that a comparison of trends from the mid-1960s onwards, perhaps the critical period for Sahelian migrants, is not possible.

The later period (1990–2000) in the present study coincided with a period when the Sahel was less consistently dry. During this time, although open farmland and grassland remained important, there was a marked association of declining migrants with more structurally complex habitats (farmland and grassland with shrubs and trees). During this period, the previously relatively strong relationship between rainfall and over-winter survival in several species is no longer evident (e.g. White Stork: Nevoux *et al.* 2008), perhaps suggesting increasing importance of other potential limiting factors on wintering, staging or breeding grounds.

Land cover, land use changes and migrant birds in the Sahel

African-Eurasian migrants have long been thought to be sensitive to human-induced habitat change, as well as climate change, in the wintering grounds (Grimmett 1987, Lack 1990, Morel and Betlem 1992, Morel and Morel 1992, Jones 1995, Jones *et al.* 1996, Vickery *et al.* 1999, Wilson and Cresswell 2006, Zwarts *et al.* 2009, Robson and Barriocanal 2011). Agricultural land dominates large parts of the Sahel (Mayaux *et al.* 2004) and rapid economic development and agricultural expansion is taking place in some areas (Cour 2001). Human population growth rates in the Sahel have generally been over 3% per year over the periods 1970–1990 and 1990–2000, (i.e. a doubling in under 23 years) and there will have been considerable associated land cover change. Detailed assessments of land cover change across the whole of the Sahel are not available and figures cannot be safely drawn from simple comparison of land cover maps from more local studies due to differing methodologies.

However, in a number of case studies, analysis of satellite images shows the extent of land cover change. Between 1975 and 2000, 29.2% of non-forest vegetation (savanna and shrubland) was lost from the central and eastern Sahel and this was coupled with a 14.2% increase in agricultural land (Brink and Eva 2009). Tappan *et al.* (2004) showed that, although there was a small national reduction in woodland cover in Senegal between 1965 and 2000, there were large regional variations. For example, agricultural expansion in some areas (e.g. the groundnut basin in west-central Senegal) had reduced woodland cover by almost 90% (Tappan *et al.* 2000). Similarly in the Sahelian central sandy Ferlo of north-eastern Senegal, analysis of images showed decline in the cover of woody vegetation from 10–15% in 1965 to 1–5% in 1994 (Tappan *et al.* 2004). There was a concomitant increase in the cover of rain-fed agriculture (mostly groundnuts and millet) from 1% in 1965 to 16% in 1999.These studies make it clear that the spatial pattern of change is complex. This has implications as many migrant species exhibit a high degree of spatial migratory connectivity, with different breeding populations often separated on the wintering grounds.

Other, more local, studies do document qualitatively similar patterns. Woodland declined, for example from 52% to 17% of land cover between 1967 and 2003 in a small 90 km^2 study area in Mali, while the area of agriculture rose from 11% to 23% (Ruelland *et al.* 2010). Around a protected area on the border of Benin, Burkina Faso, Niger and Togo, 14.5% of savanna was replaced by agriculture between 1984 and 2002 (Clerici *et al.* 2006). Other local studies report conversion of woodland to farmland, for example in Senegal (Morel and Betlem 1992, Gonzalez 2001) and north-eastern Nigeria (Geomatics International1998, Cresswell *et al.* 2007).

The causes of land cover change are complicated (Benjaminsen 2001, Tappan and McGahuey 2007, Brink and Eva 2009). Research has shown farmers and herders carefully manage soil fertility (Mortimore and Harris 2005), tree cover and biomass (Mortimore *et al.* 1999, Gautier *et al.* 2005). Low rainfall and human activities interact in complex ways. Woodlands in the Sahel (and further south) may be affected by climate-mediated stresses in low rainfall years as well as economic demands for agricultural land, fuelwood or livestock grazing (Gonzalez 2001, Newton 2004, Wilson and Cresswell 2006, Cresswell *et al.* 2007). There is evidence of the 'reversal' of desertification (Rasmussen *et al.* 2001), and the 'greening' of the Sahel since the early 1980s as vegetation recovers from the dry decades of the late twentieth century (Olsson *et al.* 2005). However this does not necessarily mean that the vegetation that birds require is restored. In a case study in Senegal, there had been an overall reduction in woody species richness, a loss of large trees, an increasing dominance of shrubs, and a shift towards more arid-tolerant, Sahelian species since 1983 (Herrmann and Tappan 2013).

The use of a participatory approach to harness and synthesise expert knowledge

The use of expert opinion to construct predictive models of species distribution has been criticised and found not necessarily to be appropriate for novel areas (Seoane *et al.* 2005). Our study simply described broad habitat associations, and has not attempted to extrapolate these to mapping potential distributions (something we do not think appropriate from our data). The lack of suitable temporally and spatially referenced bird and habitat data meant that a combination of published and in many cases peer-reviewed publications and expert opinion was the best available resource to determine habitat preferences. We suggest that as a 'data gathering' process the participatory approach worked well for a number of reasons, relating to both the planning and execution phases. First, in relation to planning, the research team undertook an extensive data-gathering exercise in advance and shared this with the participants. Additionally, participants had a clear understanding of the aim of the exercise, the specific objective and scope of the workshop, as well as the desired 'end product'. This was achieved through advance information and short introductory sessions, and was facilitated by a well-briefed chair. The choice of experts will undoubtedly influence the scores and we took measures to minimise bias by first defining the scope (species and habitats) and providing our 'preliminary habitat importance scores' based on published literature. This helped to maintain the focus and direct discussions towards the single, realistic 'product'—essentially a table of habitat importance scores for each species.

In retrospect, the process could have been improved in a number of ways: the project was not sufficiently resourced to allow us to invite workshop participation by experts from outside Europe, particularly those from countries within the Sahelian zone in question. However, a number of the workshop participants have lived for a number of years in the Sahelian countries involved, and others have spent a great deal of time undertaking fieldwork in those countries. This was mitigated to some extent by inviting participation via email, although, if resources allowed, similar exercises in the future could, perhaps more usefully, be undertaken in the country or region under focus.

Implications

Predicted future anthropogenic climatic change and increasing demands for food for growing human populations are likely to have impacts on ecosystems and wild species (Tilman *et al.* 2001, Walther *et al.* 2002, Green *et al.* 2005, Royal Society 2009). Many of the Sahelian countries are signatories to international instruments such as the Convention on Migratory Species and the Convention on Biological Diversity, but the knowledge to support decision-making for birds is inadequate given the complexity of the system. Our understanding of the implications of land use change in the Sahel for migrant birds is limited by knowledge of their habitat requirements. As a result, our understanding of how to make the large-scale influences necessary to improve habitats across large areas of the Sahel, and other habitats used by migrants in Africa, is even more limited. This is perhaps not surprising given that capacity for such research in many of the relevant African nations is relatively low and undertaking the extensive and detailed fieldwork required to identify the biological and environmental processes impacting bird populations in the northern winter is logistically challenging and financially expensive. Similarly, land cover change is the result of the interaction of local decisions of farmers and other land managers, the economic aspirations of growing rural and urban populations, and the economic context set by national policies and international investment, aid and trade; but detailed knowledge about how to influence these drivers is lacking.

In Europe, legal instruments such as the Birds and Habitats Directives, coupled with financial support through agri-environment schemes, provide a mechanism for making potentially very large cross-border changes in the wider environment. These schemes are supported by a large body of ecological research which allows evidence-based interventions. The challenges are different in the Sahel. The poverty of Sahelian countries makes the welfare of their urban and rural people the overwhelming policy priority. The decline of migrant landbirds in the Sahel may not seem important in relation to the Millennium Development Goals. Therefore, it is an important conservation priority to identify development strategies that sustain and do not damage the habitats of greatest importance to migrant birds. Developing a funding strategy, possibly involving some of the larger international policy instruments, to address this is an urgent and major challenge.

Currently the most rapidly declining migrants are those that inhabit woodland. Some of these will winter further south than the Sahel in the Guinea savannas but stage in the Sahel. Interventions that meet local development needs while sustaining tree and woodland cover (supporting changes happening spontaneously: Mortimore 1998, 2005) could be beneficial for migrant landbirds. Other forms of development (for example large-scale commercial farming, or commercial woodland monocultures of fast-growing exotic species such as *Eucalyptus* or *Prosopis*) could have negative impacts on both birds and local people. Engagement between the conservation and development communities is imperative if rural land use change in the Sahel is to be influenced in ways that benefit birds and local people.

Supplementary Material

The supplementary materials for this article can be found at journals.cambridge.org/bci

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