Bird Study

ISSN: 0006-3657 (Print) 1944-6705 (Online) Journal homepage: http://www.tandfonline.com/loi/tbis20

Habitat use of the Wood Warbler Phylloscopus sibilatrix during spring migration versus breeding season based on citizen science data

Nadja Weisshaupt & Javier Rodríguez-Pérez

To cite this article: Nadja Weisshaupt & Javier Rodríguez-Pérez (2017): Habitat use of the Wood Warbler Phylloscopus sibilatrix during spring migration versus breeding season based on citizen science data, Bird Study

To link to this article: http://dx.doi.org/10.1080/00063657.2017.1364696

Published online: 08 Sep 2017.

BIRD STUDY, 2017
https://doi.org/10.1080/00063657.2017.1364696

Habitat use of the Wood Warbler *Phylloscopus sibilatrix* during spring migration versus breeding season based on citizen science data

Nadja Weisshaupt and Javier Rodríguez-Pérez

Department of Ornithology, Aranzadi – Society of Sciences, Donostia-San Sebastian, Spain

ABSTRACT

Capsule: Citizen science data on Wood Warblers *Phylloscopus sibilatrix* showed that the species non-selectively used a wide variety of habitats during migration but had a tendency for settling to breed in forest and natural areas.

Aims: We tested the hypothesis that habitat used during spring stopovers in Spain differed from habitat use during the breeding period in Switzerland in a year of exceptional abundance as a result of persistent easterly winds in the Mediterranean.

Methods: Habitat use during spring migration 2015 was compared by using bootstrapping resampling techniques on citizen science data from Spain and Switzerland, comparing the land-cover categories between locations of observations with random pseudo-absences.

Results: Wood Warblers showed no preference for habitat features during migration and covered practically all available habitat types from urbanized areas to wetlands and forests, whereas in the breeding range birds showed an increasing tendency to be present in forest habitats.

Conclusions: Habitat use during spring migration covered most available habitat types from urbanized areas to wetlands and forests. Breeding habitat use was restricted to forested areas. Citizen science allowed a quick collection of biological data over a wide area to potentially identify large-scale biological patterns. This is essential to potentially manage international conservation efforts for declining species.

ARTICLE HISTORY
Received 29 November 2016
Accepted 20 July 2017

Bird migration is shaped by a variety of environmental factors directly modulated by the ecology and physical conditions of birds (Richardson 1978, Alerstam 1990). Adverse weather conditions (e.g. unfavourable winds, precipitation) can increase energy consumption or lead to unintended deviations from the migration route, so that only birds in good physical shape can cope. During their migratory journeys, birds pass through a diverse suite of habitat types, which could potentially fulfil their ecological requirements (Berthold 1975). In order to have sufficient energy resources, suitable habitats are essential for refuelling during migratory stopovers, in particular before and after crossing extensive geographical barriers such as the Mediterranean Sea, the Alps or the Sahara desert (Arizaga *et al.* 2011a, 2011b, Andueza *et al.* 2014). Birds associate these stopover sites with habitat features promising great food abundance and appropriate shelter (Petit 2000). Food availability is identified as the key driver for species' preference of stopovers during migration (Buler *et al.* 2007). Upon arrival at the breeding habitats, the choice in favour or against potential nesting sites would be generally determined by features related to patch quality (i.e. predator avoidance, intra- and inter-specific competition) and site fidelity (Cody 1985). So it could be hypothesized that habitat features useful for breeding might play a minor role while on the move (Fuller 2012). In the case of long-distance migrants with a declining population trend and/or high sensitivity to habitat quality, it is necessary to understand their habitat requirements throughout their life cycle to be able to provide transboundary management plans for their conservation.

The Wood Warbler *Phylloscopus sibilatrix* is an insectivorous long-distance migrant that winters in sub-Saharan Africa (Hoyo *et al.* 2006). It has been known that during the reproductive season the Wood Warbler exhibits low site fidelity when establishing territories (Herremans 1993, Wesolowski *et al.* 2009). A common feature of breeding habitat in northern and southeastern Europe is mature woodlands of Pedunculate Oak *Quercus robur* and Common Beech *Fagus sylvatica* (Glutz von Blotzheim & Bauer 1991). Its migratory journey leads it across the Mediterranean to Africa and back (Pilastro *et al.* 1998). The main

CONTACT Nadja Weisshaupt nw@nweisshaupt.net Department of Ornithology, Aranzadi – Society of Sciences, Zorrogagaina 11, 20014 Donostia-San Sebastian, Spain

migration flow concentrates in the central to eastern Mediterranean, with only few migrants passing the westernmost part (Pilastro *et al.* 1998, Barriocanal *et al.* 2011, Gargallo *et al.* 2011). Apart from the fact that the number of annual sightings are scarce on the Iberian Peninsula (De Juana & Garcia 2015), relatively little is known about the species' temporal, seasonal and geographical distribution when crossing this region on its migratory journey to its breeding quarters. Coinciding with a long period of easterly winds in the western Mediterranean in spring 2015 (MeteoCat), there was an unusually high influx of Wood Warblers in the northern and northeastern Iberian Peninsula at the western and eastern edges of the Pyrenees. Numbers of Wood Warblers usually reach about 10–50 observations in Catalonia in non-peak years (ornitho.cat). For the Basque Country there is no long-term data available to state any average numbers, but annual numbers are in the low one-digit range, if anything (ornitho.eus).

The aim of this study is to elucidate habitat use of the Wood Warbler during spring migration on the Iberian Peninsula in a year of exceptional abundance as a result of persistent easterly winds in the Mediterranean. First, habitat use was studied at regional scales to understand the habitat use during spring migration when crossing the Pyrenees. Then habitat use during migration was compared with the habitat use in a region located in the main breeding distribution. It is hypothesized that Wood Warblers choose a broader span of habitats during migration, depending on the habitat suitability, than during the breeding season.

Methods

Study area

In order to compare habitat use at stopover versus breeding sites, the study area comprised two regions: (1) the Iberian Peninsula, a highly important area for many bird species during migration (Moreau 1956), with a focus on the Basque Country and Catalonia, which are part of the natural border at the western and eastern ends of the Pyrenees (referred to as 'southern Pyrenees'); and (2) Switzerland which covers a variety of different habitats, from lowlands to the mountainous regions of the Alps (Figure 1). Stopover sites are occupied during migration, but vacated after a short period to reach the breeding grounds in due time, while range-margin breeding areas would remain occupied for actual breeding. Wood Warblers usually migrate over Italy in spring and autumn (Barriocanal *et al.* 2011), far from the Basque Country and Catalonia, whereas Switzerland is located in Central Europe, harbouring breeding populations of Wood Warblers (Hagemeijer & Blair 1997). The Basque Country (7200 km^2) has a predominantly oceanic climate and comprises of a mosaic of deciduous broad-leaf forest, managed coniferous forest, scrubland and pastures. Catalonia (32 000 km^2) has a Mediterranean climate and is dominated by evergreen broad-leaf and pine forests, alpine meadows and steppes. Forests are widespread in both areas including extensive areas of oak and beech forest, which would be suitable breeding habitat of Wood Warblers (Glutz von Blotzheim & Bauer 1991). Other habitat types include wetlands and dry semi-open and open landscapes such as parks and agricultural areas, which may be used as stopover sites by many migratory birds. Switzerland (41 000 km^2) has a variable climate including the entire range from Mediterranean to alpine climates. This area excels also in high habitat diversity, with mosaics of forests, agricultural landscapes, freshwater lakes, alpine meadows and largely uninhabited mountain ranges contrasting with the highly urbanized areas dominating the lowlands. These landscape features of Switzerland are similar to those available in the northern Iberian Peninsula, but embedded within the main breeding range of Wood Warblers (Figure 1). As Wood Warblers are still scarce breeders on the northern slopes of the Pyrenees (Issa & Muller 2015), the Swiss records were considered a suitable reference for habitat use.

Habitat use during spring migration and the breeding season

In order to test whether the Wood Warbler relies on a specific set of habitat features during the migration and breeding seasons, data were retrieved from the public ornithological data portals 'ornitho' of Catalonia (ornitho.cat), the Basque Country (ornitho.eus) and Switzerland (ornitho.ch). These platforms collect ornithological observations based on citizen science, typically including the basic information on species, date and location (global positioning system, GPS, location fixes with 20 m precision), as reported by any registered observer. Several other pieces of information can be entered additionally, such as number of individuals, activity, atlas code during the breeding season, comments or images. For the present study, Wood Warbler sightings were downloaded from Catalonia (ornitho.cat) and the Basque Country (ornitho.eus) and were limited to the period of April–June 2015, which corresponds to the species' peak migration period and the onset of its breeding season. In order to compare migration habitat against that

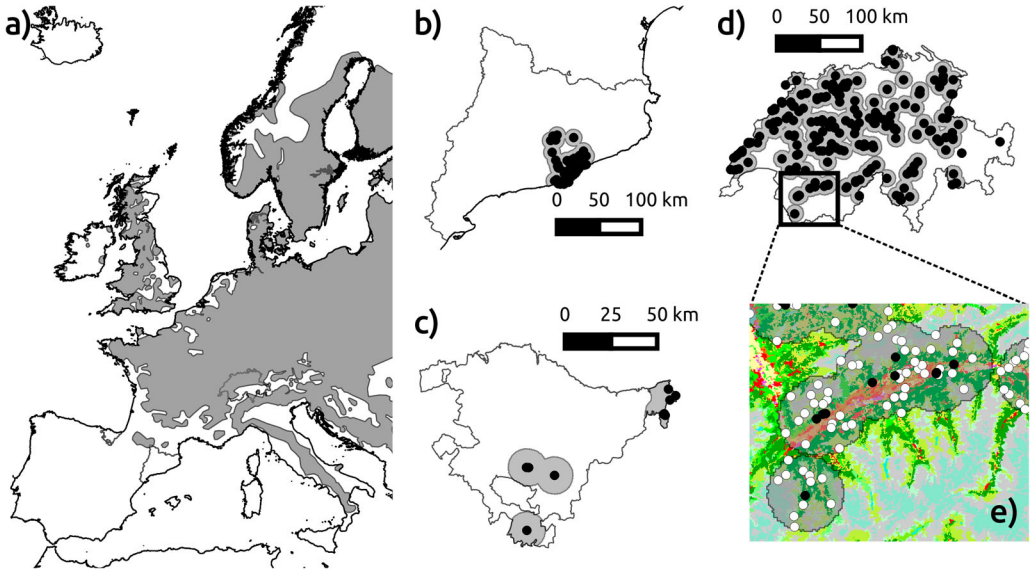

Figure 1. Breeding range of the Wood Warbler and studied regions (left panel), detail of studied regions (central panels), and the studied site on the northern Iberian Peninsula. (a) Grey areas depict the regular breeding range of Wood Warblers (BirdLife), and grey polygons represent the regions of (b) Catalonia, (c) the Basque Country and (d) Switzerland. Black points represent Wood Warbler sightings in spring 2015, encircled by grey areas with high probability of presences or sightings, and where we re-sampled pseudo-absences (see Methods). (e) Details of an area in Switzerland with colours representing habitat types derived from CORINE land-cover classification (European Environmental Agency), black points for locations with presences and white points for pseudo-absences (see Methods).

used at the breeding sites, Wood Warbler observations were obtained from Switzerland (ornitho.ch), which is part of the main breeding range (Hagemeijer & Blair 1997). Swiss records were restricted to mid-May to end of June 2015, corresponding with the main breeding period (Glutz von Blotzheim & Bauer 1991).

As we sought to explore the fine-scale habitat use at regional scale, environmental data were obtained from the CORINE (coordination of information on the environment) land-cover classification (http://dataservice.eea.europa.eu/dataservice/). The original database comprises 39 types of natural and semi-natural land-cover classes at 250 × 250 m pixel ground resolution; in the present case information was based on the Level 1 hierarchical classification, namely agricultural areas, artificial surfaces (including urban fabrics, industrial, commercial and transport units and green urban areas), forests and semi-natural areas (including deciduous and evergreen broad-leaf forests and coniferous forests) and wetlands; we did not consider water bodies. By using a geographical information systems (GIS) platform (QGIS Development Team 2014), the location of each Wood Warbler observation was overlaid with the CORINE land-cover classification, to extract the land-cover features of each record.

Additionally, as the study focused on the habitat use of Wood Warblers in comparison with other (unused) habitat available, the locations of actual records (presences, hereafter) were compared with sites or locations where observers could potentially observe a broad range of species, but did not find any Wood Warblers (pseudo-absences, hereafter). In the specific cases of observational data from citizen science, databases show spatio-temporal biases that need to be taken into account before defining any hypothesis or analysis (Kelling *et al.* 2009). Pseudo-absences were thus determined as locations with a high probability (0.95) of observations, that is, in close proximity to sightings and/or areas with a high density of observers. To obtain an area of high probability of observations, a density map derived from a Kernel Density Estimation was first calculated. This method describes an area of high probability of Wood Warbler sightings, based on the spatial distribution of actual presence. The area was restricted to a distance of less than 10 km from the observation records (Figure 1). Second, pseudo-absences were randomly generated for 1000 locations, conditional to the area with high probability of observations (Figure 1). And third, land-cover information (CORINE land-cover classification) was extracted for pseudo-absence locations. This procedure was repeated for all the study regions. Kernel estimations and random point generation were calculated with QGIS (QGIS Development Team 2014).

In order to ensure that our conclusions were robust, a highly conservative approach was used, the

non-parametric bootstrapping technique for unbalanced data (Chernick & LaBudde 2011). For each region a number ($n = 30$) of presence and pseudo-absence sites (with replacement from original data) were randomly re-sampled, the proportion of presence and pseudo-absence sites in the four land-cover categories (i.e. agricultural areas, artificial surfaces, forests and semi-natural areas and wetlands) was calculated and a chi-square test was used to account for differences in the percentage of land-cover types between presence and pseudo-absence sites. The bootstrapping procedure was repeated 1000 times, and for each iteration a chi-square test between a sample of presence and pseudo-absence sites and the mean of chi-square tests over sampling replications was calculated. For more information on this approach see Chernick & LaBudde (2011). All analyses were executed using the package *ecodist* (version 1.2.2; Goslee & Urban 2007) using R software version 3.0.1 (R Development Core Team 2011).

Results

From early April to mid-May, 166 and 11 Wood Warblers were sighted in Catalonia and the Basque Country, respectively, mostly (approximately 90%) reported between the second half of April and the first half of May (Figure 2), with some staying well into June. In Switzerland, 1005 observations were recorded. For Catalonia, the habitat where Wood Warblers were located was significantly different from the random, pseudo-absence points, so Wood warbler presence did not extend to available habitat (Bootstrapped Pearson's chi-square test = 14.75, $P = 0.016$). In contrast, in Switzerland the available habitat did not differ significantly from the habitat at sites where Wood Warblers were located (Bootstrapped chi-square test = 4.05, $P = 0.351$) (Figure 3). Because of the low sample size, no analysis was performed for the habitat use in the Basque Country. In Catalonia, Wood Warblers were mostly detected on artificial surfaces and in wetlands, and only rarely in forest and natural areas. In Switzerland, by contrast, most observations originated from forests and natural areas and wetlands, while agricultural habitat yielded the lowest number of sightings.

Discussion

It is generally recognized that migrants prefer refuelling sites with high food availability given their elevated energy consumption while on the wing (Berthold *et al.* 2003). In this context they can use a broader set of habitats during migration than during the breeding season (Leisler 1990, 1992, Igl & Ballard 1999) in which other factors such as appropriate nesting sites, mate presence or level of disturbance might be decisive. In Catalonia, a high number of observations originated from artificial surfaces, attributed to the many parks with deciduous trees in cities (mainly Barcelona). The urban parks can be considered relatively safe refuelling sites with potentially lower predation pressure (given human presence), an aspect that was observed to be relevant both during stopover (Pomeroy *et al.* 2006) and breeding (Grendelmeier *et al.* 2015). These parks would be unsuitable to rear offspring, though, especially as the Wood Warbler is a ground-nesting species in need of certain vegetation cover (Grendelmeier *et al.* 2015). Also

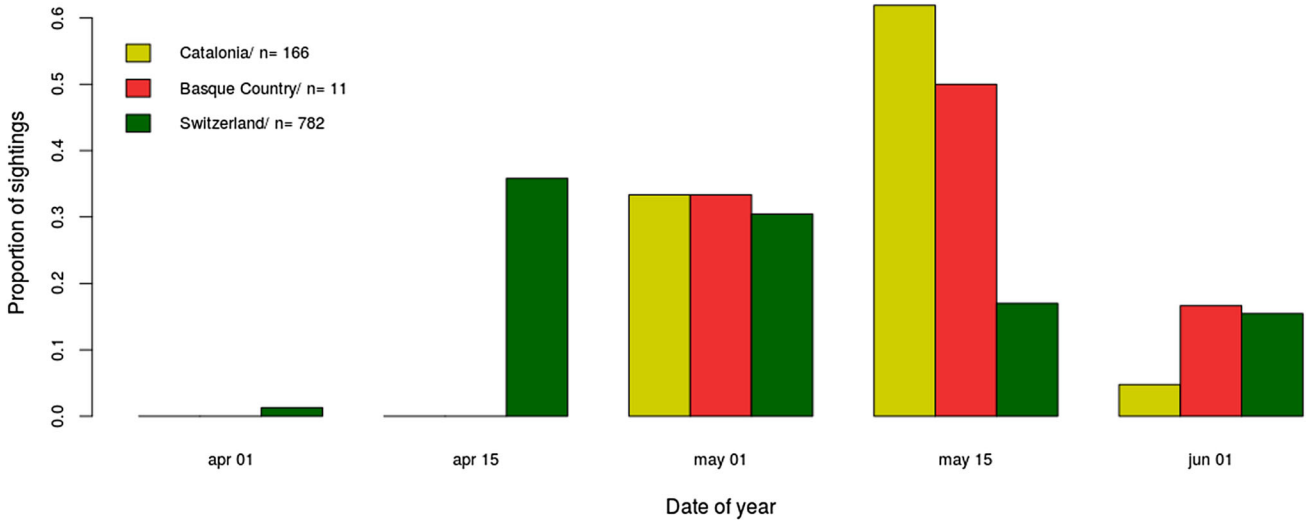

Figure 2. Proportion of sightings of Wood Warblers in Catalonia, the Basque Country and Switzerland in two-week intervals. The time on the horizontal axis denotes the start date of the two-week period. The number of observations for each region is included in the legend.

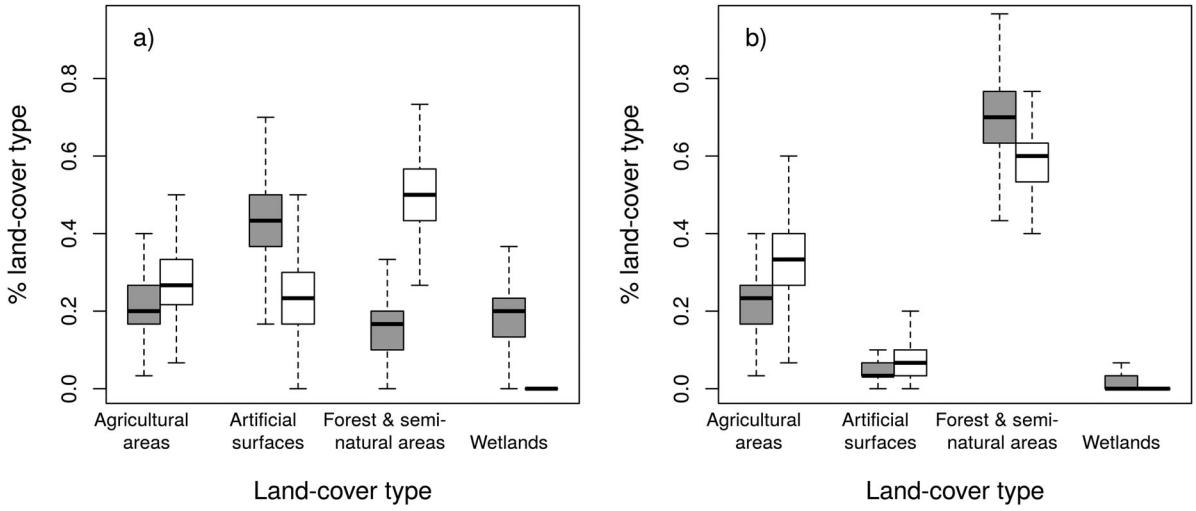

Figure 3. Proportion of four land-cover types comparing observed presences (boxplots in grey) and pseudo-absences (boxplots in white) during the stopover and the breeding period of Wood Warblers. For Catalonia (a), sightings were reported during migration from mid-April to mid-May, whereas for Switzerland (b) sightings were in the breeding season, from mid-May to the end of June.

in the view of the few sightings later in season, that is, after mid-May mostly in wetlands or well into June in forested areas in the Basque Country, the urban areas seem to be only used for a very short amount of time.

An observer bias cannot be excluded for the parks in Barcelona, but spatial biases were explicitly taken into account in the present analysis. However, given the high diversity of habitats in Catalonia, with well developed and frequented mountain areas, along with extensive forest, it seems reasonable that Wood Warblers should have been detected also in inland areas and over longer periods of time, if they had been present in similar numbers as on the coast and until the breeding season. In any case, it seems plausible that artificial habitats and coastal wetlands otherwise unoccupied by the species are voluntarily accepted as first refuelling sites after crossing the Mediterranean Sea. Still, the semi-open landscapes used during migration resemble findings on habitat use in the African staging and wintering areas, where the species preferred semi-open forested and agricultural areas (Mallord *et al.* 2016). It suggests that this species is more flexible as to habitat preference outside its breeding period.

In the western Mediterranean the species is particularly common in northeast Morocco, Algeria and on the Balearic Islands, which suggests that some birds must follow more southwest–northeast routes to their European breeding grounds (Gargallo *et al.* 2011) or be heading to breeding sites in north or northwest Europe. Peak years of Wood Warbler presence on the Iberian Peninsula, as was the case in 2015 (MeteoCat), have been linked to strong easterly winds (Barriocanal *et al.* 2011). It can be assumed that presence in 2015 was triggered by easterly winds over the Mediterranean too, rather than adverse conditions in more northern breeding regions (e.g. unusually high precipitation rates in April and May 2015 [MET Norway, SMHI]) that might have halted migration. Adverse conditions in the north would not lead to an eastward shift of migration in the south, so migrants would still be expected to enter via the Italian Peninsula. Therefore the sightings on the Iberian Peninsula would most likely be due to birds that deviated considerably from their usual trajectory when crossing the central or eastern Mediterranean, following a south-to-north flight direction from North Africa. Such birds, having suffered from wind drift, might find themselves in rather poor conditions (Drake *et al.* 2014).

The westernmost edge of the northern Iberian Peninsula (which includes the Basque Country and Navarre in Spain) does not represent a regular transit area of the Wood Warbler. However, its backcountry exhibits habitat features similar to the lowlands, which could potentially be attractive for the species. For instance, during the unusual influx of birds in spring 2015, five confirmed different Wood Warblers were detected through their singing activity in the mature oak and oak-beech forests of Artikutza (Navarre, north Spain). The first was discovered on 10 May 2015 (N.W.) and the last one on 5 June 2015 (J.R.), with recurring observations during April and May 2017 (ornitho.eus). The presence of females could not be confirmed and no interaction between the individual males could be observed. Similar habitat features are found in the foothills and valleys of the Alps in Switzerland, that is, patches of deciduous and coniferous forests, agricultural areas and a tight network of human settlements.

It is important to highlight that the differential habitat use observed during Wood Warbler migration could not be considered as a proxy of habitat preference. Observation records, especially of birds during migration, give no evidence for actual habitat use for refuelling or just resting before the next bout of flight. In any case, after controlling for areas with high observation probability great differences in habitat use were observed which potentially suggests the use of specific areas along the species' migration route. During spring migration, the largest relative frequencies are at well-vegetated sites with some forested areas, suggesting that the Wood Warbler is sensitive in terms of habitat requirements (Gargallo *et al.* 2011), and that may have relevant conservation implications for this declining species (BirdLife International 2004).

Conclusions

Growing evidence has been collected in recent decades that many trans-Saharan migrants are facing a marked population decline (Schmid *et al.* 2001, Heldbjerg & Fox 2008), mainly as a consequence of large-scale factors (i.e. drivers of global change) along migration routes and in wintering areas (Mallord *et al.* 2016). To conserve long-distance migratory species it is essential to understand the habitat use both within and outside the breeding area, along the migration routes and in the wintering areas, to potentially coordinate and link conservation efforts across borders. One tool to collect sightings is offered by standardized citizen science observation platforms such as those consulted in this study of the long-distance migrant Wood Warbler, which enable quick collection of biological data over a wide area and which allow us to anticipate and mitigate large-scale threats to biodiversity (Kelling *et al.* 2009). It proved of great value having standardized observation platforms in the sampled areas. Considering the importance of southern Europe for both migratory and sedentary birds whose dynamics are still poorly studied in many parts, efforts towards a nationwide coverage through bird observation platforms should be encouraged. Such platforms would provide the basis for standardized cross-border data, enabling analyses related to large-scale migration and use of wintering grounds.

Acknowledgements

We thank all active observers who contributed their Wood Warbler sightings in different parts of Europe as well as the ornitho teams of Aranzadi Society of Sciences, the Swiss Ornithological Institute and the Catalan Ornithological Institute (ICO) for providing us with the observation records. Finally we acknowledge the valuable inputs of two anonymous reviewers that contributed to improve an earlier version of the manuscript.

Funding

This study was partially funded by the City Council of Donostia/San Sabastian (Spain) with the aim of improving the knowledge on the biodiversity of the Special Area of Conservation (SAC) Artikutza.

References

Alerstam, T. 1990. *Bird Migration*. Cambridge: Cambridge University Press.

Andueza, M., Arizaga, J., Barba, E. & Tamayo-Uria, I. 2014. Spatial distribution and habitat use of reed warblers *Acrocephalus scirpaceus* during the autumn migration. *Behaviour* **151:** 799–817.

Arizaga, J., Belda, E. & Barba, E. 2011a. Effect of fuel load, date, rain and wind on departure decisions of a migratory passerine. *J. Ornithol.* **152:** 991–999.

Arizaga, J., Sánchez, J.M., Díez, E. Cuadrado, J.F., Asenjo, I., Mendiburu, A., Jauregi, J.I., Alfredo Herrero, H., Zuriñe Elosegi, H.Z., Iñaki Aranguren, I., Miren Andueza, M. & Alonso, D. 2011b. Fuel load and potential flight ranges of passerine birds migrating through the western edge of the Pyrenees. *Acta Ornithol.* **46:** 19–28.

Barriocanal, C., Monserrat, D. & Robson, D. 2011. The influence of wind direction on the capture of the wood warbler (*Phylloscopus sibilatrix*), an uncommon migratory species in the western Mediterranean. *Int J Biometeorol.* **55:** 789–795.

Berthold, P. 1975. Migration control and metabolic physiology. In Farner, D.S., King J.R. (eds) *Avian Biology*, Vol. **5:** 77–128. Academic Press, New York, NY.

Berthold, P., Gwinner, E. & Sonnenschein, E. 2003. *Avian Migration*. Springer Verlag, Heidelberg.

BirdLife International. 2004. *Birds in Europe: Population Estimates, Trends and Conservation Status*. Birdlife International, Cambridge.

Buler, J.J., Moore, F. & Woltmann, S. 2007. A multi-scale examination of stopover habitat use by birds. *Ecology.* **88:** 1789–1802.

Chernick, M.R. & LaBudde, R.A. 2011. *An Introduction to Bootstrap Methods with Applications to R.* John Wiley & Sons, Inc, Hoboken, NJ.

Cody, M.L. 1985. An introduction to habitat selection in birds. In Cody, M.L. (ed) *Habitat Selection in Birds*. Chapter 1: 4–58. London: Academic Press Inc.

De Juana, E. & Garcia, E. 2015. *The Birds of the Iberian Peninsula*. Christopher Helm, London.

Del Hoyo, J., Elliot, A. & Christie, D. (eds) 2006. *Handbook of the Birds of the World. Volume 11: Old World Flycatchers to Old World Warblers*. Barcelona: Lynx Edicions.

Drake, A., Rock, C.A., Quinlan, S.P., Martin, M. & Greer, D.J. 2014. Wind speed during migration influences the survival, timing of breeding, and productivity of a Neotropical migrant, Setophaga petechia. *PLoS ONE* **9:** e97152. Doi:10.1371/journal.pone.0097152.

Fuller, R.J. 2012. Habitat quality and habitat occupancy by birds in variable environments. In Fuller, R.J. (ed) *Birds and Habitat: Relationships in Changing Landscapes*, 37–62. Cambridge University Press, Cambridge.

Gargallo, G., Barriocanal, C., Castany, J., Clarabuch, O., Escandell, R., López-Iborra, G., Rguibi-Idrissi, H., Robson, D. & Suárez, M. 2011. Spring migration in the western Mediterranean and NW Africa: the results of 16 years of the Piccole Isole project. *Monografies del Museu de Ciencies Naturals* **6:** 1–364.

Glutz von Blotzheim, U.N. & Bauer, K.M. 1991. *Handbuch der Vögel Mitteleuropas*. 12/11: Passeriformes (3.Teil). Aula, Wiesbaden.

Goslee, S.C. & Urban, D.L. 2007. The ecodist package for dissimilarity-based analysis of ecological data. *J. Stat. Softw.* **22**: 1–19.

Grendelmeier, A., Arlettaz, R., Gerber, M. & Pasinelli, G. 2015. Reproductive performance of a declining forest passerine in relation to environmental and social factors: implications for species conservation. *PLoS ONE* **10:** e0130954. Doi:10.1371/journal.pone.0130954.

Hagemeijer, E.J.M. & Blair, M.J. (eds) 1997. *The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance*. T & A.D. Poyser, London.

Heldbjerg, H. & Fox, T.A.D. 2008. Long-term population declines in Danish trans-Saharan migrant birds: capsule long-distance migrant birds show less favourable trends than sedentary/short-distance species. *Bird Study* **55:** 267–279.

Herremans, M. 1993. Clustering of territories in the Wood Warbler *Phylloscopus sibilatrix*. *Bird Study* **40:** 12–23.

Igl, L.D. & Ballard, B.M. 1999. Habitat associations of migrating and overwintering grassland birds in southern Texas. *Condor* **101:** 771–782.

Issa, N. & Muller, Y. 2015. *Atlas des oiseaux de France métropolitaine. Nidification et presence hivernale*, Vol 2. des Ptéroclididés aus Embérizidés LPO/SEOF/MNHN Delachaux et Niestlé, Paris.

Kelling, S. Hochachka, W.M., Fink, D., Riedewald, M., Caruana, R., Ballard, G. & Hooker, G. 2009. Data-intensive science: a new paradigm for biodiversity studies. *BioScience* **59:** 613–620.

Leisler, 8. 1990. Selection and use of habitat of wintering migrants. In Gwinner, E. (ed) *Bird Migration*, 156–174. Springer Verlag, Berlin

Leisler, 8. 1992. Habitat selection and coexistence of migrants and afrotropical residents. *Ibis* **134:** 77–82.

Mallord, J.W., Smith, K.W., Bellamy, P.E., Charman, E.C. & Gregory, R.D. 2016. Are changes in breeding habitat responsible for recent population changes of long-distance migrant birds? *Bird Study* **63:** 250–261.

MeteoCat - Servei Meteorologic de Catalunya. http://static-m.meteo.cat/wordpressweb/wp-content/uploads/2014/11/19090032/EMA_taules2015.pdf [Last accessed 9 April 2017].

Moreau, R. 1956. The Iberian Peninsula and migration. *Bird Study* **3:** 1–25.

Ornitho.cat. www.ornitho.cat, ICO-Institut Català d'Ornitologia (Catalan Ornithological Institute). Doi: 10.15470/dijq3a [Last accessed 18 April 2017].

Ornitho.ch. www.ornitho.ch, Swiss Ornithological Institute. [Last accessed 18 April 2017].

Ornitho.eus. www.ornitho.eus, Aranzadi Science Society. Doi:10.15470/jpxois [Last accessed 18 April 2017].

Petit, D. R. (2000) Habitat use by landbirds along Nearctic-Neotropical routes: implications for conservation of stopover habitats. In Moore, F.R. (ed) *Stopover Ecology of Nearctic-Neotropical Landbird Migrants: Habitat Relations and Conservation Implications. Studies in Avian Biology 20*, 15–33. Kansas: The Cooper Ornithological Society.

Pilastro, A., Macchio, S., Massi, A., Montemaggiori, A. & Spina, F. 1998. Spring migratory routes of eight trans-Saharan passerines through the central and western Mediterranean; results from a network of insular and coastal ringing sites. *Ibis* **140:** 591–598.

Pomeroy, A.C., Butler, R.W. & Ydenberg, R.C. 2006. Experimental evidence that migrants adjust usage at a stopover site to trade off food and danger. *Behav. Ecol.* 1041–1045. Doi:10.1093/beheco/arl043.

QGIS Development Team. 2014. QGIS Geographic Information System. Open Source Geospatial Foundation. http://qgis.osgeo.org.

R Development Core Team. 2011. R: A Language and Environment for Statistical Computing. Vienna, Austria: the R Foundation for Statistical Computing. ISBN: 3-900051-07-0. http://www.R-project.org/.

Richardson, W.J. 1978. Timing and amount of bird migration in relation to weather: a review. *Oikos* **30:** 224–272.

Schmid, H., Burkhardt, M., Keller, V., Knaus, P., Volet, B. & Zbinden, N. 2001. Die Entwicklung der Vogelwelt in der Schweiz. Avifauna Report Sempach 1, Annex.

Swedish Meteorological and Hydrological Institute (SMHI). http://www.smhi.se/klimatdata/meteorologi/nederbord [Last accessed 13 May 2016].

Wesolowski, T., Rowinski, P. & Maziarz, M. 2009. Wood Warbler *Phylloscopus sibilatrix*: a nomadic insectivore in search of safe breeding grounds? *Bird Study* **56:** 26–33.