GfÖ
GfÖ Ecological Society of Germany, Austria and Switzerland
Basic and Applied Ecology 17 (2016) 177–187
Basic and Applied Ecology
www.elsevier.com/locate/baae

Use of stable isotope fingerprints to assign wintering origin and trace shorebird movements along the East Atlantic Flyway

Teresa Catry[a,*], Pedro M. Lourenço[a], Ricardo J. Lopes[b], Pierrick Bocher[c], Camilo Carneiro[d,e,f], José A. Alves[e,f], Philippe Delaporte[g], Stuart Bearhop[h], Theunis Piersma[i,j], José P. Granadeiro[a]

[a]*Centro de Estudos do Ambiente e do Mar, Departamento de Biologia Animal, Faculdade de Ciências da Universidade de Lisboa, 1749-016 Lisboa, Portugal*
[b]*CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Universidade do Porto, 4485-661 Vairão, Portugal*
[c]*Laboratory Littoral Environnement et Sociétés, UMR 7266 LIENSs, CNRS-University of La Rochelle, 2 rue Olympe de Gouges, 17000 La Rochelle, France*
[d]*Museu Nacional de História Natural e da Ciência, Universidade de Lisboa, Rua da Escola Politécnica 58, 1250-102 Lisboa, Portugal*
[e]*Centro de Estudos do Ambiente e do Mar, Universidade de Aveiro, Campus Universitário de Santiago, 3180-193, Aveiro, Portugal*
[f]*South Iceland Research Centre, University of Iceland, Tryggvagata 36, IS-800 Selfoss, Iceland*
[g]*Réserve Naturelle Nationale de Moëze-Oléron, Ligue pour la Protection des Oiseaux, Plaisance, 17180 Saint-Froult, France*
[h]*Centre for Ecology & Conservation, Penryn Campus, University of Exeter, Penryn TR10 9EZ Cornwall, UK*
[i]*NIOZ Royal Netherlands Institute for Sea Research, PO Box 59, 1790 AB, Den Burg, Texel, The Netherlands*
[j]*Global Flyway Ecology, Animal Ecology Group, Centre for Ecological and Evolutionary Studies, University of Groningen, PO Box 11103, 9700 CC Groningen, The Netherlands*

Received 7 May 2015; accepted 27 October 2015
Available online 3 November 2015

Abstract

Migratory connectivity can be defined as the flux of individuals or populations among areas between stages of an animal's life cycle. Many shorebird species perform long-distance migrations and while moving between breeding and wintering grounds, they depend on a network of intermediate wetlands (stopover sites) where populations of different origins extensively overlap. The difficulty to discriminate such populations represents a serious obstacle to the identification of the links between breeding or wintering areas and stopover sites, and also precludes the estimation of demographic parameters for each population. In this study, we test if linear discriminant models based on stable carbon and nitrogen isotope ratios in toenails can be used to identify populations of several shorebird species of different wintering origins overlapping at two stopover sites of the East Atlantic Flyway. In addition, we evaluate the ability of this approach to infer migratory phenological patterns of shorebirds. Linear discriminant analyses performed overall well in distinguishing the isotopic signals of birds from wintering areas (in France, Portugal, Morocco, Mauritania and Guinea-Bissau) in most species, correctly classifying over 80% ($n = 542$) of all wintering

*Corresponding author. Tel.: +351 217500000; fax: +351 217500028.
E-mail address: teresa.catry@gmail.com (T. Catry).

http://dx.doi.org/10.1016/j.baae.2015.10.005

individuals sampled at these areas. Assignment rates of shorebirds captured during spring migration were also high (96%, $n=323$) at the Tejo estuary, Portugal, but lower (40%, $n=185$) at Marennes-Oléron Bay in France, and also differed among species. A large proportion of spring migrants captured in Portugal and France were assigned to Banc d'Arguin in Mauritania, the most important wintering area in the flyway. Phenological patterns derived for dunlins (*Calidris alpina*), common ringed plovers (*Charadrius hiaticula*) and grey plovers (*Pluvialis squatarola*) suggest that the first northward migrants started arriving at the Tejo estuary during the second half of March, with peaking numbers occurring during April or May.

Zusammenfassung

Migrationskonnektivität kann als die Wechselrate von Individuen oder Populationen in bestimmten Gebieten zwischen zwei Phasen im Lebenszyklus einer Art definiert werden. Viele Watvögel legen weite Strecken zurück, und während des Zuges zwischen Brut- und Überwinterungsgebieten benötigen sie ein Netzwerk von Feuchtgebieten als Rastplätze, wo Populationen unterschiedlicher Herkunft zusammen kommen. Die Schwierigkeit, solche Populationen zu unterscheiden, stellt ein schwerwiegendes Hindernis für die Bestimmung der Verbindungen zwischen Brut- bzw. Überwinterungsgebieten und den Rastplätzen dar und verhindert außerdem die Bestimmung von demographischen Parametern für einzelne Populationen. Wir testeten, ob -basierend auf den Signaturen der stabilen Kohlenstoff- und Stickstoffisotope in Zehennägeln- lineare Diskriminanzmodelle eingesetzt werden können, um die unterschiedlichen Überwinterungsgebiete von Watvögeln zu identifizieren, die an zwei Rastplätzen entlang des Ostatlantischen Zugweges zusammentrafen. Wir bewerteten außerdem die Fähigkeit dieser Methode, Rückschlüsse auf phänologische Muster der ziehenden Watvögel zuzulassen. Die lineare Diskriminanzanalyse bewährte sich für die meisten Arten gut bei der Unterscheidung von Isotopensignaturen der Vögel aus unterschiedlichen Überwinterungsgebieten (Frankreich, Portugal, Marokko, Mauretanien und Guinea-Bissau). Mehr als 80% ($n=542$) der in diesen Gebieten untersuchten überwinternden Individuen konnten korrekt eingeordnet werden. Die Zuordnungsraten der Watvögel, die während des Frühjahrszuges im Mündungsgebiet des Tejo gefangen wurden, waren ebenfalls hoch (96%, $n=323$), sie waren aber geringer (40%, $n=185$) in der Marennes-Oléron-Bucht (Frankreich) und variierten zwischen den Arten. Ein hoher Anteil von Frühjahrsziehern, die in Portugal und Frankreich gefangen wurden, wurde dem Banc d'Arguin-Nationalpark (Mauretanien) zugeordnet, dem wichtigsten Überwinterungsgebiet des Zugweges. Phänologische Muster von Alpenstrandläufer (*Calidris alpina*), Sandregenpfeifer (*Charadrius hiaticula*) und Kiebitzregenpfeifer (*Pluvialis squatarola*) legten nahe, dass die ersten nordwärts ziehenden Vögel während der zweiten Märzhälfte im Mündungsgebiet des Tejo ankamen, wonach die Spitzenwerte im April oder May erreicht wurden.

Keywords: Migratory connectivity; Stable isotopes; Stopover sites; Discriminant analysis; Toenails

Introduction

The study of migratory connectivity involves not only linking populations across geographic areas between different stages of their annual cycle but also quantifying demographic flows and identifying migratory strategies (Webster & Marra 2005). Many of the ecological processes that determine population dynamics of migrants are triggered by individual behavioural decisions, such as where to go, how long to stay, and when to leave (Bearhop, Hilton, Votier, & Waldron 2004; Schaub, Jenni, & Bairlein 2008; Covino, Holberton, & Morris 2014). Therefore, identifying the origins of individuals sharing migratory routes and stopover sites is crucial to interpret inter-individual behavioural variability and further determine how changes driven by rapid habitat and/or climatic alterations in particular areas will impact populations.

Most shorebird species perform long-distance migrations, the individuals completing, twice a year, lengthy flights linking breeding and wintering grounds (van de Kam, Ens, Piersma, & Zwarts 2004). While breeding areas are mainly confined to the Arctic tundra and other high-latitude grounds, wintering shorebirds disperse over much wider latitudinal ranges, both through the northern and southern hemispheres. Beside their impressive migrations, shorebirds are also notorious for gathering in large numbers and by their dependence on a network of stopover sites along migratory routes (Delany, Scott, Dodman, & Stroud 2009). These areas are critical for birds to rest and to fuel the remaining migratory journey, and may form significant bottlenecks for migration (Buehler & Piersma 2008; Iwamura et al. 2014). At stopover sites, populations of mixed origins often adopting different migratory strategies overlap extensively (e.g. Atkinson et al. 2005; Masero et al. 2009), and the overall inability to discriminate such populations represents a serious obstacle for the estimation of demographic parameters for each one of them.

Tracking technology, which largely replaced ringing approaches that provided low and biased amounts of data, currently faces rapid development and new devices are being