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The Indian Ocean Dipole as an indicator of climatic conditions affecting European birds

Piotr Tryjanowski[1,*], Nils Chr. Stenseth[2], Beata Matysioková[3]

[1]Institute of Zoology, Poznań University of Life Sciences, 60-625 Poznań, Poland
[2]Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biosciences, University of Oslo, 0316 Oslo, Norway
[3]Department of Zoology and Laboratory of Ornithology, Palacký University, 77146 Olomouc, Czech Republic

ABSTRACT: Variation in large-scale climatic conditions can have profound effects on local weather patterns and ecological processes. For example, it is well known that a positive shift in the North Atlantic Oscillation (NAO) during the last 2 decades has coincided with warmer, wetter winters over Northern Europe and advances in spring phenology, including both migration and breeding of birds. However, the effect of the NAO is not evident throughout the Northern Hemisphere and the same is true of the El Niño-Southern Oscillation (ENSO), which has been linked to survival of northern birds wintering in Africa. Recently, a growing body of evidence suggests that an independent ocean circulation system in the Indian Ocean, the Indian Ocean Dipole (IOD), is partly responsible for driving climate variability in the surrounding landmasses. The IOD had traditionally been viewed as an artefact of the ENSO system, although increasingly evidence is accruing that it is a separate and distinct phenomenon. Here we present some results on the causes of the IOD, how it develops within the Indian Ocean, its relationships with the ENSO, and the consequences for East African climate dynamics and associated impacts on ecosystems, in particular along the Eastern Arc Mountains of Kenya and Tanzania. In this opinion article we evaluate current research initiatives focused on characterizing the IOD, and examine how effective these will be in determining climate change impacts on East African ecosystems, particularly with respect to avian lifecycles.

KEY WORDS: Climate changes · ENSO · Indian Ocean Dipole · IOD · Migratory path · Large-scale indices · NAO · Spatial-temporal changes

1. INTRODUCTION

Climate changes in recent decades have had a strong documented worldwide impact on ecosystems and organisms, with the greatest impact on phenology (Walther et al. 2002). Plants are blooming and leafing earlier, insects have advanced their first flights or time of spring emergence, and an earlier start of reproduction has been observed in some amphibians, reptiles and mammals. Similarly in birds, which are undoubtedly the best-studied group, climate change has affected the timing of arrival at nesting sites and of breeding (Dunn 2004, Newton 2008, Knudsen et al. 2011).

Migration is a key aspect of the life histories of migratory birds (Newton 2008), and its timing is known to have an effect on their survival and reproductive performance. For example, reproductive success usually decreases with later arrival time (Dunn 2004). However, premature arrival can also be disadvantageous if ecological conditions on breeding grounds are unfavourable (Newton 2008). Similarly, birds could become ecologically mismatched if the advance in their arrival date has not fully compensated for climate change and thus the timing of arrival to the breeding grounds is not synchronized with the peak of their food source (Saino et al. 2011). In recent decades, advance in spring arrival dates of

*Email: piotr.tryjanowski@gmail.com

both short- and long-distance migrants has been observed (Knudsen et al. 2011). Advanced arrivals can thus result from earlier departure and/or quicker migration. There are several ways that climate can affect both the timing of departure and migration speed. For example, onset of migration can be determined by food availability in wintering areas (Studds & Marra 2011, Altwegg et al. 2012), which is in turn affected by weather conditions. In this way, timing of departure can be indirectly affected by climate fluctuations. Similarly, weather conditions have an effect on the number and duration of stopovers, which in turn influence migration speed (Gordo 2007, Tøttrup et al. 2012). Moreover, favourable weather conditions (e.g. tailwinds) can increase flying speed while unfavourable weather conditions (e.g. headwinds, crosswinds, heavy rainfall) can decrease it (Richardson 1978). Hence, by influencing conditions in wintering areas and along the migration route, climate changes can influence arrival times of migratory birds (Lehikoinen et al. 2004, Both 2010).

Here we suggest that using information on the Indian Ocean Dipole (IOD) could improve understanding of the response of European birds to climate factors.

2. LARGE-SCALE CLIMATE INDICES

Large-scale climatic characteristics (freely available from the Internet) are often used to ascertain the relationship between climate and avian phenology. However, large-scale climate indices, by definition, are characterized by low geographical resolution (Stenseth et al. 2003). Despite the fact that over a dozen large-scale climate indices have been defined by climatologists, only the El Niño-Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) are commonly used by ecologists (Stenseth et al. 2003).

In simple words, the ENSO is an irregular fluctuation between cold (La Niña) and warm (El Niño) phases occurring across the tropical Pacific Ocean (Latif & Keenlyside 2009). During the warm El Niño phase, extensive rainfall (extensive drought) can be observed in the eastern (western) Pacific. The (winter) NAO is defined as the difference between the normalized sea-level pressures at the Azores and Iceland averaged over the period December–March, characterizing the meteorological situation in winter and early spring. A positive NAO phase is associated with increased temperature and precipitation in northern Europe and south-eastern North America, and drier conditions over southern Europe and the Mediterranean (Hurrell & Loon 1997). The effects of the ENSO can be directly observed in the climate of the subtropical and tropical Pacific Ocean while the NAO is the major cause of weather and climate fluctuation in the North Atlantic region (Stenseth et al. 2003, Latif & Keenlyside 2009).

Phenological studies are geographically biased, and most of the studies on climate and avian phenology come from the Northern Hemisphere. Therefore, it is not surprising that the NAO is used frequently in phenology studies (reviewed in Gordo, 2007). A relationship between the NAO and avian phenology has been detected in a number of studies, especially in short-distance migrants showing advanced arrival dates in years with a positive NAO index (Hubálek 2003, Palm et al. 2009). However, this relationship was not observed in most of the studied long-distance migrants (Hubálek 2003, Palm et al. 2009, but see Hüppop & Hüppop 2003, Horev et al. 2010). Null or weak relationships between the NAO and arrival time in long-distance migrants is often explained by the onset of migration being under stronger endogenous control in those species (Newton 2008). This could be maladaptive in a changing climate, and could become an evolutionary trap (Schlaepfer et al. 2002). However, it is possible that the timing of migration in those species is flexible and under the influence of climatic conditions in wintering areas or along the migration route, but that indices with only low predictive values are being used.

A number of species from central and eastern Europe migrate to their wintering grounds via the Balkan Peninsula and the Middle East, and winter in East Africa (Newton 2008, Shobrak 2011), where the signal of the NAO is weak (Hurrell & Loon 1997). For example, in the Czech Republic and Slovakia >24 % of long-distance migrants with a known direction of migration (n = 37) migrated to their wintering grounds in Africa in a southeastern direction via the Balkan Peninsula and the Middle East (Cepák et al. 2008). Moreover, nearly 58 % of Czech and Slovakian long-distance migrants (n = 66) wintered (at least partly) in East or Central Africa (Cepák et al. 2008). Therefore, the value of using the NAO in studies of long-distance migrants breeding in central and eastern Europe to investigate relationships between climate and avian phenology is questionable.

Birds wintering in sub-Saharan Africa are not able to predict weather conditions prevailing in Europe and to adjust departure time accordingly (Lehikoinen et al. 2004). The decision to depart is thus influenced by weather conditions at their wintering grounds in Africa rather than those prevailing at that time in Europe (Gordo et al. 2005, but see Saino & Ambrosini 2008). Weather (especially precipitation) is the best predictor of biomass productivity, and thus probably also of the quality of wintering habitats in Africa (Herrmann et al. 2005). Hence, it can indirectly affect departure time and migration speed by affecting body condition of migrating individuals (Gordo 2007).

3. THE INDIAN OCEAN DIPOLE

Previously it was assumed that precipitation in East Africa was influenced by the ENSO (Indeje et al. 2000). However, it appears that the observed relationship between East African rainfall and the ENSO is rather a manifestation of a connection between the ENSO and the IOD (Black 2005). The IOD had traditionally been viewed as an artifact of the ENSO, but it is now considered to be independent (Saji et al. 1999, Ashok et al. 2003). It is an oscillation of sea surface temperature (SST) gradient between the western and eastern parts of the Indian Ocean. The gradient is called Dipole Mode Index (DMI). When the DMI is positive, the phenomenon is referred to as the positive IOD (and vice versa). During positive IOD events, there is above-average SST in the western Indian Ocean and lower-than-average SST in the eastern side. Similarly, a positive IOD is associated with higher precipitation in eastern Africa, while rainfall in Indonesia and Australia is reduced, resulting in severe drought (Saji et al. 1999). Growing evidence shows that the climate (especially precipitation) of eastern Africa is influenced by the IOD (Black 2005, Hashizume et al. 2009). By influencing precipitation, the IOD has previously been shown to have an indirect impact on, for example, malaria epidemics in western Kenya (Hashizume et al. 2009) and vegetation development in tropical East Africa (Marchant et al. 2007). The DMI data can be obtained from the Frontier Research Centre for Global Change (www.jamstec.go.jp/frcgc/research/d1/iod/e/index.html).

4. WHY USING THE IOD COULD HELP AVIAN PHENOLOGY

We believe that using the IOD to explain the phenology of European migratory species wintering in eastern Africa and/or migrating via the Balkan Peninsula and the Middle East would be better than the commonly used NAO. For example, climatic indices were repeatedly used to explain the timing of arrival at the breeding grounds of the White Stork *Ciconia ciconia* (Hubálek 2003, Hubálek & Čapek 2008). However, the white stork populations in Europe are divided into populations wintering in the western Sahel and in eastern and southern Africa (Kanyamibwa et al. 1993). Despite this, the NAO was used in all studies, i.e. also in those populations wintering in eastern and southern Africa (Hubálek 2003, Hubálek & Čapek 2008), where using the IOD could be more appropriate. Similarly, the relationship between arrival dates and the NAO was studied in 32 long-distance migrants breeding in Moravia, Czech Republic (Hubálek 2003). There was no correlation between the NAO and arrival date in most (94 %) of those species. However, 69 % of the studied species winter (at least partly) in East Africa (Cepák et al. 2008). Moreover, 25 % of the species for which migration route is known (n = 24) migrate via the Middle East and the Balkan Peninsula (Cepák et al. 2008) and thus should be little affected by the NAO during most of their journey. Although, we cannot totally rule out the possible impact of spring temperatures on European long-distance migrants prevailing after they reach the European continent (Both 2010), the signal of NAO during spring is weak in central Europe (Pokorná et al. 2007).

Despite its great potential, the use of the IOD as a correlate of avian phenology is very rare, especially in comparison with the large number of studies which use the NAO and the ENSO (Fig. 1). We are aware of just 2 studies in which the IOD was used as a correlate of avian phenology. Hušek et al. (2009) studied the relationship between the timing of breeding, variance in breeding and IOD in red-backed shrikes *Lanius collurio*. Timing of breeding was best explained by population size and climatic conditions on breeding grounds (temperature in May). On the other hand, after accounting for the effects of covariates (number of studied nests), variance in the timing of first clutches was best predicted by the IOD (based on Akaike weights; Hušek et al. 2009) and the relationship was positive (J. Hušek pers. comm.). Differences in timing of breeding are typically explained by individual conditions of breeding birds (Verhulst & Nilsson 2008). The positive relationship between the IOD and variability in the timing of first clutches thus suggests that the IOD can possibly influence body condition of wintering birds. In the second study, the relationship between the passage time of steppe eagle *Aquila nipalensis* at Eilat, Israel and the IOD was examined

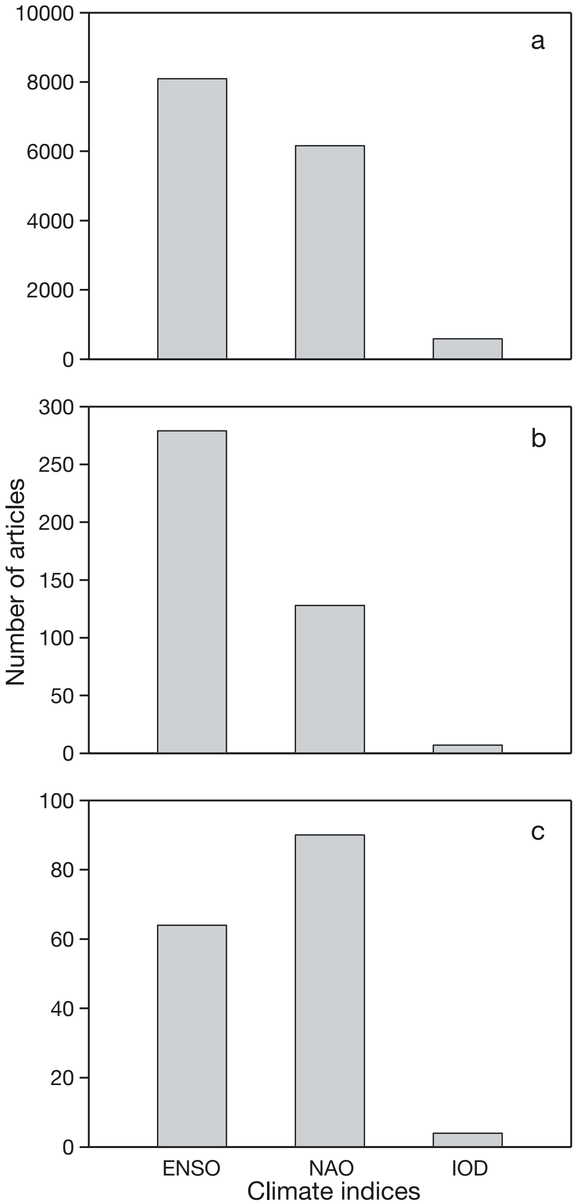

Fig. 1. Number of articles (indexed by Science Citation Index, updated 15 Apr 2012) that refer to El Niño-Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO) and the Indian Ocean Dipole (IOD) by (a) mentioning them in the abstract and/or keywords, (b) linking them to ecology; and (c) linking them to avian phenology

(Zdunjak et al. 2010). They did not find any significant correlation between passage phenology and the IOD. In steppe eagles, however, birds of different ages use different wintering grounds: adults winter mainly in eastern Africa and juvenile and immature birds in southern Africa (Shirihai et al. 2000), where the effect of the ENSO prevails (Ambrosino et al. 2011, Philippon et al. 2012). Hence, we speculate that different results could be obtained if we

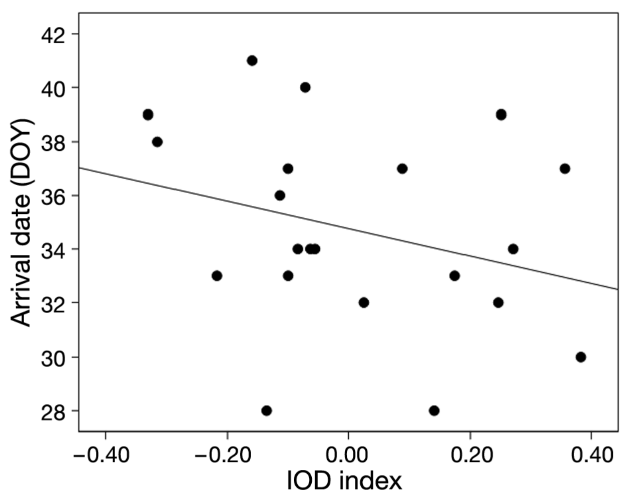

Fig. 2. Relationship between the Indian Ocean Dipole (IOD; Nov–Mar) and red-breasted flycatcher *Ficedula parva* arrival time (day of the year, DOY) to Bialowieza Primeval Forest in 1983–2004 (r_s = −0.643, n = 21 yr, p = 0.002). Data on arrival times after Mitrus et al. (2005, 2012). Regression line superimposed

analyzed those 2 age groups separately. We also detected a readable signal of IOD when re-analysing data on the arrival pattern of a species wintering in the Indian subcontinent, the red-breasted flycatcher *Ficedula parva* (Fig. 2).

5. CONCLUSIONS

In summary, we believe that using only the NAO or the ENSO in studies of avian phenology can miss some key existing patterns. This is especially true for birds using the eastern migratory path in Europe, when the effect of circulation patterns over the Atlantic Ocean will definitely have less influence. These indices are well recognized and have generated robust explanations of the phenology, survival patterns and population dynamics of many bird species. However, we suggest that using the neglected IOD in studies of the phenology of migrant species wintering in eastern Africa could be more appropriate. More studies are clearly necessary, investigating the link between weather conditions in breeding and wintering areas, as well as during both spring and autumn seasonal migration.

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