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Original article

Calendar-effects and temperature-impacts in migratory waterbirds at three tropical Indian wetlands

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ABSTRACT

We analysed the relationships of the arrival and departure, abundance and assemblages of 13 migratory waterbirds in three tropical wintering abodes, with calendar-effect and air temperature. The birds arrive at the wetlands in October–November and most of the long-distance migrants spent 4–5 months, while the short-distance local migrants stayed there for almost 7 months. Much like the onset of autumn migration from the breeding ground, the period of arrival at these wintering abodes was influenced by photoperiod confounded with other calendar-date effects. There was a significant negative relationship between this variable and the abundance of all the 13 species and their maximum abundances corresponded closely with the shortest day length. The temperature tended to fine-tune the migration schedule. The migration phenology and abundances of all the species exhibited strong negative correlations with this environmental variable and maximum abundances were observed during the middle of January, which experienced the coldest temperatures of the region. The long-distance migrants left the wetlands earlier than the short-distance local migrants. Both the photoperiod confounded with other calendar-date effects and temperature affected dissolved oxygen concentration and phytoplanktonic productivity of the wetlands, which influenced the waterbirds. Dissolved oxygen concentration affected the abundances of most of these waterbirds probably through its impact on their food resources. Phytoplanktonic productivity might also influence overall food supply to the waterbirds.

1. Introduction

Onset of migration in birds is influenced by a number of endogenous and exogenous factors (Berthold, 2001). Annual change in the day length is known to be the most reliable predictive cue used by birds, especially by the long-distance migrants wintering in the tropics, to initiate migration both on the breeding and on the wintering grounds (Kok et al., 1991; Mason, 1995; Coppack and Both, 2002; Coppack and Pulido, 2004; Lehikoinen et al., 2004; Jonzén et al., 2006; Knudsen et al., 2011). A number of birds start their migratory activity at the same time, indicating that endogenous factors (e.g. circannual rhythm), synchronised with photoperiod, determine the onset of migration (Gwinner, 2003).

In addition to endogenous mechanisms, the timing of migration may be constrained by the environmental factors, such as, local temperatures, temperatures en route, temperatures at the wintering grounds and global climatic indices (e.g. NAO, ENSO) of a particular area (Lehikoinen et al., 2004; Gordo, 2007; Knudsen et al., 2011), etc. Departure schedules from wintering grounds may also be affected by habitat occupancy *via* differences in food abundance, which is linked to rainfall (Marra et al., 1998; Studds and Marra, 2005, 2007). Migration requires fuel deposition and for some species completion of winter moult, and a poor food supply can delay the rate of both and hence departure dates (Saino et al., 2004; Newton, 2008). Weather conditions do have a major influence on the incidence and speed of avian migration, stopover duration and fuel deposition rate (Pulido, 2007). Among these environmental variables temperature is most frequently related to avian phenology (Lehikoinen et al., 2004; Root et al., 2005; Gienapp et al., 2007; Gordo, 2007).

Although much has been written and experimentally shown with respect to the factors triggering the onset and termination of migration, research has been strongly limited to studies that take a northern-hemisphere, breeding-site perspective and very little is known of these aspects from the tropics, wintering-site perspective. Moreover, most of our knowledge on the environmental control of migration timing has been acquired from the studies under captive or simulated conditions and there is currently a lack of information in the wild, particularly from the tropics. Therefore, the potential effects of photoperiod (with or without confounding

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with calendar-date) and climate at the wintering grounds on migratory onset should be given adequate importance (Studds and Marra, 2007; Gordo, 2007). Although India is known as one of the important wintering grounds for a wide variety of long-distance migrants (Kazmierczak, 2003), particularly those from Europe, Eurasia and Central Asia (Sinha et al., 2011), no comprehensive work on these aspect has yet been undertaken, except for that of Khan et al. (2005), which dealt with the calendar-effects on the diversity of migratory waterbirds in Santragachhi Lake, West Bengal.

On the other hand, most studies dealing with avian migration phenology have used first arrival (FAD) or first departure (FDD) dates or various estimations of peak passage dates (Sparks et al., 2001; Lehikoinen et al., 2004). The use of FAD or FDD has been considered problematic (Mills, 2005) since FAD represents the leading edge of species–abundance curve, while FDD denote its trailing end (Mills, 2005). Estimation of peak passage dates requires frequent banding or marking and considerable sample sizes, which are not always time and cost efficient (Mezquida et al., 2007). Changes in bird population size can be another source of bias. In many birds, there is a strong relationship between earlier arrival dates and increased population size (Tryjanowski and Sparks, 2001). However, practically nothing is known of the photoperiodic effect, calendar-effect and temperature-impacts on the abundance and community composition, especially in the tropics, although such studies would more adequately explain the relationship between bird migration and these environmental attributes. This is mainly because of the fact that such studies are based on the species abundance data collected right from the period of arrival, through the time of peak abundance, to the period of departure, which can give a complete species–abundance curve and thereby a clear-cut picture of the relationship between environmental variables and part of the migration phenology completed in the wintering ground.

Thus, there are still unanswered questions regarding the factors that control the timing of migration in the wintering grounds. To achieve a better understanding of these important aspects of the life-history strategies of migrants, we need to assess the significance of multiple factors potentially affecting the phenology of migration. In the present study, we used two environmental variables and focused on the importance of each variable affecting the arrival, departure, abundance and assemblages of waterbirds in three tropical wintering abodes. This study constitutes the first detailed analysis of the confounding effect of photoperiod, used as a proxy for all calendar-date effects and the impact of temperature on these attributes. The study was confined to three wetlands around Calcutta, India. Since these wetlands were located within 0.1° of latitude, we could not separate the effects of calendar-date from the photoperiodic effect, and failed to eliminate the possibility of confounding effects of these two variables. Therefore, using the term 'calendar-effect' instead of photoperiodic effect seems to be the best way forward.

The principal objective of this article is to answer some of the pertaining questions in this regard like: (1) Do calendar-effect and temperature have any influence on the migration phenology of waterbirds? (2) How do these environmental variables affect their abundance? (3) Do they impact the assemblages or community composition of waterbirds? (4) Do they have any effect on important water parameters, which, in turn, might affect the migratory waterbirds? (5) Are the observed calendar-effects the results of the effects of day length? In search of the answer to the fourth question, the effects of dissolved oxygen content and phytoplanktonic productivity on the waterbirds have been included in the study, both of which are greatly influenced by these environmental variables. Moreover, they are known to affect migratory waterbirds significantly (Khatri, 1984; Manasrah et al., 2006; Khan, 2010).

2. Material and methods

2.1. Study site

The study was conducted in three wetlands, situated around Calcutta, West Bengal, India. They are (i) Santragachhi Wetland (lat. 22.580° N; long. 88.283° E), (ii) Nalban Wetland Complex (lat. 22.566° N; long. 88.426° E) and (iii) Dankuni Wetland Complex (lat. 22.665° N; long. 88.296° E). These wetlands were selected on the basis of their variations in size, surroundings, human interference, vegetation, soil type and some basic water parameters like dissolved oxygen concentration, phytoplanktonic productivity, nitrate and phosphate content, etc. so that each of them can represent a type of the wetlands present in the region. Moreover, they are among the few wetlands that harbour nearly all the important winter migrants found in the region around Calcutta. Brief descriptions of these wetlands are given below.

(i) *Santragachhi Wetland*: The wetland extends over an area of 24 ha, of which 18 ha constitute a lake that provides suitable habitat for waterbirds. Being located inside a densely populated industrial area, Santragachhi has become subjected to degradation due to imprudent anthropogenic activities. A sizeable portion of the waterbody remains clogged with water hyacinth (*Eichhornia crassipes*) throughout the year. The lake supports a wide variety of zooplankton, molluscs and fish that cater the waterbirds with required dishes (Khan, 2010). A detailed description of this wetland is given by Khan et al. (2005).

(ii) *Nalban Wetland Complex*: This Complex constitutes a portion of East Calcutta Wetlands, a Ramsar Site. It is formed of large areas of ponds, marshes and swamps, situated immediately south-east of Calcutta city boundary. Formerly it covered an area of 8100 ha but now only about 2500 ha have been left. The vast wetlands of eastern Calcutta used to attract large numbers of waterbirds in the past. However, over the years, as the city expanded itself to this portion and the new Salt Lake City was built, the wetlands vanished rapidly. Now only a fraction of the original remains scattered in small fragments as symbols of days gone by. The only large water body remaining in this area is the Nalban Bheri and although pisciculture and recreational activities are carried out, some waterbirds still come here in all seasons. It has been the favourite wintering ground of a number of long-distance migratory ducks and snipes. Like Santragachhi, considerable portions of these wetlands remain covered with water hyacinth throughout the year.

(iii) *Dankuni Wetlands Complex*: This complex is formed of 10 small ponds and marshes, situated in the rural belt, 9 km north-west of Calcutta metropolitan boundary and 17 km north of Santragachhi Lake. These wetlands extend over an area of 44 ha, the largest being the Jheel 2, which has been used by the local people for pisciculture. One of the busiest railway tracks of the region, Howrah-Bardhaman Chord, passes through the complex, while National Highway 2 demarcates its eastern boundary. Most of these wetlands attract waterbirds throughout the year including migratory ones during winter days. However, the highest diversity was observed in Jheel 2.

2.2. Waterbird census

Total counts of all waterbirds were performed in each month from October, 2007 to April, 2011. Therefore, four study seasons (i.e. October, 2007–April, 2008; October, 2008–April, 2009; October, 2009–April, 2010; and October, 2010–April, 2011) were covered