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ORIGINAL ARTICLE

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Known and predicted African winter distributions and habitat use of the endangered Basra reed warbler (*Acrocephalus griseldis*) and the near-threatened cinereous bunting (*Emberiza cineracea*)

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Abstract The Basra reed warbler (*Acrocephalus griseldis*) and the cinereous bunting (*Emberiza cineracea*) are the only two Western Palearctic passerine bird species that overwinter in East Africa and are classified by BirdLife International as endangered and near-threatened, respectively. To refine the African wintering ranges of these two species, we made an effort to collect as much distributional data as possible. We then used the available point-locality data to predict the wintering distributions using a Geographic Information Systems (GIS) based inductive modelling technique called BIOCLIM. For this purpose, we developed four environmental GIS layers that are presumed to reflect the environmental preferences of migrant birds. Our data showed that the known winter distribution of the Basra reed warbler was concentrated in Kenya, Tanzania, Malawi and Mozambique, where it was usually found in dense vegetation growing in coastal scrub, woodland thickets, swamps, marshes, flooded pools and grasslands, and along ditches and edges of rivers, ponds, lagoons and lakes. The predicted winter distribution of this species includes most of East Africa but, given the habitat preferences of this species, is probably limited to low-lying areas near the coastline. The known winter distribution of the cinereous bunting is so far limited to Eritrea, where the species has been observed in October, November, February and March, in sparsely vegetated, sandy or rocky habitats on coastal plains and deserts. The predicted winter distribution of this species includes the plains and hills along the Red Sea coasts in southern Egypt, Sudan, Eritrea, Ethiopia and Sudan, as well as a few inland areas in Sudan, Ethiopia and Kenya.

Keywords *Acrocephalus griseldis* · BIOCLIM · *Emberiza cineracea* · Migration · Wintering distribution

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Introduction

The conservation of migratory bird species poses special problems associated with their annual movements which often span continents, because species survival is dependent on the conservation of not only breeding grounds, but also stop-over sites and wintering grounds (Salathé 1991; Crick and Jones 1992; Bibby 2003). For the over 300 species breeding in the Palearctic region which migrate, in numbers estimated at 3,000–5,000 millions, to their African wintering grounds (Moreau 1972; Curry-Lindahl 1981), we know their breeding grounds and principal migration routes through Europe and the Mediterranean quite well (Cramp 1998; Glutz von Blotzheim 2001), but knowledge concerning the distribution of these migrants in Africa is still fragmentary (Walther and Rahbek 2002). For many species, knowledge of distribution may be as superficial as "occurs in Eastern Africa" or the necessarily oversimplified range maps in the otherwise impressive *Birds of Africa* series (Brown et al. 1982; Urban et al. 1986, 1997; Fry et al. 1988, 2000, 2004; Keith et al. 1992). Such information is insufficient in spatial resolution for proper scientific analyses and conservation management.

In an effort to pull together information on migrants in Africa, a research project at the Zoological Museum, University of Copenhagen, aims to establish a publicly accessible database on the geographical distribution of western Palearctic migratory birds in Africa. The information in this database will hopefully enhance our understanding of the whereabouts of migrants in Africa as well as guide conservation decisions (Walther and Rahbek 2002). To illustrate the potential use of such data, we here present the predicted winter distributions of two threatened western Palearctic passerine species.

The Basra reed warbler (*Acrocephalus griseldis*) and the cinereous bunting (*Emberiza cineracea*) are the only two western Palearctic passerine bird species that overwinter in East Africa (Urban et al. 1997; Fry et al. 2004) and are classified by BirdLife International (2004) as endangered and near-threatened, respectively. The Basra reed warbler breeds in thick marshy waterside vegetation in Iraq and possibly Iran and Kuwait (Cramp 1998; BirdLife International 2004). The marshes in southern Iraq have been extensively damaged in recent decades, and this massive habitat loss may have caused the population of the Basra reed warbler to deteriorate to less than 10,000 birds, putting it in the endangered category (Birdlife International 2004). The Basra reed warbler migrates through the Arabian peninsula and northeastern Africa to its overwintering range in southern Somalia, Kenya, Tanzania, Malawi, Mozambique and South Africa (Urban et al. 1997). The subspecies *cineracea* of the cinereous bunting breeds on Greek islands and around Develi and Kilis in Turkey, while the subspecies *semenowi* breeds from southeast Turkey up to the Iraqi-Iranian border (BirdLife International 2004). They both migrate through the Middle East and the Gulf Region to their overwintering range in southern Saudi-Arabia, Yemen, Sudan and Eritrea (Chappius et al. 1973; de Knijff 1991).

To refine the African wintering ranges of these two species, we made an effort to collect as much available distributional data as possible, using various published and unpublished sources (e.g. museum specimens, personal communications, etc.). However, assuming that many areas in Africa still remain undersampled, we use the available point-locality data to predict the wintering distributions using Geographic Information Systems (GIS) based modeling techniques which have, for example, been used to model the wintering grounds of the common crane (*Grus grus*) (Franco et al. 2000) and the migration of the Swainson's Flycatcher (*Myiarchus swainsoni*) across the South American continent (Joseph and Stockwell 2000). Two types of analytic models are commonly used to predict species distributions: so-called deductive and inductive models (Corsi et al. 2000). In this study, we exclusively use inductive models that use point-locality data to derive a species' environmental preferences. These preferences are then used to predict other suitable areas which may include areas occupied by the species and areas not occupied by the species even though they are suitable. Therefore, distributional maps based on inductive models may 'overpredict' the actual range because they include not just the realised, but also the potential, distribution of the species, thereby ignoring historical and biogeographical influences. Nevertheless, we hope that such distributional maps will focus future research of these two species by narrowing the areas where field workers may go looking for them.

Migrant birds in Africa are known to favour the more open habitats of the savannas (e.g. the Sahel) characterised by pronounced seasonal rainfalls which determine the emergence of green vegetation and the consequent increase of insect and bird life (Moreau 1972; Curry-Lindahl 1981; Lövei 1989; Jones 1995, 1998; Jones et al. 1996; Hockey 2000). The annual north-south movement of the Inter-tropical Convergence Zone across Africa causes rainfall patterns to shift across the continent, with the north receiving most precipitation during the months of May through November and the south during the months of November through April. As rainfall increases, plant productivity and insect abundance increase sharply, thus providing insectivorous birds with a rich food supply. It is generally assumed that this superabundant food source cannot fully be exploited by resident birds, which then can be used by migrant birds (Pearson and Lack 1992; Jones 1995; Hockey 2000; Hurlbert and Haskell 2003). To possibly reflect these habitat preferences of migrants, we chose to develop environmental GIS layers that presumably reflect the migrants' preference for open habitats with pronounced environmental and seasonal variation.

Methods

Data acquisition

To acquire information about the winter distribution of Palearctic migratory birds in Africa, we contacted over 200 individuals or organisations plus all ringing schemes within Europe through EURING and in Africa that we knew of requesting data or references. Almost 100 people and, with the approval and support of EURING, almost all ringing schemes responded and sent data and references (see Acknowledgements). These data were entered into an Access database currently containing about 60,000 distributional records. Each record contains the species name, habitat, date, and locality (plus additional information not used in this paper). The geographical coordinates of each locality were established as follows: if the source did not provide coordinates, we consulted the Times Atlas (Bartholomew 1956), various other printed gazetteers, or the internet-based gazetteer of the National Imagery and Mapping Agency (2003). If these gazetteers provided better coordinates, we corrected the coordinates provided by the original sources.

Environmental data layers

Inductive models of species distributions require environmental data layers that contain the values (e.g. degree temperature in Celsius) of environmental variables for the study area. For our layers, we chose to divide the African continent into grid cells of 0.05° resolution. Each data layer was generated at the same resolution using Arc/Info 8.0. The following layers were developed and used.

Average temperature of the coldest month

We calculated average temperature of the coldest month from the monthly minimum temperature layers provided by the Centre for Resources and Environmental Studies (CRES) (Hutchinson et al. 1996). The CRES dataset provides average minimum monthly temperatures interpolated from 1,504 meteorological stations based on 60-year mean (1920–1980) interpolated estimates. We kept the data at their original spatial resolution of 0.05° and calculated this variable layer using an ARC/INFO script.

Elevational range

We calculated elevational range within each 0.05° grid cell from the 1-km resolution digital elevation model provided by CRES which is based on 1:1 million scale air navigation charts with a standard error for elevation ranging between 20 and 150 m. We then calculated this layer as the maximum minus minimum elevation within 0.05° grid cells.

Habitat heterogeneity

We calculated habitat heterogeneity from the 1-km resolution University of Maryland Global Land Cover Facility map which is based on Advanced Very High Resolution Radiometer (AVHRR) and categorises the landscape into 13 broad categories (evergreen needleleaf forest, evergreen broadleaf forest, deciduous needleleaf forest, deciduous broadleaf forest, mixed forest, woodland, wooded grassland, closed shrubland, open shrubland, grassland, cropland, bare ground, and urban and built up) (http://glcf.umiacs.umd.edu). The resulting grid shows the number of land cover categories within each 0.05° pixel (range 1–8).

Percent forest cover

We calculated percent tree cover from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite 500-m Global Vegetation Continuous Fields dataset (Hansen et al. 2002, 2003). This dataset provides percent tree cover as estimated from satellite imagery collected from 31 October 2000 to 9 December 2001. MODIS data yield greater spatial detail in the characterisation of tree cover compared to past efforts using AVHRR data, and initial validation efforts show a reasonable relationship between the MODIS estimated tree cover and tree cover from validation sites (Hansen et al. 2002, 2003). We resampled the original 500 m resolution dataset to 0.05 degree resolution with Arc/Info Grid 8.0.

Modelling species distribution

We modelled species distributions using BIOCLIM (Busby 1991; Doran and Olsen 2001) and the environmental layers described above. BIOCLIM identifies values for each environmental layer that coincide with the species' point-locality records to calculate environmental envelopes. These environmental envelopes are defined by percentile limits that exclude the extremes of the distribution. For example, the 95% environmental envelope excludes the lower and upper 2.5% of the records from each tail of each environmental variable's distribution, while the 100% envelope is the most inclusive using all records (Nix 1986). BIOCLIM then uses the environmental envelopes to map the potential distribution of the species by assessing whether each cell across the study area is inside or outside the envelope. Because climatic models often overpredict species distributions, many researchers limit the amount of overprediction by clipping the predicted distributions with the boundaries of vegetation maps that coincide with species locality records. For this purpose, we used a GIS layer containing ecoregion polygons for all of Africa (Burgess et al. 2004) which we used to clip the distribution made by the BIOCLIM model thus producing a refined map of the species' distribution.

Results

Known migration, winter distribution and habitat of the Basra reed warbler

The migration and winter distribution of the Basra reed warbler was previously described by Pearson (1982), Pearson et al. (1978, 1988), and Pearson and Lack (1992). Table 1 presents all African localities where Basra reed warbler has been recorded that we are aware of, and Table 2 summarises these records by country and month (see also Fig. 1). The Basra reed warbler usually reaches Sudan and Ethiopia in August, peaks there in September and continues migrating through until October (although it was also recorded at Dar es Salaam, Tanzania from August to October). It usually reaches Somalia, Uganda, Kenya and Tanzania in November, with the peak at Ngulia station (whose records make up more than 80% of all Kenyan records) in December. Much further south, some individuals already reach Malawi and Mozambique in November and December. During January and February, the Basra reed warbler has regularly been recorded in Kenya, Tanzania and Malawi. The few records for Mozambique, Botswana and South Africa for this time period could either be vagrant records or perhaps represent the

Table 1 Recorded localities for the Basra reed warbler (*Acrocephalus griseldis*) across East African countries (countries arranged from north to south). For each locality, locality description, its geographical coordinates (degrees, minutes and seconds), number of records and months of observations are given. Sources for these records are unpublished data provided by Neil E. Baker and Elizabeth M. Baker, Robert Dowsett, John Miskell, Gerhard Nikolaus, David Pearson, and Robert Prŷs-Jones as well as published data provided in: Hartlaub 1891; Shelley and Sclater 1898; Madarász 1915; Someren 1929, 1932; Grote 1930; Friedmann and Loveridge 1937; Moreau and Moreau 1937; Jackson and Sclater 1938; Benson 1944; Smith 1957; Pearson 1972a, 1972b, 1978, 1979, 1980, 1981, 1982, 1983a, 1983b, 1984, 1986, 1987, 1989a, 1989b; Backhurst et al. 1973, 1986; Clancey 1975; Lack 1975, 1985; Hanmer 1976a, 1976b, 1979, 1994; Pearson and Backhurst 1976, 1978; Backhurst and Pearson 1977, 1979, 1980, 1981, 1983a, 1983b, 1984, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 2000; Benson and Benson 1977; Britton and Britton 1977; Turner 1977, 1991, 1992; Ash 1978, 1981; Britton 1978, 1981; Pearson et al. 1978; Nikolaus 1979, 1981, 1982, 1983a, 1983b; Lack et al. 1980; Ash and Miskell 1981, 1998; Cyrus 1986; Sinclair and the Rarities Committee 1986; Boothroyd 1987; Dowsett et al. 1988; Turner and Pearson 1988; Hockey 1990, 1995; Douthwaite and Miskell 1991; Tyler et al. 1991, 1997; Ryall 1992; Jackson 1996; Logan 1996; Urban et al. 1997; Hustler 1998; Sub-committee of the EANHS Bird Committee 2001

Locality	Coordinates	No.	Months
Sudan			
60 km east of Atbara, NE Sudan	17.35.00N, 34.25.00E	1	9[a]
Juba along the Nile, Sudan	04.52.00N, 31.30.00E	1	8
Khor Arba'at, Sudan	19.56.00N, 37.00.00E	33	8–10
Suakin, Sudan	18.50.00N, 37.25.00E	3	9
South of Suakin, Sudan	19.06.14N, 37.19.48E	1	9
Wad Medani, Sudan	14.24.00N, 33.32.00E	1	10
Ethiopia			
Gambela (= Gambela Post), W Ethiopia	08.15.00N, 34.35.00E	1	10
Koka, Shoa Province, Ethiopia	08.27.00N, 39.06.00E	1	9
Lake Koka, Ethiopia	08.23.00N, 39.05.00E	2	8–9
Djibouti			
Gibdo, 29 km SW of Assab, Djibouti	11.53.55N, 42.39.04E	1	4
Somalia			
Danno (= Dannow), close to river Webi Shebelle, Somalia	01.44.00N, 44.37.00E	7	3–4,11–12
Kismayu (= Chisimaio), lower Juba River, S Somalia	00.22.00S, 42.32.00E	1	11
Mogambo rice scheme, Somalia	00.08.00N, 42.41.00E	1	11
Uganda			
Gaba, 10 km E of Kampala, Uganda	00.15.53N, 32.37.38E	2	11
28 km E of Serere, Uganda	01.30.00N, 32.42.00E	1	11
Kenya			
Aruba Dam, Tsavo National Park East, Kenya	03.21.00S, 38.49.00E	7	2–3,11–12
Athi River, Kenya	01.27.00S, 36.59.00E	2	11
Bamburi, near Mombasa, Kenya	04.00.00S, 39.43.00E	10	1–2,4,11–12
Baringo, Kenya	00.38.00N, 36.02.00E	3	4
Buomo (= Baomo?), Tana River, Kenya	01.50.00S, 40.08.00E	1	2
Garissa, Tana floodplain, Kenya	00.28.00S, 39.28.00E	1	3
Habaswein, Isiolo District, Kenya	01.02.00N, 39.30.00E	1	11 to 1[b]
Karawa, southern edge of Tana delta, Kenya	02.38.00S, 40.12.00E	4	3–4
Kiambere, Tana River, Kenya	00.42.00S, 37.47.00E	2	4,11
Kilifi, Kenya	03.38.00S, 39.51.00E	2	1
Lake Bilisa, Garsen, Kenya	02.14.00S, 40.08.00E	1	3
Lake Kenyatta, near Lamu, Kenya	00.25.00S, 40.40.00E	1	3
Lake Naivasha, Kenya	00.45.00S, 36.25.00E	1	12
Eastern shore of Lake Naivasha, Kenya	00.48.00S, 36.24.00E	1	2
Northern shore of Lake Naivasha, Kenya	00.46.00S, 36.21.00E	2	1,12
Lake Shakababo, Tana River delta, Kenya	02.25.26S, 40.11.48E	4	2–3,12
Mackinnon Road, Kenya	03.45.00S, 39.05.00E	1	12
Maji ya Chumvi, Kenya	03.47.00S 39.42.00E	1	3
Mara Game Reserve, Kenya	01.18.00S, 35.00.00E	1	11
Mara Safari Club, Kenya	01.25.00S, 34.55.00E	6	4
Mtito Andei, Kenya	02.41.00S, 38.10.00E	3	2,12
3 km northeast of Mtito Andei, Kenya	02.39.00S, 38.12.00E	5	1,3,12
4 km northeast of Mtito Andei, Kenya	02.39.00S, 38.13.00E	11	1–2,11–12
6 km west of Mtito Andei, Kenya	02.39.00S, 38.08.00E	1	2
Ngulia Safari Lodge, Tsavo National Park West, Kenya	03.00.00S, 38.13.00E	433	1,4,10–12
Nguuni, Kenya	03.56.00S, 39.39.00E	1	12
North Uaso Nyiro (= Uaso Ngiro, Guaso Nyiro), Kenya	01.20.00S, 38.10.00E	2	1,12
Nyambe crater, Mount Kenya, Kenya	00.10.00S, 37.20.00E	1	12
Near Sabaki River mouth, Kenya	03.09.00S, 40.08.00E	1	3
Safarilands, Lake Naivasha, Kenya	00.47.00S, 36.13.00E	1	2
Shimoni, Kenya	04.39.00S, 39.23.00E	2	12
Tana, 30 km N of Garsen, Kenya	02.00.00S, 40.10.00E	1	3
Tana, N of Bilisa (Lake Bisila), Kenya	02.08.00S, 40.11.00E	2	1
Tana River at Idsowe, Kenya	02.18.00S, 40.16.00E	2	1,3

Table 1 (Contd.)

Locality	Coordinates	No.	Months
near Tana River at Garsen, Kenya	02.16.00S, 40.07.00E	1	3
The Ark, Aberdares, Kenya	00.21.00S, 36.45.00E	2	11
Voi, Tsavo National Park East, Kenya	03.23.00S, 38.34.00E	8	2[c],4,12
Watamu, Kenya	03.21.00S, 40.01.00E	1	4
Tanzania			
Amani, Tanzania	05.06.00S, 38.38.00E	1	11
Bahareni, Dar es Salaam, Tanzania	05.02.00S, 39.46.00E	2	2–3
Dar es Saleem, Tanzania	06.48.00S, 39.17.00E	14	1–4,8–10
Dar es Salaam Jangwani, Tanzania	06.55.00S, 39.14.00E	3	1–3
Ifakara, Tanzania	08.08.08S, 36.41.00E	1	12
Jangwani Salt Pans, Dar es Salaam, Tanzania	06.48.00S, 39.17.00E	2	3
Kandawale, Tanzania	08.39.00S, 38.48.00E	1	4
Kidugallo, Tanzania	06.47.00S, 38.12.00E	1	12
Kilosa (= Kilossa), Tanzania	06.50.00S, 36.59.00E	2	2
West of Kitangari, Tanzania	10.39.00S, 39.18.00E	2	1, 12
Mbuyuni Ras, Dar es Salaam, Tanzania	06.10.00S, 39.12.00E	1	3
Mikindani, Mtwara, Tanzania	10.16.30S, 40.09.00E	5	1,3,12
Morogoro, Tanzania	06.49.00S, 37.40.00E	2	2
East of Mubeza (= Mubesa), Tanzania	05.10.00S, 38.47.00E	1	3
Ngerengere river, Tanzania	06.45.00S, 38.07.00E	1	1
Nguru, Kilosa district, Tanganyika Territory, Tanzania	06.38.00S, 37.32.00E	1	Unknown[d]
Soga, Tanzania	06.52.00S, 38.57.00E	1	11
Near Tanga, Tanzania	05.04.00S, 39.06.00E	1	3
Usangu Flats, Tanzania	08.30.00S, 34.15.00E	1	2
Malawi			
Fort Johnston, Malawi	14.29.00S, 35.14.00E	1	3
Lilongwe, Malawi	13.59.00S, 33.47.00E	1	Unknown[e]
Mangochi District Headquarters, Malawi	14.28.00S, 35.16.00E	1	3
Mount Mlosa (= Malosa, Muloza), Malawi	15.15.00S, 35.19.00E	1	11
Nchalo, lower Shire Valley, Malawi	16.14.00S, 34.56.00E	14	1–4,11–12
Zambia			
Zambezi River opposite Imbabala Camp, Kazungula, Zambia	17.47.00S, 25.16.00E	2	3
Mozambique			
Chire, Morrumbala District (Zambézia), Mozambique	16.42.00S, 35.20.00E	1	2[f]
Luia River, Tete Province, Mozambique	15.10.00S, 32.55.00E	1	4
Mopeia, north bank of Zambezi River, Mozambique	17.58.38S, 35.42.12E	4	1,4,11–12
Bridge over Pungwe (= Punge) River on the main Chimoio to Beira Road, Punge River floodplain, Mozambique	19.25.00S, 34.28.00E	1[g]	12
Botswana			
Phakalane, 15 km north of Gaborone, Botswana	24.34.00S, 25.58.00E	1	1
South Africa			
Empangeni Bird Sanctuary, Natal, South Africa	28.46.00S, 31.54.00E	1	2
Levuvhu River, N of Punda Maria, Kruger N.P., South Africa	22.25.00S, 31.18.00E	3	2
Richards Bay, Natal, South Africa	28.48.30S, 32.03.30E	1	1

The following records have inaccurate dates or locations for the following reasons:
[a] In a bird cemetery in the Nubian desert, Nikolaus (1983b) found a dead individual whose date of death is thus uncertain
[b] Pearson (1982) wrote "between November and early January" for this record
[c] R. Meinertzhagen deposited specimen BMNH 1965.M.13672 supposedly collected on 2 February 1915, but given Meinertzhagen's fraudulent track record (e.g. Knox 1993), neither the date nor the locality can be trusted (R. Prŷs-Jones, personal communication)
[d] Emin Pasha collected the type specimen giving the locality without date (Hartlaub 1891; Jackson and Sclater 1938; Backhurst et al. 1973)
[e] Urban et al. (1997) gave this locality without date
[f] The date of the recovery letter for this record is 1 February 1977, but the actual recovery date is unknown (Ash 1978, 1981)
[g] This record is based on a sight observation of one individual in reedbeds (Logan 1996), but the species identification is thus uncertain (Vincent Parker, personal communication)

extreme southern extent of the wintering range. During March and April, the Basra reed warbler seems to return swiftly to its breeding grounds in Iraq, passing through Mozambique, Malawi, Zambia, Tanzania, Kenya, Somalia and Djibouti.

On migration, the Basra reed warbler was observed in low reeds above water (Nikolaus 1979), mangroves and gardens (Nikolaus 1981, 1983a). All wintering areas are below 1,000 m (Urban et al. 1997). In Somalia, the Basra reed warbler was found in man-made lakes entirely overgrown with dense 3 to 4-m high *Typha* sp. stands (Ash and Miskell 1981). In Uganda and Kenya, it overwinters in coastal scrub consisting of 1–2 m high dense *Suaeda monoica* saltbushes and moist dense green thickets (e.g. *Terminalia*) with tall rank grass and sedges near or over wet or drying ditches, swamps, lakes and flood pools, often seasonally inundated with brackish water, with a density of 10–20 birds per hectare, and occasionally in herbaceous woodland undergrowth (Pearson 1972b, 1982; Pearson et al. 1978;

Table 2 Migration of the Basra reed warbler (*Acrocephalus griseldis*) across East African countries (with countries roughly arranged from north to south). For each month, the number of records in the respective country is given. The total number of records in our database for each country is given in the second column, with the number of undated records given in brackets.

Country	No. records	August	September	October	November	December	January	February	March	April
Sudan	39 (1)	12	23	4						
Ethiopia	4	1	2	1						
Djibouti	1									1
Somalia	9				3	2			2	2
Uganda	3				3					
Kenya	528 (2)			1	197	263	23	12	15	17
Tanzania	42 (1)	1	1	1	2	4	9	8	12	4
Malawi	17 (1)				2	3	3	2	5	2
Zambia	2								2	
Mozambique	5 (2)				1	1	1			2
Botswana	1						1			
South Africa	5						1	4		

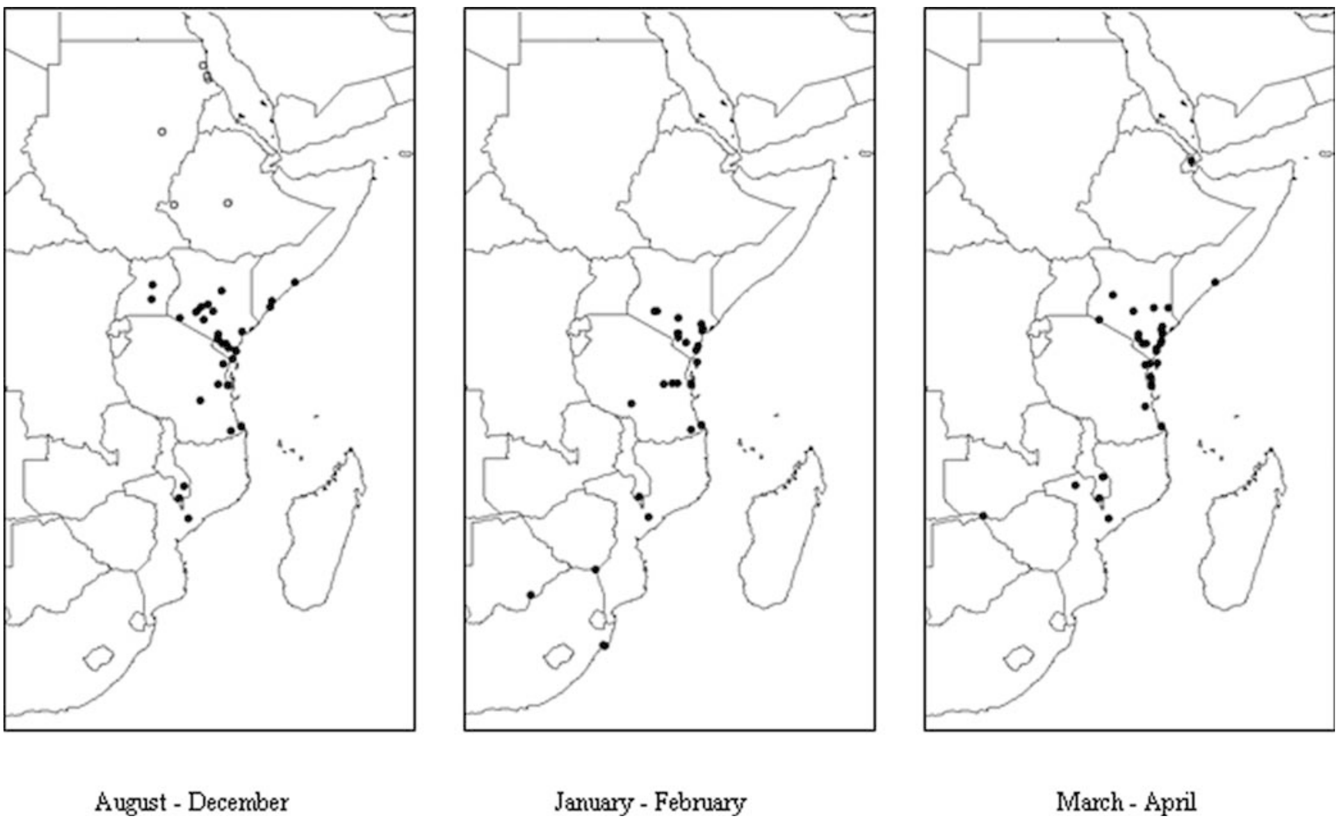

Fig. 1 The migration of the Basra reed warbler (*Acrocephalus griseldis*) across East Africa during three time periods (August–October and November–December records are depicted by *grey* and *black circles*, respectively). All records of uncertain date or locality were excluded (for details, see Table 1)

Britton 1980; Urban et al. 1997). It is also found in flooded grassland, papyrus swamp (Tyler et al. 1991), river vegetation and woodland thickets (Lack 1985). In Malawi, the Basra reed warbler is typically observed in dense long grass, *Combretum*-*Commiphora* thickets, *Typha* sp. bulrush vegetation near ponds, and sometimes in more open vegetation, e.g. in a *Morus nigra* mulberry tree in a garden (Hanmer 1979). Newman et al. (1992) reported it in reed marshes, long rank grass, and, perhaps surprisingly, often in dry thickets away from water. In Tanzania, Zambia, Mozambique and Botswana, it was found in wet coastal scrub (Neil Baker, personal communication), *Phragmites* reedbeds (Hustler 1998), reeds and scrub thickets (Hanmer 1976b), riverine thickets (record from Luia River provided by Vincent Parker, personal communication), and *Typha* sp. swamps near sewage lagoons (Tyler et al. 1997), respectively.

Predicted winter distribution of the Basra reed warbler

Given the paucity of information about the migration of the Basra reed warbler, any arbitrary decision about which records to include or not would appear to be

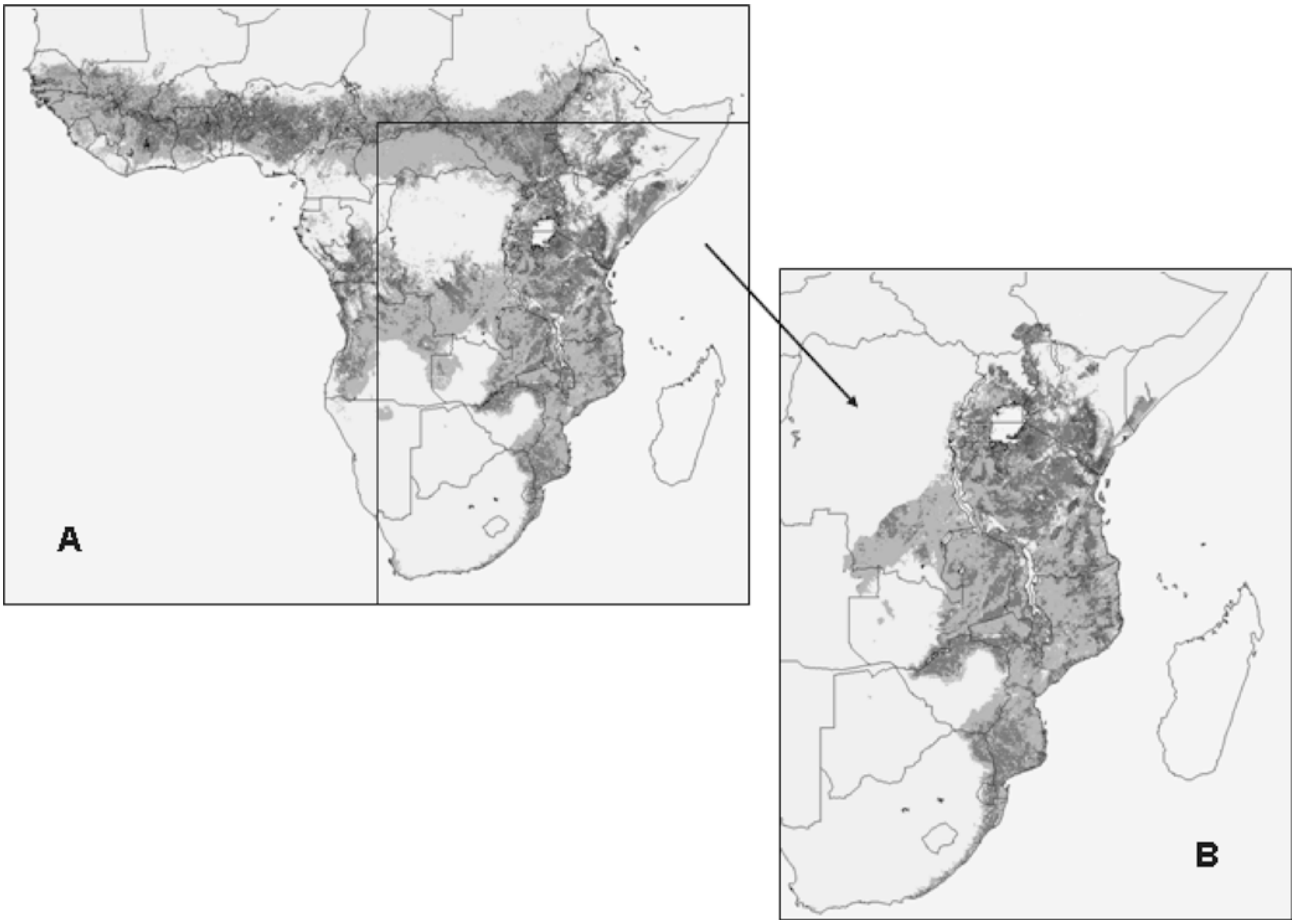

Fig. 2 a BIOCLIM predicted distribution of the Basra reed warbler (*Acrocephalus griseldis*) using four environmental GIS data layers (average temperature of the coldest month, elevational range, habitat heterogeneity, percent forest cover) and point-locality records for the months of November through February (see Fig. 1). *Colours* range from dark grey to white (using 10 steps) representing highest to lowest suitability, respectively, as determined by the BIOCLIM envelopes. **b** BIOCLIM predicted distribution as in **a** clipped by those ecoregions with no point-locality records

haphazard. Therefore, we chose fixed time periods as the most unambiguous way to select records. We defined three wintering periods: (1) all records from November and December (even though some of those may involve migratory individuals), (2) all records from January and February (excluding the Botswana and South African records as vagrants because currently these records appear to be rare incidences of individuals overshooting their wintering range, but see Discussion), and (3) all records from November through February (i.e. periods 1 and 2 together). If several records came from the same locality, we only used the locality once in the analyses, so that each locality had equal weight.

The predictions using the four GIS layers (average temperature of the coldest month, elevational range, habitat heterogeneity, percent forest cover) as predictors suggest that suitable locations for wintering Basra reed warblers should be found in a belt all across Africa from Senegal to Ethiopia, and then circling the Congo basin and stretching down the Indian Ocean coastline all the way to South Africa (Fig. 2a). The predictions for the three wintering periods were so similar that we consider all records from November through February from here on. The predictions shown in Fig. 2a are a clear example of overprediction in which the BIOCLIM model predicts all suitable areas in Africa, even such areas that for historical or biogeographical reasons are most likely never used by the species. To restrict our predictions, we therefore clipped our map using the African ecoregion layer. All ecoregions with no point-locality records of the Basra reed warbler were excluded from the predictions, yielding a much more restricted prediction for southeastern Africa (Fig. 2b). This much more realistic map predicts wintering areas for the Basra reed warbler along the Indian Ocean coastline from southern Somalia down to eastern South Africa and includes inland areas in southern Sudan, Uganda, Kenya, Rwanda, Burundi, Tanzania, southern Zaire (now Democratic Republic of the Congo), eastern Zambia and Zimbabwe, Malawi, Mozambique and Swaziland. The highest prediction values are naturally found in southern Kenya and Tanzania, from which most records originate. Interestingly, most southern

Table 3 Recorded localities for the cinereous bunting (*Emberiza cineracea*) in Africa (records arranged temporally). Sources and details of each record are specified under each record number below. Subspecies, age, sex (*F* female, *M* male), and numbers observed (*No.*) are given if known. The date is stated as accurately as possible given the source. The geographical coordinates are given as degrees, minutes and seconds north and east and were double-checked as stated in the Methods (e.g. record 13 was corrected from 35° 5' 0'' N 31° 5' 0'' E as given in Bruun (1984) to 30° 50' 20'' N to 33° 54' 2'' E using the written locality description). Details of each specimen: *1* Collected by Heuglin (1869, pp. 660–661) and deposited under the name *Emberiza cinerea* Strickl. in the Staatliches Naturhistorisches Museum Braunschweig, Germany (in Sharpe (1888, p. 529) and Reichenow (1904–1905, p. 281), the year of Heuglin's reference is given as 1871). *2* Collected by Schrader "at the Mareb river" (Hartert 1903–1923, pp. 178–179); also referred to as *Emberiza cinerea* Strickl. Vaurie (1959, p. 683), supposedly referring to the same specimen, added the locality name "Ghadi Saati". Urban and Brown (1971, p. 99), also supposedly referring to the same specimen, added that the subspecies is *cineracea,* but gave no source for that assertion. *3* Recorded by Dal-Fiume (1907) as cited in Smith (1957). *4* Zedlitz (1910–1911, p. 42) obtained this specimen under the name *Emberiza cinerea* Strickl. *5–6* Two males (BMNH 1919.12.17.1183, BMNH 1919.12.17.1185, both very fat) and one female (BMNH 1919.12.17.1184, thin) collected by Capt. H. Lynes (Sclater and Mackworth-Praed 1918, p.464; R. Prŷs-Jones, personal communication) and deposited under the name *Emberiza cinerea*. Also referred to in Hogg et al. (1984). *7* Collected (BMNH 1965.M.16237) by Schrader and deposited by R. Meinertzhagen (1930) as a spring bird. However, it is actually in autumn plumage and, given Meinertzhagen's fraudulent track record (e.g. Knox 1993), neither the date nor the locality can be trusted (R. Prŷs-Jones, personal communication). *8* Collected (BMNH 1952.18.10) by Smith (1955) and also mentioned in Smith (1960). *9* Smith (1957) observed small migrating parties, which were again mentioned in Smith (1960). *10* Deposited at the Zoological Museum, Hebrew University of Jerusalem (Goodman and Meininger 1989, pp. 475–476). *11* Received ring no. J161368 (G. Nikolaus, personal communication). *12* Received ring no. J 161408 and was erroneously referred to as a 1980 record in Hogg et al. (1984) (G. Nikolaus, personal communication). It was part of the flocks mentioned by Prendergast (1985) (G. Nikolaus, D. J. Pearson, personal communication). *13* Observed by Bruun (1984). *14* Received ring no. J121196 (G. Nikolaus, personal communication). *15* Received ring no. J 163414 and was erroneously referred to as a 1980 record in Hogg et al. (1984) (G. Nikolaus, personal communication). *16* Observed by S.M. Baha el Din (Goodman and Meininger 1989, pp. 475–476). *17–21* Received ring nos. K11762, K11847, J198953, X25489, and X27015, respectively (G. Nikolaus, personal communication). *22* Observed by Wayne Scott (Baha El Din 1992)

Record	Subspecies	Age	Sex	No.	Date	Locality	Coordinates
1	-	1-year	F	1	October	Keren (= Cheren), Bogosland (Abessinien), Eritrea	15.46.40N, 38.27.29E
2	*cineracea*	-	-	≥1	6. 11. 1903	Ghadi Saati, Mareb (=Mereb) River, NW Eritrea, Eritrea	15.02.00N, 38.28.00E
3	*semenowi*	-	-	≥1	Winter	Daari (= Daaridaba), Eritrea	14.15.00N, 40.54.00E
4	-	Adult	M	1	15. 2. 1908	Keren (= Cheren), Bogosland (Abessinien), Eritrea	15.46.40N, 38.27.29E
5	*semenowi*	Adult	M	2	April	Erkowit, Red Sea Province, Sudan	18.46.00N, 37.07.00E
6	*semenowi*	Adult	F	1	April	Erkowit, Red Sea Province, Sudan	18.46.00N, 37.07.00E
7	*semenowi*	Adult	M	1	12. 4. 1928	Gebel Elba, Egypt	22.12.00N, 36.20.00E
8	*semenowi*	Adult	M	1	10. 2. 1952	Jebel (= Jabal) Halibai, northern Sudan border, Eritrea	17.49.00N, 38.27.00E
9	*semenowi*	-	-	≥1	Mid-March	Ghedem, Eritrea	15.30.03N, 39.33.07E
10	-	-	-	1	21. 3. 1972	St Katherine, Egypt	28.31.00N, 33.57.00E
11	-	Adult	M	1	16. 9. 1981	Suakin, Sudan	19.06.14N, 37.19.48E
12	-	Adult	M	1	17. 9. 1981	Erkowit, Sudan	18.46.00N, 37.07.00E
13	*cineracea*	Adult	M	1	11. 5. 1982	El Gorah, 32 km SSE of El Arish, N Sinai, Egypt	30.50.20N, 33.54.02E
14	-	Adult	F	1	5. 9. 1982	Khor Arba'at, Sudan	19.56.00N, 37.00.00E
15	-	Adult	-	1	17. 9. 1982	Erkowit, Sudan	18.46.00N, 37.07.00E
16	-	Adult	F	1	27. 8. 1983	20 km NE of St Katherine, Egypt	28.39.00N, 34.05.00E
17	*semenowi*	Adult	M	1	17. 9. 1983	Khor Arba'at, Sudan	19.56.00N, 37.00.00E
18	*semenowi*	Adult	M	1	18. 9. 1983	Khor Arba'at, Sudan	19.56.00N, 37.00.00E
19	-	Adult	F	1	3. 9. 1984	Khor Arba'at, Sudan	19.56.00N, 37.00.00E
20	-	1-year	-	1	9. 9. 1984	Khor Arba'at, Sudan	19.56.00N, 37.00.00E
21	*semenowi*	Adult	F	1	21. 9. 1984	Khor Arba'at, Sudan	19.56.00N, 37.00.00E
22	*semenowi*	Adult	M	1	7. 4. 1990	Sharm El Sheikh, S Sinai, Egypt	27.51.49N, 34.17.17E

vagrant records from Botswana and South Africa are also included in this prediction.

Known migration, winter distribution and habitat of the cinereous bunting

The migration and winter distribution of the cinereous bunting was previously described by Chappius et al. (1973) and de Knijff (1991). Since this study focuses on the African continent, we did not attempt to map the winter distribution on the Arabian peninsula. Table 3 presents all African records of the cinereous bunting that we are aware of (see also Fig. 3a). Four records are migratory records from the Sinai peninsula, from where both subspecies have been recorded. The only other Egyptian record, from Jebel Elba, is most likely fraudulent and should be disregarded (see Table 3). The African winter distribution thus contracts to areas close the Sudanese and Eritrean coast (three and five localities, respectively). Except for one record of the subspecies *cineracea* from 1903, all African wintering records so far pertain to the subspecies *semenowi*. Since all Sudanese records are either from September or April,

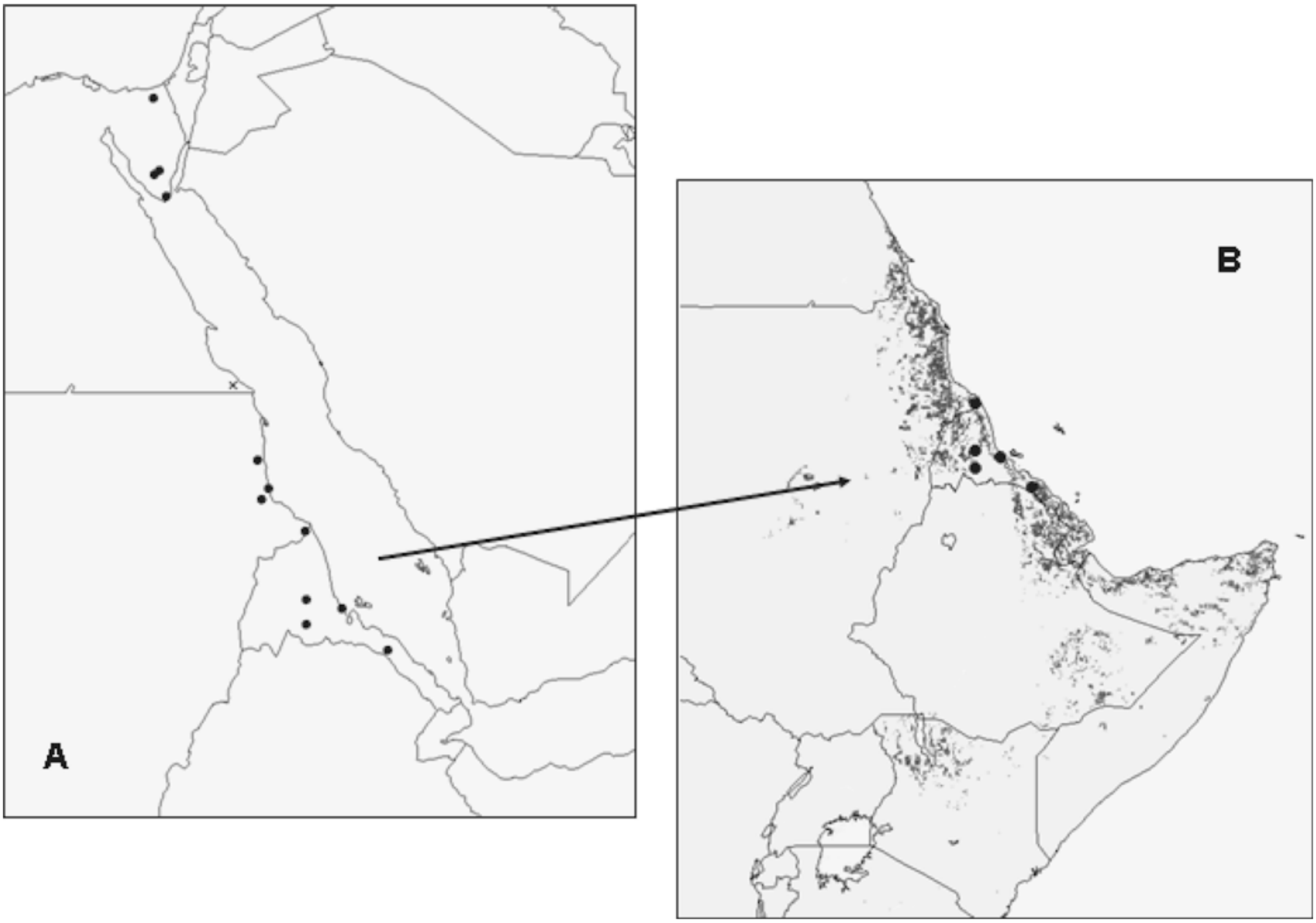

Fig. 3 A The point-locality records (*full circles*) at which the cinereous bunting (*Emberiza cineracea*) was observed in Egypt, Sudan and Eritrea during the months of August–November and February–May (for details, see Table 3). *x* The Gebel Elba locality in south-east Egypt as reported by Meinertzhagen (1930) which is almost certainly fraudulent. **B** BIOCLIM predicted distribution of the cinereous bunting (*Emberiza cineracea*) using four environmental GIS data layers (average temperature of the coldest month, elevational range, habitat heterogeneity, percent forest cover) and point-locality records for Eritrea (*full circles*, cf. **a**). *Colours* as in Fig. 2

the true wintering range may even contract further to just Eritrea where the species has been observed in October, November, February and March. The whereabouts of the species during December and January remain unknown.

The first habitat descriptions are given by Smith (1957) who observed the species on "rocky ground, short grass". In consultation with Smith, Moreau (1972) described the coastal habitat below 300 m as consisting "mainly of sandy or gravelly plains with a cover of short grass or the taller clumps of *Panicum turgidum*". He added that the open plains are interspersed with *Acacia* belts, rocky hills, channels with some food cultivation and fringed with *Tamarix*, *Salvadora* and *Zizyphus* trees. Urban and Brown (1971), without citing original references, defined the habitat as either nearly naked rock desert, open desert with annual grass or semi-desert savanna with *Acacia* and *Chrysopogon* below 1,200 m. The 1981 and 1982 records from Erkowit consist of birds netted along a dry wadi bordered by flowering *Acacia* trees and bushes where some waterholes with fresh water were available (G. Nikolaus, personal communication). Prendergast (1985) added that the surrounding country was bare rock and brown earth apart from some scattered drought-resistant vegetation so that the trees in the wadi "were probably the most inviting sights that many of the migrants had seen since they had set out". The Khor Arba'at site was a small garden on a small island in a normally dry 500-m wide river bed (Nikolaus 1983a). The vegetation consisting of Niem, lime and guava trees, date palms, Henna bushes, and grass (G. Nikolaus, personal communication) provided the only concentrated green vegetation for many kilometers, thus appearing almost like an oasis.

Predicted winter distribution of the cinereous bunting

We define the wintering grounds of the cinereous bunting as the five Eritrean localities (Table 3), assuming that all Sudanese records are of individuals still on migration (see above). If several records came from the same locality, we only used the locality once in the analyses, so that each locality had equal weight.

The predictions using the four GIS layers (tree cover, average temp of coldest month, habitat heterogeneity, elevational range) as predictors suggest that suitable locations for wintering cinereous buntings should be found mostly on the plains and hills along the Red Sea coasts in southern Egypt, Sudan, Eritrea, Ethiopia and Sudan (Fig. 3b). A few inland areas in Sudan, Ethiopia and Kenya are also predicted as suitable.

Discussion

The Basra reed warbler and the cinereous bunting are classified as endangered and near-threatened, respectively (BirdLife International 2004). There is clearly a paucity of information concerning the migration and wintering areas of these two species. We hope that by using point-locality records of wintering sites and inductive modelling to predict the wintering distribution of these two species, we have shed more light on the African migration and wintering areas of these two species (noting that the cinereous bunting also winters in the southern Arabian peninsula).

The predicted distributions pinpoint areas that may have remained undersampled and thus guide field-workers to potentially promising areas for future exploration. For the cinereous bunting, the most promising areas are clearly the plains and hills along the Red Sea coasts in southern Egypt, Sudan, Eritrea, Ethiopia and Sudan, especially for the months of December and January for which no records exist. We know that an ongoing atlas project (Ash and Atkins: *Birds of Ethiopia and Eritrea*) will probably close some of these sampling gaps.

Despite a much larger number of records, sampling gaps certainly exist for the Basra reed warbler, too. Besides possible records for Ethiopia and Eritrea, records from Northern Mozambique are certainly missing because of the minimal exploration this part of the country has seen so far (Vincent Parker, personal communication). The most promising areas for future fieldwork as regards the Basra reed warbler are probably low-lying areas (below 1,000 m) near the coastline, e.g. flooded grasslands, pools, lakes, marshes, swamps, and ditches overgrown with reeds (especially *Typha* stands), tall rank grass and sedges, mangroves, coastal and riverine scrub, and garden and woodland thickets. Especially coastal areas in Mozambique, but perhaps also suitable inland areas in Uganda, Tanzania and eastern Zambia and Zimbabwe, could yield additional records. Two ongoing atlas projects have yielded no records for Zambia, but at least 16 sites in central and southern Malawi (Robert Dowsett, unpublished data not included in our analyses). Coastal areas in South Africa may also yield additional records, but given the low number of existing records (Table 2), most individuals probably do not migrate that far south, but go no further than Malawi and northern Mozambique. However, given the low density of field workers, the Botswana and South Africa records may not be of vagrants, but part of a genuine wintering population. Further field observations in these parts of Africa are clearly needed, and we hope that our results will stimulate further investigations.

Besides the available point-locality data, inductive models are of course also influenced by the environmental layers used in the prediction. Our environmental GIS layers hopefully reflect the overall preference of migrants for open habitats with pronounced environmental and seasonal variation (see Introduction), but of course other layers (e.g. variance of temperature or NDVI) may have yielded somewhat different predictions. However, we took great care to choose environmental variables that reflect what is generally known about the habitat preferences of migrants (Moreau 1972; Curry-Lindahl 1981; Lövei 1989; Pearson and Lack 1992; Jones 1995, 1998; Jones et al. 1996; Hockey 2000), and more details are provided in a forthcoming publication (Wisz et al., in preparation). Naturally, a GIS layer containing marshy vegetation would greatly improve our predictions for the Basra reed warbler, but such specific and fine-grained GIS layers are unfortunately not yet available.

We could have clipped the predicted distribution map for the Basra reed warbler with the Central Zambezian Miombo Woodland, Southern Miombo Woodland and Zambezian and Mopane Woodland ecoregions (see Burgess et al. 2004) which would have resulted in excluding southern Zaire, eastern Zambia, Zimbabwe and Tanzania, Malawi, western Mozambique, and Swaziland from our prediction to get an even more restricted version of Fig. 2b. However, even if the Basra reed warbler does not occur in these ecoregions, for conservation purposes it was important to keep all conceivable areas in our prediction. Different inductive algorithms such as GARP (Joseph and Stockwell 2000; Peterson 2001; Peterson et al. 2002), PCA (Robertson et al. 2001) or logistic regression (Brito et al. 1999) may also have yielded somewhat different predictions. However, some of these alternative algorithms have minimal sample size requirements, are sensitive to multi-collinearity of the predictor variables, and/or assign weights to each of the predictor variables based on their explanatory power. Considering our small sample size we decided to use the BIOCLIM algorithm because it does not suffer from any of these drawbacks.

This desk study clearly showed that more fieldwork is needed to close the painful gap in the knowledge about the wintering sites of the Basra reed warbler and the cinereous bunting. It is certainly difficult to find these species in Africa, but the results from this study hopefully narrow down the areas and the habitats in which to look for them.

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