

Historical and current distribution, population size and possible migration routes of the Blue Swallow *Hirundo atrocaerulea* in Africa

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Summary

The Blue Swallow *Hirundo atrocaerulea* is restricted to sub-Saharan Africa, its population size previously estimated at fewer than 1,500 pairs, and is classified as Vulnerable. A better understanding of its current distributional range, population size, protection status and migration routes would improve our ability to conserve the species and the grassland and wetland habitat on which it depends. We now estimate that the Blue Swallow population in the 1850s may have numbered between 1,560 and 2,300 pairs. Based on an assessment of available data, we now estimate the total current Blue Swallow population at 1,006 pairs or 2,012 individuals, an estimated 36–56% decline over the last 150 years. There may be three separate Blue Swallow sub-populations and seven separate migratory routes between their breeding and non-breeding grounds. The Blue Swallow's range in South Africa and Swaziland has contracted by 74%. The majority of Blue Swallows occupy unprotected areas on their non-breeding grounds in the Democratic Republic of the Congo, Uganda and Kenya. The Blue Swallow population in Africa will continue to decline unless the causes of reduction in Blue Swallow habitat quantity and quality can be stopped and sufficient and additional habitat set aside to sustain viable Blue Swallow populations throughout their range.

Introduction

The Blue Swallow *Hirundo atrocaerulea* is restricted to sub-Saharan Africa, migrating between its breeding grounds in south-eastern and north-eastern South Africa, north-western Swaziland, eastern Zimbabwe, western Mozambique, southern and northern Malawi, north-eastern Zambia, southern Tanzania and the south-eastern Democratic Republic of the Congo (DRC) and non-breeding grounds in western Kenya, southern Uganda, north-western Tanzania and north-eastern DRC (Turner and Rose 1989, Keith *et al.* 1992). The birds occupy their breeding grounds from late-September to mid-April and their non-breeding grounds from late-April to late August or early-September (Keith *et al.* 1992). The basic biology of the Blue Swallow is summarised in Keith *et al.* (1992) and Hockey *et al.* (2007).

The global Blue Swallow population, estimated at fewer than 1,500 pairs, is classified as 'Vulnerable' due to its small and rapidly declining population, resulting from the rapid reduction in the quantity and quality of its grassland and wetland habitat (BirdLife International 2000, 2008). The East African Blue Swallow population (Uganda, Kenya and Tanzania) is classified as 'Endangered' under East Africa regional Red Data criteria (Bennun and Njoroge 1996). The South African and Swaziland populations are both classified as 'Critically Endangered' (Evans and Barnes 2000, Monadjem *et al.* 2003).

Current maps of the African distribution range of the Blue Swallow are only approximate (e.g. Turner and Rose 1989). No quantitative assessment has previously been made of the decline in

the Blue Swallow's distribution range and population size. Similarly, no assessment has been made of what portion of the Blue Swallow population is located in formally, partially, or unprotected areas on both their breeding and non-breeding grounds. Also, no attempt has been made to determine the migratory routes between their breeding and non-breeding grounds. A better understanding of the current distribution range, migratory routes, population size and protection status would improve our ability to conserve the Blue Swallow and the grassland and wetland habitat on which it and other biodiversity depends.

Materials and methods

Distribution

All literature and other available information on the Blue Swallow have been collected over the 12 years of the present study. In addition, copies of all nest record cards of Blue Swallows were obtained from BirdLife South Africa, the Avian Demography Unit, and BirdLife Zimbabwe. The Endangered Wildlife Trust's Blue Swallow Monitoring Database was also updated. Blue Swallow distribution data for South Africa and Zimbabwe, as contained in Allan and Earlé (1997), was obtained from the Avian Demography Unit as ArcView 3.2 shapefiles. The Zimbabwe Department of National Parks and Wildlife Management provided all the information on Blue Swallows contained in their Field Cards. In 2005, a request to all birders to submit their sightings and any additional information they may have collected on Blue Swallows was posted on the Southern African Bird Net. All references used are provided in Appendix 1 in Supplementary Materials.

All of the above information was carefully scrutinised and the following data extracted per country: locality, number of nests recorded, number of skins collected, number of birds sighted, the reference, and any additional notes. Only original data were included. In keeping with Harrison *et al.* 1997, locality data were used to determine in which quarter degree grid squares (15' × 15') (QDGS) Blue Swallows have been recorded. This was used in conjunction with ArcView 3.2 to compile Figures 1–7.

Migratory routes

The possible migratory routes used by Blue Swallows were largely determined by looking at the Blue Swallow breeding and non-breeding distribution ranges as they were in 1850 and classifying birds to be on passage to their non-breeding or breeding grounds if recorded outside of these areas in March–April and August–October, respectively. Information on the migratory patterns of other species was used (Berthold 1993) to compile a likely migratory scenario for the Blue Swallow.

Population decline

The South African and Swaziland distribution of the Blue Swallow based on QDGSs as it may have been in 1850 was compared with a map of the QDGSs known to contain breeding Blue Swallows in 2005. The reduction in QDGSs occupied by Blue Swallows over the past 155 years (1850–2005), and the current estimated population in South Africa and Swaziland, were used to estimate the 1850 population size for South Africa and Swaziland.

Literature was assembled on estimates of Blue Swallow populations from throughout its breeding and non-breeding range, and collated into a table. Estimates of Blue Swallow habitat surface area and the number of birds they contained were used to extrapolate the sub-population size for other population fragments. This was done for areas where they are known to occur and where there was some knowledge of suitable habitat, availability and extent. In this manner, an estimate of the entire Blue Swallow population was made per site occupied, and per country. This

was used to assess the number of Blue Swallows that are protected (formally protected areas), partially protected (Ramsar Sites, Natural Heritage Sites, Forest Reserves, Important Bird Areas that are not formally protected areas), and unprotected, on both their breeding and non-breeding grounds.

Results

Distribution and area

Throughout their entire and exclusively African distribution range, Blue Swallows have been recorded between 26.11° to 36.95°E and 2.40°N to 30.60°S (Figure 1). On their non-breeding range, the Blue Swallows may have occupied as many as 23 QDGSs in the 1850s, with a combined surface area of approximately 16,100 km² (Figures 1–2). On their breeding grounds, the Blue Swallows may have occupied as many as 138 QDGSs, in the 1850s, with a combined surface area of approximately 96,600 km² (Figures 1 and 3–5). As each QDGS is about 700 km² in size and

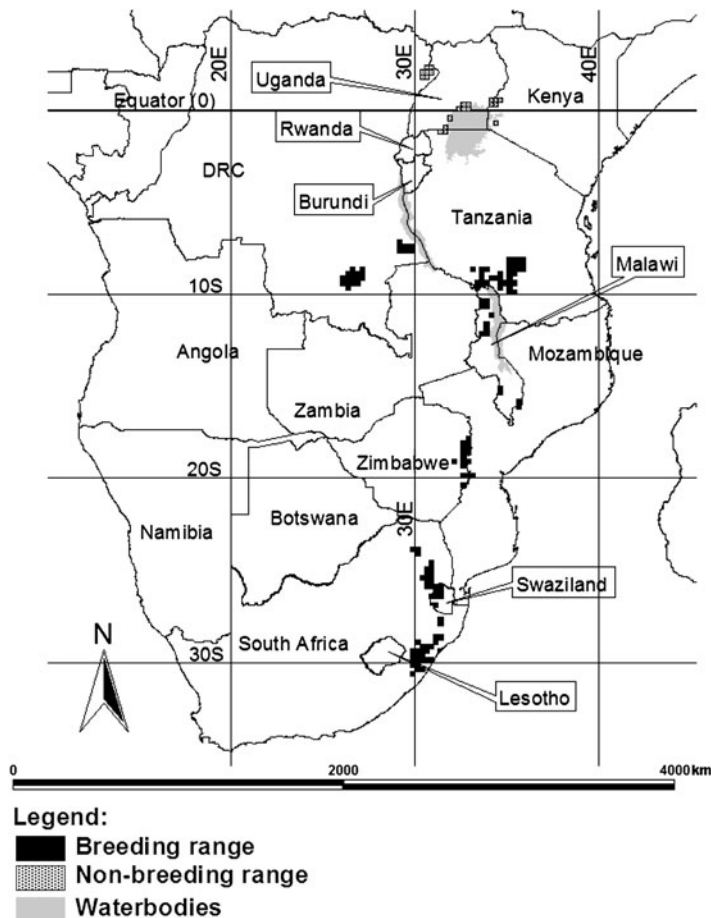


Figure 1. The Blue Swallow African distribution range per quarter degree grid square based on distribution records 1850–2005. See the supplementary material for the references used to compile this map.

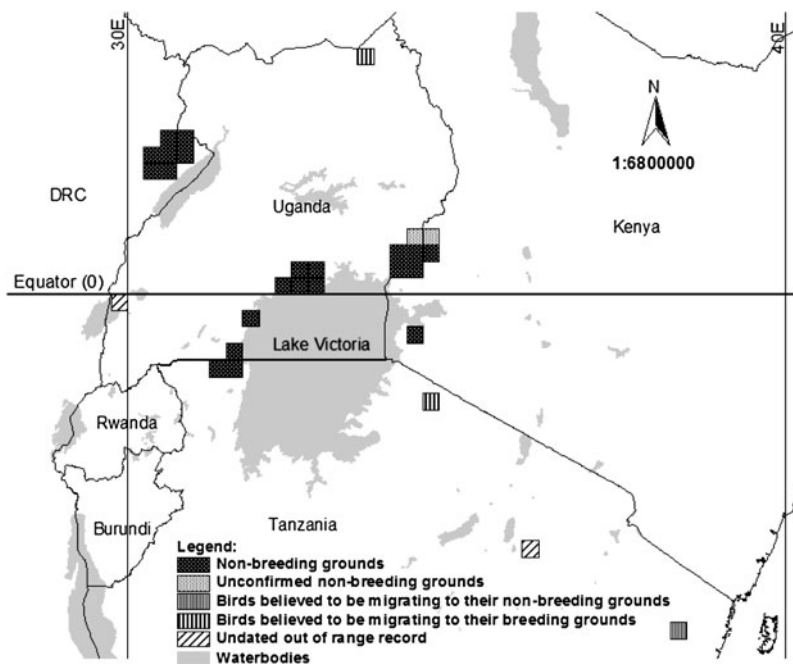


Figure 2. Blue Swallow distribution in the north-eastern DRC, Uganda, Kenya and northern Tanzania per quarter degree grid square based on distribution records 1850–2005. See Appendix 1 for the references used to compile this map.

Blue Swallows were probably not distributed throughout each QDGS, the above figures are probably an over-estimation of the 1850 range. However, based on this estimation, the original Blue Swallow breeding range was approximately 83% larger than their non-breeding range.

Migratory routes

Of the available records of Blue Swallows outside their usual breeding and non-breeding distribution ranges, it was judged that nine records were insufficiently or inaccurately dated for use in this analysis (Table 1). Based on the observation dates, six of the 11 accepted records of Blue Swallows outside their usual breeding and non-breeding ranges were of birds that may be on passage to their non-breeding grounds; the other five were probably birds on route to their breeding grounds, holding some clue as to the migratory routes used by Blue Swallows. Seven of these records are of single birds, while the others (two from Zimbabwe and one each from Malawi and Zambia) are of groups of birds. (Table 1, Figures 3 and 6).

Figure 6 illustrates possible migratory routes that Blue Swallows may use, indicating three separate Blue Swallow sub-populations. There appears to be a disjuncture in the distribution of Blue Swallows between south-western and south-eastern Uganda. Some birds from the breeding grounds may migrate around the western side of Lake Victoria and others around the eastern. We therefore considered Lakes Victoria and Albert/Edward as barriers separating eastern and western migration routes and therefore sub-populations, and these sub-populations to fly east and west of Lakes Tanganyika and Malawi on migration. The first sub-population breeds in the south-eastern DRC and migrates (Route 1) to the north-eastern DRC (Lendu Plateau). The second sub-population breeds in South Africa, Zimbabwe, Mozambique, northern and south-western Malawi

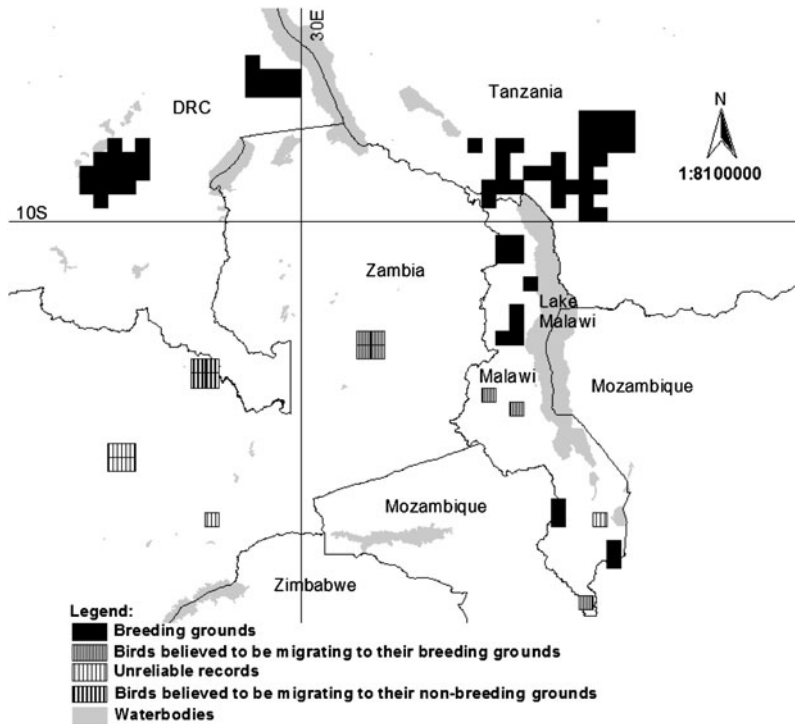


Figure 3. Blue Swallow distribution in south-eastern DRC, southern Tanzania, Malawi, adjacent Mozambique and Zambia per quarter degree grid square based on distribution records 1850–2005. See the supplementary material for the references used to compile this map.

(Misuku Hills, Nyika National Park, North and South Viphya and Kirk Range), and south-western Tanzania (Umalali Mountains, Kitulo Plateau and Mount Rungwe) and migrates (Routes 2–5) to western Uganda and north-western Tanzania. The third breeds in south-eastern Malawi (Mount Mulanje) and southern Tanzania (Livingston Mountains and Udzungwa Mountains) and migrates (Routes 6 and 7) to Kenya and eastern Uganda. Except for the larger lakes, there appear to be no major mountain ranges or deserts that would act as barriers on the proposed routes.

Blue Swallows might migrate in groups. Just prior to migration, at the Blue Swallow Natural Heritage Site (South Africa), it has been observed towards the end of three Blue Swallow breeding seasons that Blue Swallows gather in groups (of up to 13) and then disappear, suggesting group migration (S. W. Evans pers. obs).

Population size and threat status

Since 1850 and before commercial forestry, Blue Swallows were documented occupying 49 QDGSs in South Africa and Swaziland (Allan *et al.* 1997). They were also recorded outside their normal breeding distribution range in a further seven QDGSs in South Africa. Based on historic (1850) and current (2005) distribution, the Blue Swallow's range has declined by 74%, from 49 QDGSs to 13 (Figures 5 and 7). During this period in South Africa alone, there was a reduction from 41 QDGSs to 12, a 71% decline (Figures 5 and 6). During this period in Swaziland, the distribution range declined from eight QDGSs to one or possibly two, a 75–88% decline (Figures 5 and 7).

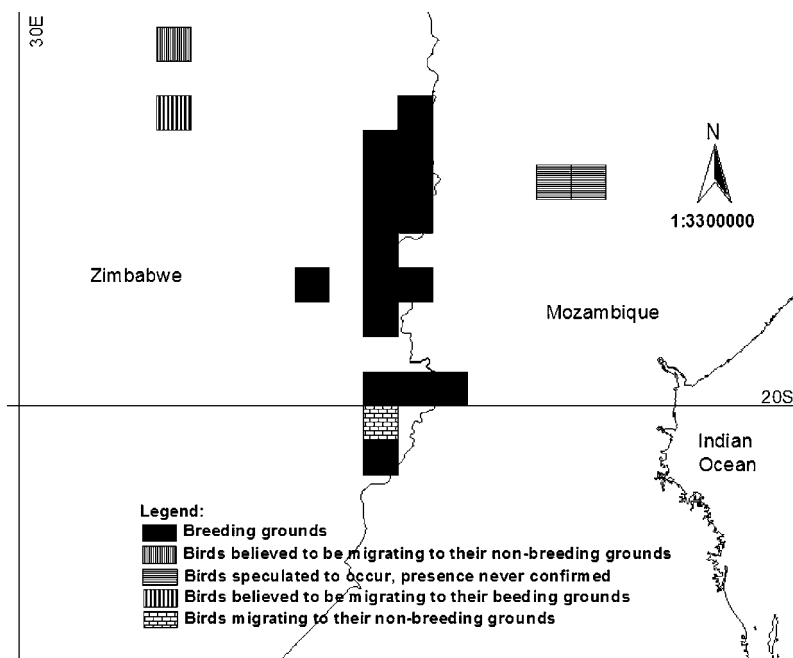


Figure 4. Blue Swallow distribution in Zimbabwe per quarter degree grid square based on distribution records 1850–2005. See the supplementary material for the references used to compile this map.

Assuming that the densities of Blue Swallows on their breeding grounds are similar to Malawi and Zimbabwe, the Blue Swallow population in the 1850s may have numbered 1,960–2,700 pairs (Table 2). Based on these estimations, the total current Blue Swallow population is calculated at approximately 1,006 pairs or 2,012 individual birds, a 36–56% decline from 1850 to 2005, compared with a decline of 74% for South Africa and Swaziland.

As the Blue Swallow is a facultative co-operative breeder (Tree 1989, Du Plessis *et al.* 1995, Wakelin 2006), the 2,012 individual birds estimated for the current Blue Swallow population, based on active nest densities, may be an underestimation of the actual number of Blue Swallows, but not of active nests, as there may be more than two birds present at each active nest (Wakelin 2006). Many Blue Swallows pairs are believed to breed co-operatively in KwaZulu-Natal with a mean of two females and one male per nest (Wakelin 2006). At the study site in Mpumalanga containing nine pairs between 1995 and 1998, there was an equal sex ratio; cooperative breeding may have been taking place at only one nest (S. Evans unpubl. data).

Information on the longevity of swallows and martins that have northern and/or southern temperate and/or tropical zone breeding migrant populations that migrate into the range of their tropical breeding resident conspecifics (Banded Martin *Riparia cincta*, Lesser Striped-swallow *Cecrops abyssinica*, Red-breasted Swallow *Cecrops semirufa* and White-throated Swallow *Hirundo albicularis*) indicates that breeding longevity is approximately 1–7 years (McClure 1974, Rydzewski 1978, Irwin 1981, Earlé 1987, Turner and Rose 1989). The same was found for tropical breeding resident swallows and martins (Brown-throated Martin *Riparia paludicola*, Pacific Swallow *Hirundo tahitica*, and Ethiopian Swallow *Hirundo aethiopica*) (McClure 1974, Rydzewski 1978, Irwin 1981, Earlé 1987, Turner and Rose 1989). A conservative estimate of Blue Swallow longevity was therefore taken to be six years, and three generations was taken to span 18 years.

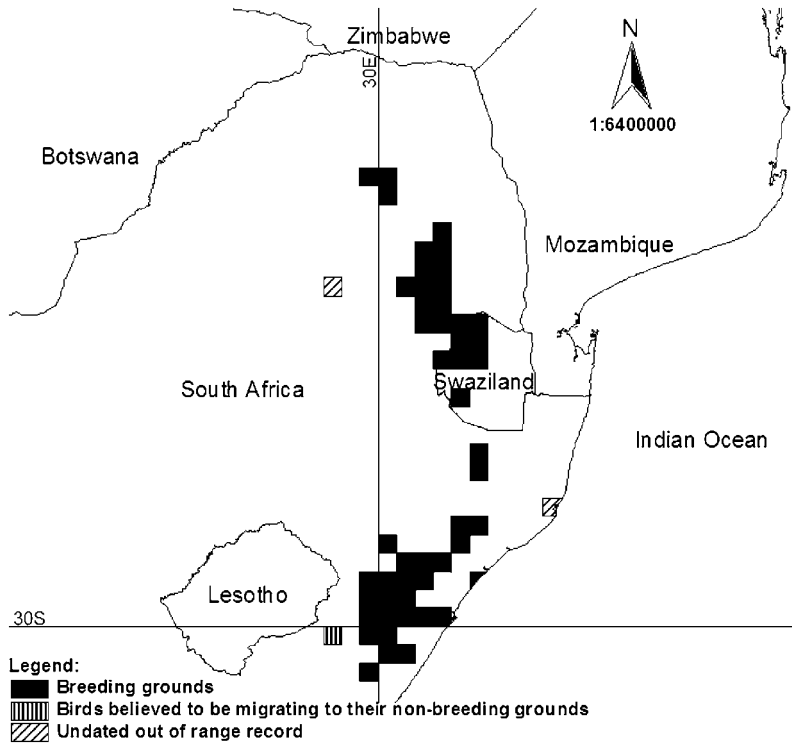


Figure 5. Blue Swallow distribution per quarter degree grid squares in South Africa and Swaziland based on all distribution records 1850–2005. See the supplementary material for the references used to compile this map.

A decline in the Blue Swallow population in South Africa and Swaziland of 74% in 155 years represents a mean decline of 0.48% per year from 1850 to 2005. However, as commercial forestry commenced in Blue Swallow areas in the late 1880s (van der Zel 1988) a 74% decline in 115 years (1890–2005) equates to a decline of 0.64% per year (Figures 5 and 7). A decline of 56% in the total Blue Swallow population over 155 years represents a mean decline of 0.36% per year from 1850 to 2005. Taking a cautious approach and therefore the worst-case scenario, the Blue Swallow qualifies as ‘Vulnerable’ under IUCN criterion C₁ as the Blue Swallow population is estimated to have declined by as much as 12% over the next three generations. In addition, the Blue Swallow qualifies as Vulnerable under IUCN criterion C_{2a(i)} due to a continuing decline projected in the number of mature individuals and no Blue Swallow sub-population estimated to contain more than 1,000 mature individuals IUCN/SSC (2000).

Protection status

Throughout their breeding range, approximately 60% of the Blue Swallow population is in strictly protected areas, a further 23% in partially protected areas (forest reserves, natural heritage sites and Ramsar sites), and an estimated 17% is unprotected (Table 3). The situation is unfortunately very different for the Blue Swallows when on their non-breeding range where only an estimated 28% of the population is in formally protected areas, an estimated 25% in partially protected areas, and an estimated 47% are unprotected (Table 3).

Table 1. Summary of the information available of all records of Blue Swallows considered out of range or on passage.

Country	No. of birds	Date	Locality	Source
Potentially on migration to the non-breeding grounds:				
Zimbabwe ⁴	1 bird	12/04/1951	Glendale Farm	Arkell and Brooke 1967
Malawi ⁴	birds	27-29/03/1958	Nsanje	Long 1959
Malawi ⁴	singles	02/03/1994	Kasungu	Dowsett-Lemaire 2006b
Malawi ⁴	singles	11/04/1992	Ntchisi Mountain	Dowsett-Lemaire 2006b
Tanzania ⁴	1 bird	??/04/<1980	Korogwe	Brown and Britton 1980
Zimbabwe ⁴	birds	??/03/<1981	Chipinga Uplands	Irwin 1981
Potentially on migration to the breeding grounds				
Malawi ¹	1 bird (skin)	23/10/1908	Zomba Plateau	Dowsett 1981
South Africa ²	1 bird	19/09/1957	Swartberg District (KZN)	Shepard 1962
Zimbabwe ⁴	1 bird	15/09/1960	Borrowdale Farm	Brooke 1962, 1963
Zambia ²	1 bird	12/09/1971	Kabulonga Dam, Lusaka	Tucker 1971
Zimbabwe ⁴	birds	??/09/<1981	Chipinga Uplands	Irwin 1981
Tanzania ⁴	1 bird	12/08/1994	Serengeti Nat. Park	Zimmerman <i>et al.</i> 1996
Uganda ⁴	1 female	??/09/1997	Kidepo Valley Nat. Park	Butchard 1996
Zambia ⁴	6 birds	05/09/????	Mutinondo Wilderness	Dowsett <i>et al.</i> 2008
Vagrants				
Zambia	1 bird	07/01/1995	Kitwe	Leonard 1995
Zambia ²	1 bird	21/01/2006	Kafue River (near Chunga)	Dowsett <i>et al.</i> 2008
Malawi ²	several	??/01/1976	Zomba Mountain	Dowsett-Lemaire & Dowsett 2006
Unknown:				
Tanzania	1 bird	?	Tarangira National Park	Baker, pers. comm. 2007
South Africa ³	1 bird	20 /13/1954	Gonubie Bird Sanctuary	Courtney-Latimer 1962, 1964
South Africa ³	1 bird	21/13/1955	Gonubie Bird Sanctuary	Courtney-Latimer 1962, 1964
South Africa	1 bird	< 1958	near Tsitsikama	Skead 1967
South Africa	1 bird	< 1960	Loskop Dam	Prozesky 1960
South Africa	1 bird	< 1980	Eastern Shores L. St. Lucia	Berruti 1980
Mozambique	1 bird	< 1980	Zambezi River Mouth	Brown and Britton 1980
South Africa ²	1 bird	< 1981	Stellenbosch	Anon 1981
Uganda	birds	< 1995	Queen E. Nat. Park	Wilson 1995

¹The locality reported for this skin should be accepted with reservation

²Unconfirmed and not used further

³The month was incorrectly documented as "13", may be either the first or third month of the year?

⁴11 records of birds possibly on migration and used in the analyses.

Discussion

Population decline

The Blue Swallow population decline (Figures 5 and 7) in South Africa and Swaziland has primarily been due to a decrease in the grassland and wetland habitat quantity and quality available (Parker 1994, Allan *et al.* 1997, Evans and Barnes 2000, Monadjem *et al.* 2006). A reduction in habitat quantity and quality on the non-breeding grounds would also support a smaller population and result in there being fewer birds returning to South Africa and Swaziland to breed and therefore a decline in the overall Blue Swallow population (Evans *et al.* 2002).

The Blue Swallow population in Africa will continue to decline unless sufficient habitat is set aside to sustain viable populations. The International Blue Swallow Action Plan compiled in 2002

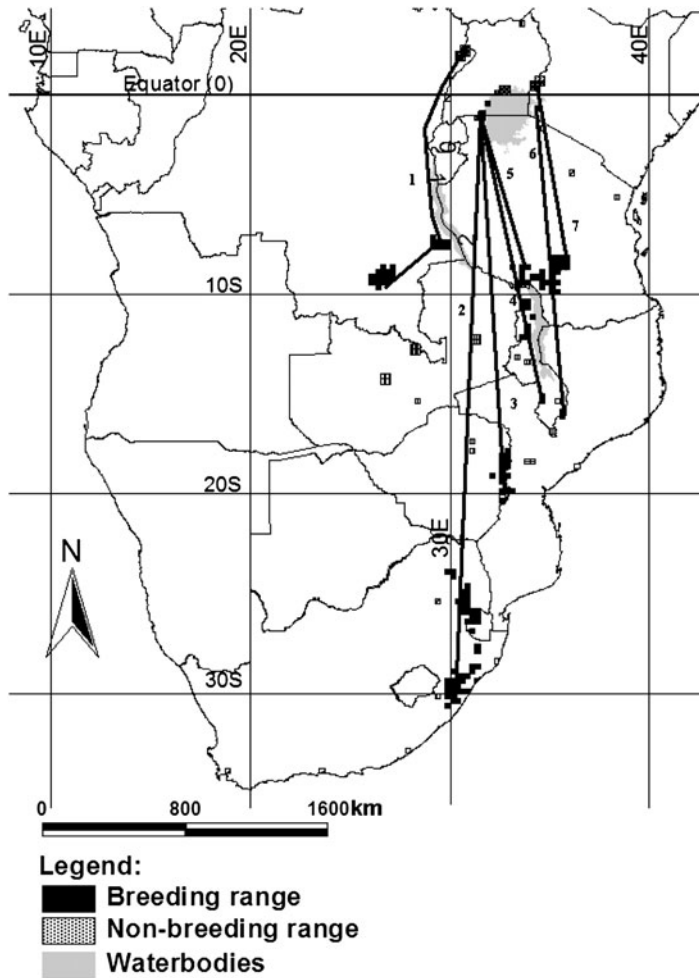


Figure 6. Seven possible migratory routes used by Blue Swallows between their breeding and non-breeding grounds (also see Table 1).

by representatives from nine of the ten Blue Swallow range states (Evans *et al.* 2002) needs to be reviewed, updated and implemented.

Important countries for conserving the Blue Swallow

The most important countries for conserving breeding populations of the Blue Swallow and its unique grassland and wetland habitats are Zimbabwe, Malawi and southern Tanzania, as combined they contain the largest numbers of breeding birds within the least fragmented habitat and contain 74% of the current estimated total breeding population (Tables 2 and 3). No dedicated survey of the Blue Swallow has been done in southern Tanzania and this is urgently needed.

When Blue Swallows are on their non-breeding range, Uganda and Kenya are the most important countries for conserving the birds and their wetland habitats, as these two countries currently contain an estimated 73% of the combined non-breeding Blue Swallow population.

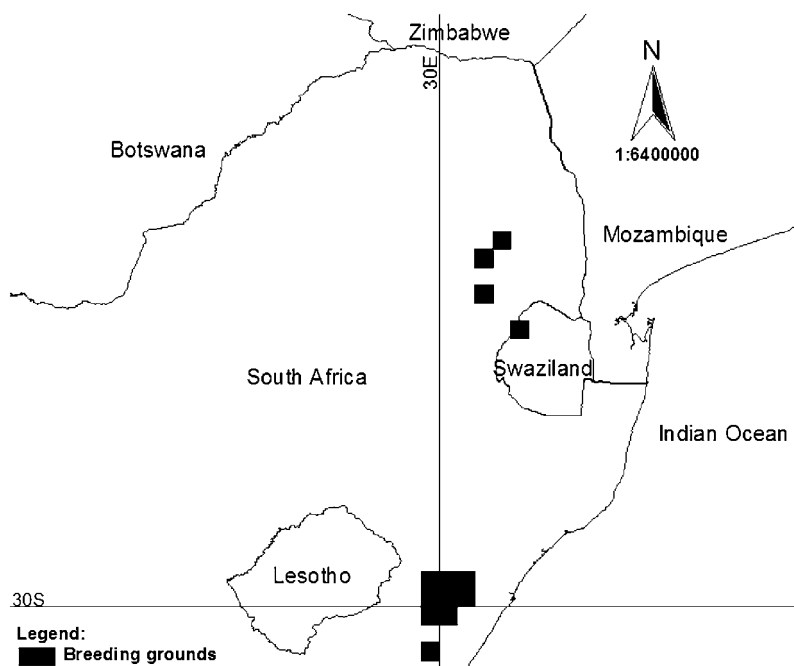


Figure 7. The 13 quarter degree grid squares in which Blue Swallows were breeding in 2005 (Monadjem *et al.* 2006).

Blue Swallow sub-populations

The Blue Swallow may be distributed within three separate sub-populations (Figure 6); it is therefore necessary to conserve the Blue Swallow on breeding and non-breeding grounds within all three separate sub-populations in order to conserve current genetic diversity. Blue Swallow stopover sites need to be identified along their migratory routes and programmes initiated to conserve them. Unfortunately, the impacts of changes along the Blue Swallow migratory routes are unknown and their effects on the population can not yet be determined. Studies are urgently needed to confirm the migratory routes used by Blue Swallows.

Protection status

Loss of habitat quality and quantity for Blue Swallows may be expected to be greatest in unprotected and partially protected areas, with very little to no habitat loss in formally protected areas. This would suggest that the current Blue Swallow population is at greatest risk on their non-breeding grounds where 47% of the population occurs in unprotected areas in Uganda and the Lendu Plateau in the north-eastern DRC.

Although this assessment was based on estimated numbers and distribution on their breeding and non-breeding range, it does provide a good indication that conservation of the Blue Swallow in Uganda and the Lendu Plateau in the DRC is important for securing its future survival.

Habitat on migratory routes

Six of the routes believed to be used by Blue Swallows are direct (Figure 6). It is believed that Blue Swallows follow Lake Tanganyika and the Albertine Rift as the leading lines aiding navigation

Table 2. Estimate of the current total number of Blue Swallows^a.

Country	No. of pairs	No. of individuals	Survey or estimate
Breeding Range (n = 8)			
South Africa	84	168	Survey
Swaziland	~ 22	~ 44	Estimate
Zimbabwe	~ 280	~ 560	Survey
Mozambique	~ 50	~ 100	Estimate
Malawi	~ 300	~ 600	Estimate
Zambia	10	20	Survey
S Tanzania	~ 160	~ 320	Estimate
SE DRC	~ 100	~ 200	Estimate
Total	~ 1,006	2,012	
Non-Breeding Range (n = 4)			
NW Tanzania		~ 346	Estimate
Kenya		~ 500	Survey
Uganda		966	Survey
NE DRC		~ 200	Estimate
Total		2,012	

^aBarnes 1998, Bennun and Njoroge 1999, 2001, Childes *in litt.* 1999, 2000, Baker and Baker 2001, Byaruhanga *et al.* 2001, Childes 2001, Demey and Louette 2001, Dowsett-Lemaire *et al.* 2001, Fishpool and Evans 2001, Leonard 2001, Parker 2001, Monadjem *et al.* 2003, Byaruhanga and Evans 2004, Stjernstedt 2004, EWT-Blue Swallow Working Group Monitoring records 2005.

between their breeding grounds in the south-eastern DRC and their non-breeding grounds on the Lendu Plateau. It was found, for instance, that migrants from North America migrating south either use the Rocky Mountains to their west or migrate south between the west coast and the Rocky Mountains to their east, as leading lines and aids to migration (Hynes 2007). A direct migratory route between breeding and non-breeding grounds need not be a straight line due to barriers such as mountain ranges and deserts that have to be crossed or avoided (Hynes 2007). The Purple Martin *Progne subis* breeds in open woodlands, farms and towns in North America, and migrates to similar habitat in South America during the non-breeding season (Turner and Rose 1989). They must cross tropical forests on migration as there is no continuous open woodland linking North and South America (Turner and Rose 1989). Aerial insectivores such as swallows and martins are able to forage on the wing and migrate by day, and when on migration, stop over near water, presumably with insects (Hynes 2007). This demonstrates that long-distance migrants such as the Purple Martin, and presumably the Blue Swallow, do not need habitats characteristic of their breeding or non-breeding habitat along the entire length of their migratory route. There are no major mountain ranges or deserts along the indicated routes (Figure 7). The 11 records of Blue Swallows outside their usual breeding and non-breeding distribution ranges were all within savannah habitat which is not typical of the grassland and wetland habitat characteristic of their breeding and non-breeding ranges (Figures 2–5 and 7).

Distribution

Sibley and Monroe (1990) erroneously included Lesotho in the southern African breeding distribution range of the Blue Swallow. Simmons and Barnard (2005) modelled Blue Swallow distribution from the distribution map and data in Harrison *et al.* (1997). This model erroneously included south-western Mozambique, south-eastern Free State, the east of Eastern Cape Province and western Lesotho as part of the Blue Swallow distribution range. The distribution map in Stevenson and Fanshawe (2002) includes Rwanda and northern Burundi in its non-breeding distribution range. In all three cases, there are no records supporting these distributions.

Table 3. Current estimated Blue Swallow numbers and proportions that are protected throughout their breeding and non-breeding ranges^a.

Country	Strictly Protected		Partially Protected		Unprotected	
	No. pairs	% of total	No. pairs	% of total	No. of pairs	% of total
Breeding ranges						
South Africa	12		10		62	
Swaziland	8		0		14	
Zimbabwe	245		20		15	
Mozambique	30		0		20	
Malawi	250		40		10	
Zambia	10		0		0	
S Tanzania	0		160		0	
SE DRC	50		0		50	
Total	605	60	230	23	171	17
Country	Strictly Protected		Partially Protected		Unprotected	
	No. birds	% of total	No. birds	% of total	No. of birds	% of total
Non-breeding ranges						
NW Tanzania	0		346		0	
NE DRC	100		0		100	
Kenya	473					27
Uganda	0		151		815	
Total	573	28	497	25	942	47

^aBarnes 1998, Bennun and Njoroge 1999, 2001, Childes, pers. comm. 1999, 2000, Baker and Baker 2001, Byaruhanga *et al.* 2001, Childes 2001, Demey and Louette 2001, Dowsett-Lemaire *et al.* 2001, Fishpool and Evans 2001, Leonard 2001, Parker 2001, Monadjem *et al.* 2003, Byaruhanga and Evans 2004, Stjernstedt 2004, EWT-Blue Swallow Working Group Monitoring records 2005.

Conclusions

Numbers of Blue Swallows have declined by 56% over the last 155 years and only about 1,000 pairs are optimistically estimated to remain. With the low numbers to start with, and fewer still remaining, the survival of this species is in the balance. The Blue Swallow has lost large parts of its breeding range in southern Africa. Remnant Blue Swallow populations in southern Africa remain precarious. The remaining populations in Zimbabwe and Malawi now constitute the best survival option, but more could be done to formalise and upgrade the protection status of these areas. The non-breeding areas also need their protection status upgrading. The possible migratory routes need confirmation, as does the identification of any threats along these routes.

Supplementary Material

The supplementary materials referred to in this article can be found at journals.cambridge.org/bci

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