**Bothalia - African Biodiversity & Conservation**
ISSN: (Online) 2311-9284, (Print) 0006-8241



# Habitat use by the critically endangered Blue Swallow in KwaZulu-Natal, South Africa

**Authors:**
James Wakelin[1,†]
Carl G. Oellermann[2]
Amy-Leigh Wilson[3]
Colleen T. Downs[1]
Trevor Hill[1]

**Affiliations:**
[1]School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, South Africa

[2]Sustainable Forestry Management Africa, Gauteng, South Africa

[3]School of Life Sciences, University of KwaZulu-Natal, South Africa

**Corresponding author:**
Colleen Downs,
downs@ukzn.ac.za

**Dates:**
Received: 06 Sept. 2016
Accepted: 17 Nov. 2017
Published: 29 Mar. 2018

**How to cite this article:**
Wakelin, J., Oellermann, C.G., Wilson, A-L., Downs, C.T., & Hill, T., 2018, 'Habitat use by the critically endangered Blue Swallow in KwaZulu-Natal, South Africa', *Bothalia* 48(1), a2173. https://doi.org/10.4102/abc.v48i1.2173



**Background:** Habitat loss and fragmentation continue to threaten the survival of many species. One such species is the Blue Swallow *Hirundo atrocaerulea*, a critically endangered grassland specialist bird species endemic to sub-Saharan Africa.

**Objectives:** Past research has shown a serious decline in range and abundance of this species, predominantly because of habitat transformation and fragmentation.

**Method:** The influence of land cover on Blue Swallow habitat and foraging home range, in both natural and transformed habitats, was investigated by radio tracking adult birds.

**Results:** Results showed that tracked birds spent over 80% of their forage time over grasslands and wetland habitats, and preferentially used these ecotones as forage zones. This is likely owing to an increase in insect mass and abundance in these habitats and ecotones. There was reduced selection and avoidance of transformed habitats such as agricultural land, and this is a concern as transformed land comprised 71% of the home range with only 29% of grassland and wetland mosaic remaining for the Blue Swallows to breed and forage in, highlighting the importance of ecotones as a key habitat requirement. The results indicate that management plans for the conservation of Blue Swallows must consider protecting and conserving natural habitats and maintaining mosaic of grassland and wetland components to maximise ecotones within conserved areas.

**Conclusion:** To this end, the stewardship programme spearheaded by local conservation agencies, which aims to formally conserve privately owned patches of untransformed grassland and other natural habitats, may have a strong impact on the long-term persistence of Blue Swallow populations.

## Introduction

Understanding the ecological requirements of organisms is a key prerequisite for the implementation of conservation strategies. Given the rate of transformation of natural landscapes owing to anthropogenic activities, habitat loss is one of the principal challenges faced by many species (Sala et al. 2000). Habitat transformation includes changes in both land use and land cover (Weyer et al. 2015), with remaining patch size, edge effects and extent of isolation all impacting species loss (Bruna, Vasconcelos & Heredia 2005; Kareiva & Wennergren 1995; Yahner 1997). In addition, a loss of suitable habitat often results in a population decrease simply by reduced space available for territories, nest sites and resources (Rolstad 1991). Many studies have recognised that rare and endangered species are more susceptible to the effects of habitat transformation (Gonzalez & Chaneton 2002; Wilcove et al. 1998). Indeed, more than 80% of the global population of endangered bird species have been negatively impacted by habitat loss (Temple 1986). One such species is the Blue Swallow, *Hirundo atrocaerulea* Sundevall, a critically endangered grassland specialist endemic to sub-Saharan Africa (Barnes 2000; BirdLife International 2012, 2013; Combrink & Little 2012; Evans et al. 2003; O'Connor 2002; Spottiswoode 2005; Wakelin 2004).

Blue Swallows are intra-African migrants with the total distribution extending from the KwaZulu-Natal Midlands northwards through Mpumalanga, Swaziland, and the eastern highlands of Zimbabwe, north-eastern Zambia, Malawi, southern Tanzania, south-eastern Democratic Republic of Congo, Uganda and south-western Kenya (Allan & Earlé 1997; Evans & Barnes 2000; Spottiswoode 2005; Turner 2004). The breeding distribution of Blue Swallows includes Democratic Republic of the Congo, Tanzania, Zambia, Malawi, Zimbabwe, Mozambique, South Africa and Swaziland (Evans & Bouwman 2010).

**Note:** †, 1972–2008.

The preferred habitat of Blue Swallows is open mistbelt grasslands interspersed with drainage lines and wetland systems (Keith, Urban & Fry 1992). Blue Swallows are aerial hunters that feed on the wing with a fast and erratic flight (Spottiswoode 2005; Wakelin & Hill 2007). Accordingly, Blue Swallows prefer to forage in open, uncluttered areas, free of trees, shrubs and steep slopes (Allan et al. 1987; Clancey 1985; Ginn, Mcllleron & Milstein 1989).

Blue Swallows breed between October and March and construct cup-shaped nests underground in riverbanks, sinkholes, aardvark (*Orycteropus afer*) burrows, areas of river erosion, road cuttings and abandoned mine shafts (Combrink & Little 2012; Evans & Bouwman 2010; Evans et al. 2002). In South Africa, there is generally only one nest per site with nest densities ranging from one pair in 52 ha to as little as one pair in 300 ha (Evans et al. 2002).

In many countries, including South Africa, Blue Swallow populations occur almost entirely in unprotected areas (Evans et al. 2002) and are severely threatened by anthropogenic activities such as habitat transformation (Allan et al. 1987; BirdLife International 2012; Evans et al. 2003; O'Connor 2002; Spottiswoode 2005; Turner 2004; Wakelin 2004; Wakelin & Hill 2007). Past research and field observations suggest that both the range and abundance of Blue Swallows have seriously declined over the past 20 years, predominantly as a direct result of continued anthropogenic activities, resulting in habitat transformation and fragmentation of the swallows' preferred Mistbelt Grassland habitat (BirdLife International 2013; Combrink & Little 2012). In recent years, the South African and Swaziland subpopulation has suffered an alarming decline of approximately 54%, with the population now consisting of only approximately 57 pairs (Evans et al. 2015).

The largest Blue Swallow breeding population in South Africa is resident in the Midlands Mistbelt Grasslands of KwaZulu-Natal (Allan & Earlé 1997; Matterson 2001). Unfortunately, this habitat is well suited to intensive agriculture, in particular afforestation, owing to high rainfall and deep, well-drained soils (Mucina & Rutherford 2011). Consequently, the Midlands Mistbelt Grassland has suffered considerable transformation and is now regarded as one of the most threatened vegetation types in KwaZulu-Natal (Mucina & Rutherford 2011). Indeed, more than 70% of the KwaZulu-Natal grasslands has been irreversibly fragmented and altered by various anthropogenic activities, with only about 1% remaining in a near-pristine state (Scott-Shaw 1999).

Blue Swallows have very specific nesting and foraging requirements, and it has been widely suggested that a correlation exists between the loss of Mistbelt Grassland and the number of active Blue Swallow nests. Consequently, our aim was to investigate the influence of land cover on Blue Swallow habitat use and foraging home range in both natural and transformed habitats. We predicted that Blue Swallows would preferentially forage in or near natural habitats rather than in the surrounding transformed habitats.

# Material and methods

We conducted the study in the KwaZulu-Natal Midlands of South Africa on a 1150 ha privately owned commercial farm (Figure 1). The farm consists of natural Midlands Mistbelt Grassland and wetland systems and land transformed for the production of sugar cane, tea, timber and beef.

Three Blue Swallow nest sites were selected: Diptank, Florida and Tafeni. All nest sites were located in natural grassland, surrounded by various transformed habitats and all have well established long-term records of successful Blue Swallow nesting and chick rearing. Distances between the nest sites varied, with the Florida and Tafeni nest sites being furthest apart (1831 m). Nest sites were selected based on two criteria: the age of the nestlings and the availability of suitable base station positions for telemetry readings. The Blue Swallows used in the study were adults involved with the breeding at a nest site with chicks on the nest aged between 5 and 10 days. A single adult bird was captured using a small modified mist net while it entered the nest cavity. This offered some certainty that the captured individual was involved with the raising of the brood.

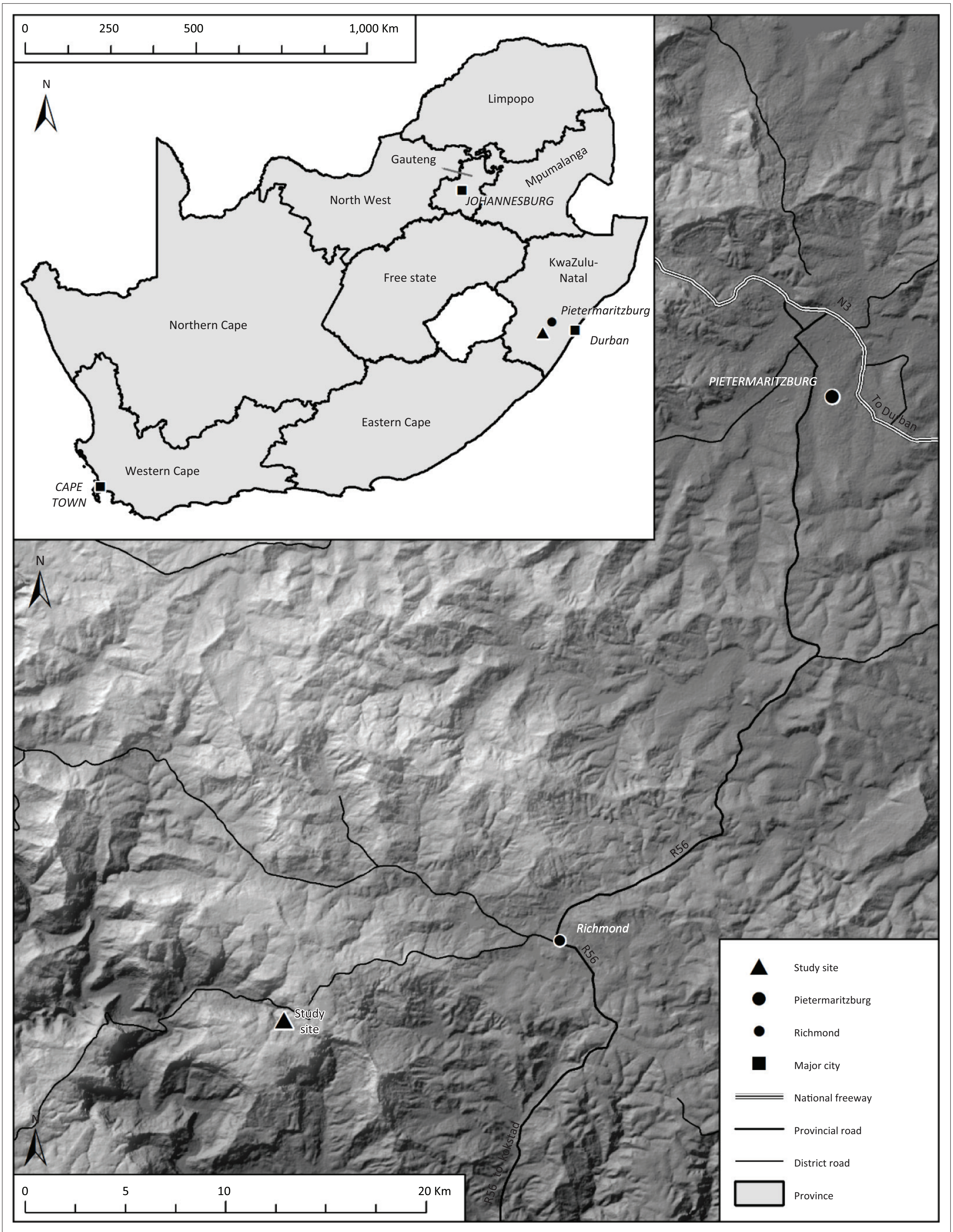
## Radio tracking of Blue Swallows

PIP3 radio tags were fixed onto the middle tail rectrix of three adult Blue Swallows (one male and two females) and radio tracked for 5, 8 and 9 days, respectively. Radio tags consisted of an Ag317 battery, which powered the tags for up to 14 days, and a whip antenna measuring 116 mm in length and weighing between 340 mg and 360 mg (within the accepted threshold of 3% – 5% body weight [Cochran 1980; Kenward 2001]).

Two independently located base stations for direction finding (Kenward 2001) were set up for each site. Base station sites were chosen primarily for their proximity to the nest site and visibility over the surrounding landscape. A 360° plastic compass was fixed to the foot of the antenna (a flexible three-element Vagi antenna [Lintec Antennas Ltd., West Sussex, United Kingdom] weighing 500 g with a bandwidth of approximately 2 MHz, a beamwidth of 80° and a gain of 6 dB stand). The base stations were in line of sight of each other to enable the correct base line zeroing (i.e. the 360° at the first base station faced the second base station and vice versa). A metal peg was driven into the ground at the 360° mark so that if inclement weather prevented visibility between the base stations, an accurate zero degree baseline could be re-established. The readings were made by inserting a needle through the base of the Vagi antenna stand, which pointed to the direction, in degrees, where the Vagi antenna was aimed.

## Determination of foraging home range and land cover analysis

The maximum foraging home range for breeding Blue Swallows was assumed to be the maximum distance




*Source*: Gijsbertsen, B., 2017, Cartographic Unit, Discipline of Geography, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal.

**FIGURE 1:** Locality map of the study site in KwaZulu-Natal, South Africa.

obtained using radio tracking for a Blue Swallow tied to its active nest site. A circular area of 525 ha was calculated as the potential feeding habitat around an active nest site, using 1296 m (the furthest recorded distance) as the radius.

The nest locality data were obtained using a Global Positioning System (GPS), set up according to WGS84. These data were projected, using the Projector extension in ArcView, into Transverse Mercator in WGS84 and overlaid onto digital orthophotos. Land cover types were digitised on-screen and then cleaned using the ArcView extension Edit Tools version 3.3. The digitised land use data were then overlaid with the positional data for each radio tracked Blue Swallow. A Digital Terrain Model was used to determine the habitat in line of sight from each base station which was then combined to spatially delineate a catchment area surrounding each active nest that determined the potential feeding habitat that could be radio tracked.

The land cover on and adjacent to the study site was digitised as polygons, and classed into a land cover type based upon the homogeneity of the physical attributes of the type of land cover. A simplified label was used to describe the classification of the land cover (Table 1).

From field observations, it appeared as if Blue Swallows tended to increase their activity along the boundaries between the grassland and wetland habitats. To corroborate this observation, the distances of the points to an ecotone of a habitat were determined for the 940 radio telemetry points collected from the birds. The distances of 940 randomly generated points were then compared with the distances of the 940 observed points. A non-parametric Chi-square goodness of fit test ($X^2$) was used to statistically compare the radio telemetry point data set and the number of expected locality points occurring within each of the habitat types.

**TABLE 1:** Descriptions of land cover classes used in the current study.

| Land cover class | Description |
|---|---|
| Aliens | Informal self-established stands of alien plants such as black wattle *Acacia mearnsii* and American bramble *Rubus* spp., and stands of bugweed *Solanum mauritianum*. |
| Arable | Land that is ploughed for annual cropping, subsistence or cash cropping. |
| Forest | Wooded grassland and indigenous mistbelt forest. |
| Grassland | Only unploughed, unplanted and not irrigated primary grasslands. |
| Orchard | Established crop of fruit trees. |
| Plantation | Only commercial timber plantations in a regular array of trees. |
| Settlement | All human settlements, formal and informal; this category includes the portion of land around a homestead used as a living area. |
| Sugar cane | All forms of agricultural practices where ground is broken to plant sugar cane as a crop. |
| Tea | All forms of agricultural practices for the production of tea. |
| Waterbody | All dams with standing water. |
| Wetland | All areas where hydromorphic soils predominate; this habitat type is usually associated with sedges, reeds and other water-tolerant plants. |

## Ethical considerations

Ethical clearance was granted by Ezemvelo KwaZulu-Natal Wildlife and the Endangered Wildlife Trust Blue Swallow Working Group (EWT-BSWG).

# Results

## Foraging area and distance

A total of 940 positional data points were gathered over 22 days for the three nest sites. The Florida bird had the largest foraging home range and both the Florida and Tafeni birds' foraging home ranges overlapped with that of the Diptank bird (see Figure 2). The Diptank and Florida birds foraged further from the nest (1030 m and 1296 m, respectively) than the Tafeni bird (524 m). For spatial composition of the foraging home ranges for the three nest site areas, see Table 2. A total of 58% of the total observed locations occurred within 20 m of all habitat boundaries and 69% within 30 m (Figure 3a). In contrast to these findings, the randomly generated expected frequencies delivered 31% and 43%, respectively (Figure 3b). The Chi-square test produced highly significant findings ($p < 0.001$) between the observed and expected frequencies.

## Land cover type of area used by Blue Swallows

Grassland was the largest land cover type at the Diptank and Tafeni nest sites (104 ha and 59 ha, respectively, Table 3), while sugar cane fields (39 ha) and grassland (33 ha) were the largest land cover types at the Florida nest site. Of the 940 viewshed data points obtained, grassland habitat was the highest habitat type represented across all three nesting sites with a total of 708 points (75% in total and 75%, 69% and 80% for Diptank, Florida and Tafeni nest sites, respectively). As a land cover, commercial timber plantations were well represented at all three nest sites but only represented 0.7% of the total recorded point localities for all three nest sites and all were from the Diptank nest site. Orchards and settlements were not represented with any location point data within the viewshed areas.

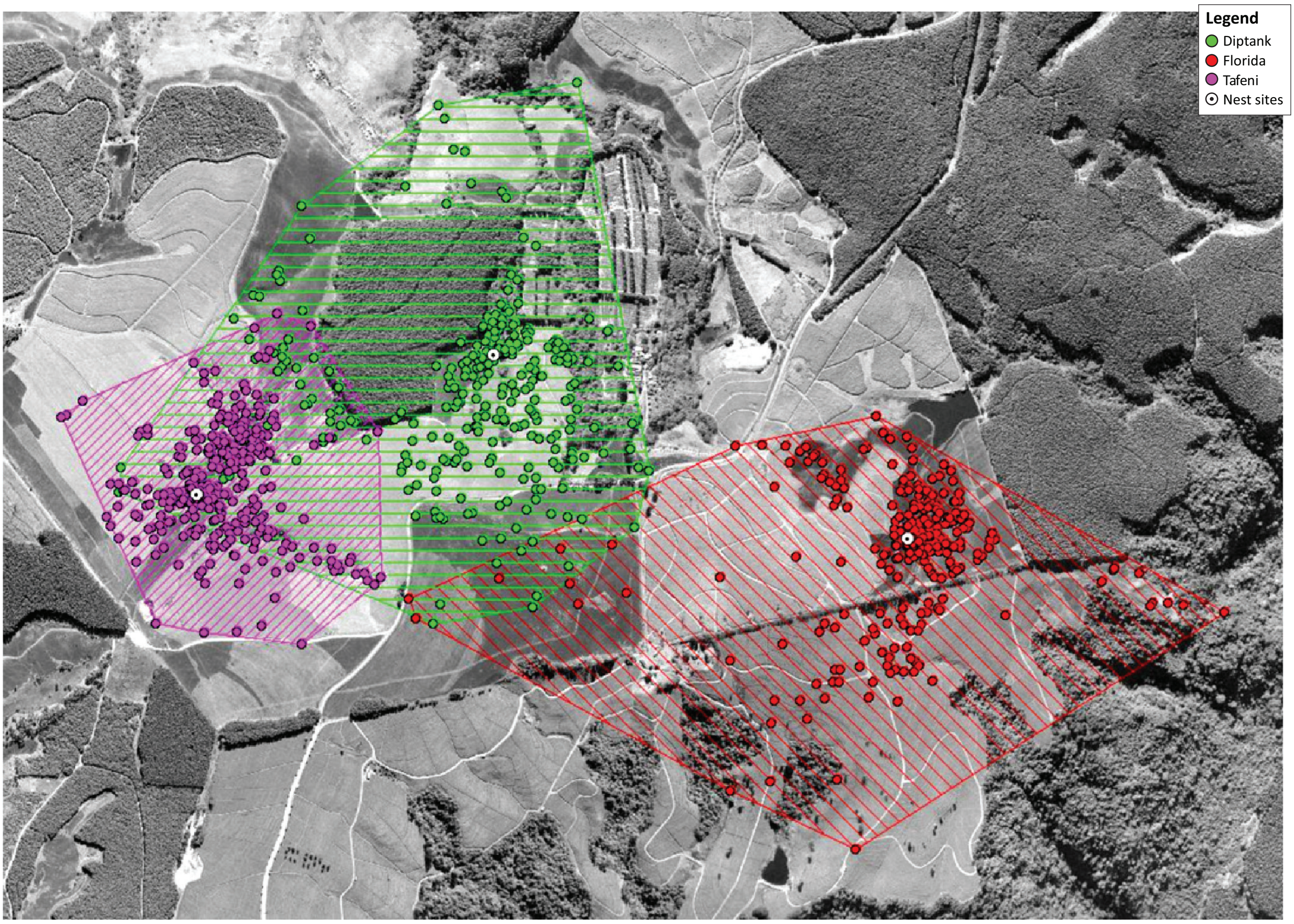
**TABLE 2:** Spatial composition of the foraging home ranges for the three nest site areas, Diptank, Florida and Tafeni.

| Land cover | Diptank | | Florida | | Tafeni | |
|---|---|---|---|---|---|---|
| | No. of patches | Area (ha) | No. of patches | Area (ha) | No. of patches | Area (ha) |
| Aliens | 49 | 46.6 | 55 | 33.1 | 63 | 26.9 |
| Arable | 2 | 1.8 | 0 | 0.0 | 2 | 0.8 |
| Forest | 8 | 17 | 6 | 161.1 | 7 | 13.6 |
| Grassland | 8 | 187.1 | 8 | 65.5 | 9 | 178.9 |
| Orchard | 1 | 4.5 | 1 | 4.5 | 1 | 2.0 |
| Plantation | 5 | 105.8 | 4 | 117.5 | 4 | 198.6 |
| Settlement | 11 | 9.9 | 3 | 3.2 | 11 | 6.7 |
| Sugar cane | 5 | 98.1 | 4 | 59.2 | 6 | 39.5 |
| Tea | 1 | 46.6 | 1 | 74.7 | 1 | 55.2 |
| Waterbody | 9 | 2.7 | 6 | 2.6 | 8 | 1.0 |
| Wetland | 11 | 4.9 | 7 | 3.6 | 8 | 1.8 |
| **Total** | **110** | **525** | **95** | **525** | **120** | **525** |

**TABLE 3:** Positional and land cover data for Diptank, Florida and Tafeni nest sites, indicating percentage of telemetry points recorded per habitat type.

| Land cover | Diptank | | | Florida | | | Tafeni | | |
|---|---|---|---|---|---|---|---|---|---|
| | Area (ha) | Telemetry points | Points / habitat (%) | Area (ha) | Telemetry points | Points / habitat (%) | Area (ha) | Telemetry points | Points / habitat (%) |
| Aliens | 26.33 | 51 | 18.8 | 4.44 | 1 | 0.4 | 1.66 | 6 | 1.5 |
| Forest | 0.47 | 0 | 0 | 1.73 | 2 | 0.7 | 0.71 | 9 | 2.3 |
| Grassland | 103.78 | 204 | 75 | 33.2 | 191 | 69.2 | 59.21 | 313 | 79.8 |
| Orchard | 4.46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Plantation | 30.19 | 7 | 2.6 | 16.25 | 0 | 0 | 17.62 | 0 | 0 |
| Settlement | 1.29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sugar cane | 29.98 | 4 | 1.5 | 39.36 | 17 | 6.2 | 19.29 | 40 | 10.2 |
| Tea | 0 | 0 | 0 | 7.42 | 32 | 11.6 | 0 | 0 | 0 |
| Waterbody | 0.52 | 0 | 0 | 1.31 | 0 | 0 | 0.23 | 4 | 1 |
| Wetland | 0.73 | 6 | 2.2 | 3.1 | 33 | 12 | 1.19 | 20 | 5.1 |
| **Total** | **197.75** | **272** | **100** | **106.81** | **276** | **100** | **99.91** | **392** | **100** |

The area of each habitat type is included.




*Source*: Gijsbertsen, B. & Hill, T., 2017, Cartographic Unit, Discipline of Geography, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal.

**FIGURE 2:** Distribution of radio telemetry points obtained for three radio-tagged Blue Swallows across the study site. Shaded areas indicate the minimum convex polygon for each individual swallow to show their foraging range.

The individual [Diptank ($X^2 = 123.9$, df = 5, $p < 0.0001$), Florida ($X^2 = 338.1$, df = 6, $p < 0.001$), Tafeni ($X^2 = 168.3$, df = 4, $p < 0.001$)] and combined ($X^2 = 601.6266$, df = 9, $p < 0.001$) Chi-square and *p*-values for habitat preferences were statistically significant.

## Spatial land cover

Of the 11 different land covers represented in the foraging home ranges, 10 were represented in the combined foraging areas, with only the arable habitat class not represented. The total area of the combined areas amounted to 405 ha. Alien vegetation had the highest number of patches (73) but only contributed 8% to the land cover. Grasslands contributed the most to the land cover (49%) with 196 ha. Besides the alien land cover, settlements (0.3%), waterbodies (0.5%) and forests (0.7%) contributed the least. Nests were all located in grasslands and telemetry points congregated around the nest sites (Figures 3 and 4).

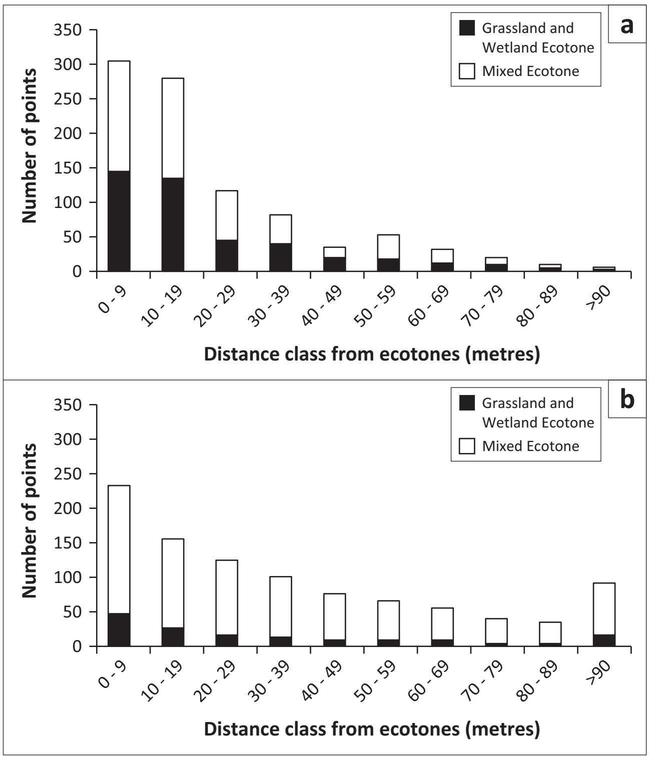



**FIGURE 3:** Distance of the 940 (a) observed and (b) randomly generated locations from the different habitat ecotones at 5 m interval classes within the viewshed areas for the three nest sites.

# Discussion

## Radio tracking

The furthest distance travelled by a radio-tagged Blue Swallow was 1296 m and 1030 m, recorded from adult female birds from the Florida and Diptank nests, respectively. It is reasonable to assume that the majority of the foraging activity would take place within 2 km of their nest sites while bound to the nest sites because of chick rearing activities.

Interestingly, the area covered by the adult male Blue Swallow from the Diptank nest appeared to be greater in comparison with the areas recorded for the two female birds. It is known that the male of a species ranges over a larger area than the female (Chandler, Ketterson & Nolan 1997). This increased range could be associated with the male bird seeking extra-pair copulations, which has been noted to be the case in other Hirundines (Turner 2004). Increased movement could be attributed to many factors, including increased testosterone levels, food availability, body mass and population density (Benson, Chamberlain & Leopold 2006; Chandler et al. 1997).

The height of the tagged bird off the ground affected the strength of the radio signal. During the warmer periods of the day, normally between 11:00 and 14:00, the Blue Swallows socialised and flew at higher distances than during active foraging sessions, resulting in much stronger tag signals. However, obtaining reliable signals from afar was limited by topography. This was evident with the positional data obtained from the tagged Tafeni female bird, which frequently disappeared in a southerly direction towards the tea estate where radio tag signal was concomitantly lost. Occasionally, the signal was recovered, but not for long enough periods to obtain an accurate positional fix. This loss of signal owing to terrain is clearly evident in the spatial distribution maps of the Tafeni female, which spent considerable time over the tea plantation during the warmer periods of the day.

The results from the radio tagging showed that commercial timber plantations were clearly avoided by the Blue Swallows. As the majority of these point locations fell just onto the edge of existing plantations, it is more than likely that the points plotted within plantations are possibly a result of error bias during triangulation; an idea supported by the observation that Blue Swallows avoided plantations even though wind direction could have been blowing insects from inside the plantation into the grassland areas (J. Wakelin., pers. obs., November 2004). However, M. McNamara (pers. comm., 2006) has observed Blue Swallows flying along plantation edges in Mpumalanga Province, South Africa. It is likely that Blue Swallows avoid plantations owing to them being aerially cluttered habitats, which structurally do not allow fast-flying aerial foraging birds, such as the Blue Swallows, an unobstructed and safe forage opportunity (Wakelin & Hill 2007).

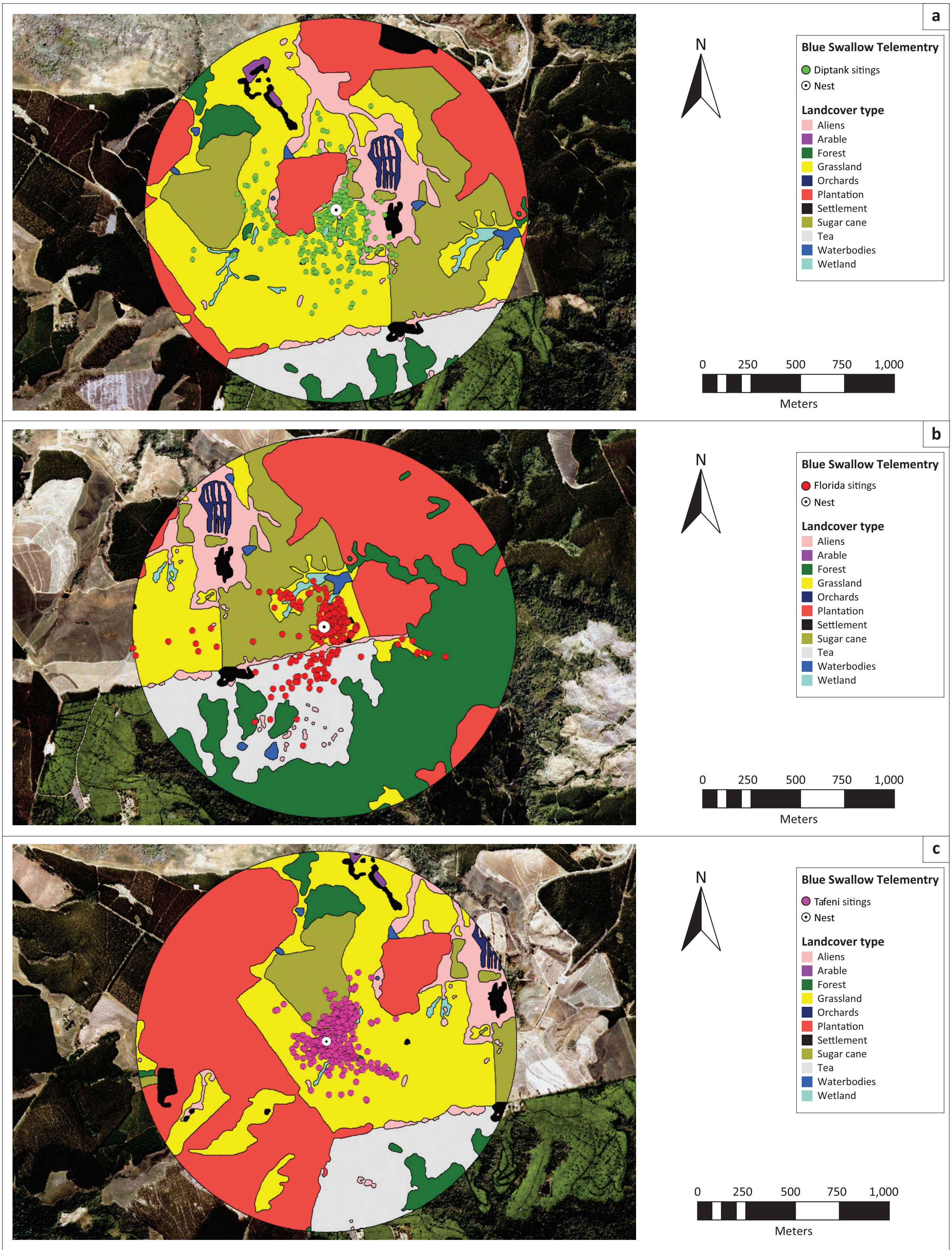
Alternatively, Blue Swallows, as habitat specialists, could possibly use ecotones within the interior of natural untransformed habitats rather than the periphery of these natural habitats, which have transformed sections. If this is the case, then transformation and habitat fragmentation of the preferred grassland and wetland habitats could have significant conservation implications for the persistence of the species, where fragmentation increases patch number and perimeter length, but reduces available core habitat with suitable interior ecotones (Bruna et al. 2005; Kareiva & Wennergren 1995; Yahner 1997).

Clumps of wattle, *Acacia mearnsii*, categorised as aliens, were not ignored by the Blue Swallow as a source for insects. The Blue Swallows at the Diptank nest site spent time foraging around small clumps of wattle, and in particular in the lee of these clumps when a wind was blowing. These small clumps of wattle trees were well augmented by indigenous undergrowth. Nevertheless, in time, the situation could change when these wattle clumps might outgrow the protective function that they currently provide to the indigenous species that have established beneath them (Galatowitsch & Richardson 2005).

Waterbodies played a major role in the foraging of the Blue Swallows, which bathed frequently on the wing, almost fully submerging themselves. Faecal sacks were often deposited into the dam by the birds (J. Wakelin, pers. obs., November 2004).

## Foraging

The radio-tagged Blue Swallows spent over 80% of their time foraging over grasslands and wetland habitats and




*Source*: Gijsbertsen, B. & Hill, T., 2017, Cartographic Unit, Discipline of Geography, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal.

**FIGURE 4:** Spatial representation of the study site and positional data for (a) Diptank, (b) Florida and (c) Tafeni nest sites.

the remainder over tea and sugar cane plantations. This preferential foraging is possibly a result of the increased insect mass and abundance in these habitats (Wakelin 2006). One needs to take cognisance of the fact that grasslands now exist as, in this case, 25 isolated fragments, which could possibly not have been the case in the past, with natural grassland being a single contiguous section interspersed with indigenous forest and wetlands (Camp 1997). These fragments had the third longest perimeter of all the habitats in the study area. Furthermore, these fragments result in extensive perimeter with less suitable habitats and can result in zones of increased threats. It is noteworthy that human-occupied areas were avoided by the Blue Swallows.

Only two land cover classes, other than grassland, are natural: wetland and indigenous forests. As in the case of grassland, natural wetland habitat would have been lost through the construction of dams (Begg 1991), thus reducing a choice habitat for Blue Swallows (Evans et al. 2003; Spottiswoode 2005). Blue Swallows were observed to preferentially use the grassland and wetland habitats' ecotones as forage zones, more than any other ecotone combination. According to Frouz and Paoletti (2000), insect diversity and abundance is increased on the ecotone between two habitats and may explain this feeding behaviour.

Soil humic content has been suggested to play a key role in determining insect abundance in an area (Callaham et al. 2003; Holland 2004). This may explain the reduced selection by Blue Swallows of the sugar cane fields, which are burnt every 18 months for harvesting, leaving the soil bare and devoid of humus and plant litter. Blue Swallows were observed to forage more frequently and for longer periods over unburnt and ungrazed grassland sections than over recently burnt sections, indicating that fire had possibly negatively affected the quantity of insects available (Callaham et al. 2003; Hanula & Wade 2003).

Loss of suitable natural forage and breeding habitats for the Blue Swallow is cause for serious concern (Evans et al. 2003; Wakelin 2004). Transformed land comprises 71% of the entire combined home range areas. This figure includes 12% of indigenous forest, which has limited use for Blue Swallows as only the ecotones are used for foraging. In effect, there remains intact approximately 29% of grassland and wetland mosaic for the Blue Swallows to breed in and forage on within their active home range areas. Furthermore, increases in fragmentation and perimeter increase the negative edge effect of the transformation (Camargo & Kapos 1995). This in turn reduces habitat availability for the swallows through reducing suitable forage range.

Considering the small and highly fragmented nature of the natural habitats that remain intact, some transformed habitats, such as the tea plantation, are fulfilling an important surrogate role for foraging. Loss of these areas to other land covers less suitable for the Blue Swallow could potentially reduce the availability of forage to less than the critical threshold, which could lead to local extirpation of the species.

## Conclusions

Blue Swallows were observed to spend over 80% of their time foraging over grasslands and wetland habitats, and within these habitats, they preferentially used ecotones as forage zones. These observations can possibly be explained by the results of Wakelin (2006) where wetland and grassland habitats were found to have the highest mass and abundance of edible insects. Insect diversity and abundance have been found to increase on the ecotone between two habitats (Frouz & Paoletti 2000). Plantations were clearly avoided by the birds, likely as a result of them being aerially cluttered habitats, which would hinder the flying capabilities of the swallows. In the current study, transformed land comprised 71% of the home range area, with only 29% of grassland and wetland mosaic remaining for the Blue Swallows to breed and to forage, highlighting the importance of ecotones as a key habitat requirement for Blue Swallows. Management plans for the conservation of Blue Swallows must thus be aimed at both protecting and conserving natural habitats and maintaining mosaic of grassland and wetland components to maximise ecotones within conserved areas. To this end, the stewardship programme spearheaded by Ezemvelo KwaZulu-Natal (EKZN) Wildlife, which aims to formally conserve privately owned patches of untransformed grassland and other natural habitats, may have a strong impact on the long-term persistence of Blue Swallow populations.

## Acknowledgements

The authors thank the land owners for allowing them the opportunity to hide-out on their land for so many misty days. They thank Brice Gijsbersen who through his cartographic skills improved figures to a great extent. The authors are grateful to the reviewers for their constructive comments that enriched the final version of this article. We are grateful to the National Research Foundation (South Africa) for the funding of this research.

### Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

### Authors' contributions

J.W. designed the project with C.T.D. and T.H. J.W., T.R.H. and C.G.O. conducted the fieldwork. J.W., T.R.H., C.G.O. and A.L.W. analysed the results. J.W., T.R.H., A.L.W. and C.T.D. wrote the manuscript.

## References

Allan, D., Gamble, K., Johnson, D.N., Parker, V., Tarboton, W.R. & Ward, D.M., 1987, *Report on the Blue Swallow in South Africa and Swaziland*, Blue Swallow Working Group, Endangered Wildlife Trust, Johannesburg.

Allan, D.G. & Earlé, R.A., 1997, 'Blue Swallow *Hirundo atrocaerulea*', in J.A. Harrison, D.G. Allan, L.G. Underhill, M. Herremans, A.J. Tree, V. Parker & C.J. Brown (eds.), *The Atlas of Southern African Birds, vol. 2: Passerines*, pp. 52–53, BirdLife South Africa, Johannesburg.

Barnes, K.N. (ed.), 2000, *The Eskom red data book of birds of South Africa, Lesotho and Swaziland*, BirdLife South Africa, Johannesburg.

Begg, G., 1991, 'The wetlands of Natal and KwaZulu policy proposals', *Environmental Planning and Management* 2, 14–21.

Benson, J.F., Chamberlain, M.J. & Leopold, B.D., 2006, 'Regulation of space use in a solitary felid: Population density or prey availability', *Animal Behaviour* 71, 685–693. https://doi.org/10.1016/j.anbehav.2005.08.005

BirdLife International, 2012, '*Hirundo atrocaerulea* The IUCN Red List of Threatened Species 2012: e.T22712318A38565168', viewed 31 May 2016, from http://10.2305/IUCN.UK.2012-1.RLTS.T22712318A38565168.en.

BirdLife International, 2013, 'Species factsheet: *Hirundo atrocaerulea*', viewed 29 January 2016, from http://www.birdlife.org.

Bruna, E.M., Vasconcelos, H.L. & Heredia, S., 2005, 'The effect of habitat fragmentation on communities of mutualists: Amazonian ants and their host plants', *Biological Conservation* 124, 209–216. https://doi.org/10.1016/j.biocon.2005.01.026

Callaham, M.A., Blair, J.M., Todd, T.C., Kitchen, D.J. & Whiles, M.R., 2003, 'Macroinvertebrates in North America tallgrass prairie soils: Effects of fire, mowing, and fertilization on density and biomass', *Soil Biology and Biochemistry* 35, 1079–1093. https://doi.org/10.1016/S0038-0717(03)00153-6

Camargo, J.L.C. & Kapos, V., 1995, 'Complex edge effects on soil moisture and microclimate in central Amazonian forest', *Tropical Ecology* 11, 205221. https://doi.org/10.1017/S026646740000866X

Camp, K.G.T., 1997, *The Bioresource Groups of KwaZulu-Natal*, Natural Resource Section, Report No. N/A/97/6, KwaZulu-Natal Department of Agriculture, Cedara.

Chandler, C.R., Ketterson, E.D. & Nolan, V., 1997, 'Effects of testosterone on use of space by male dark-eyed juncos when their mates are fertile', *Animal Behaviour* 54, 543–549. https://doi.org/10.1006/anbe.1996.0448

Clancey, P.A., 1985, *The rare birds of Southern Africa*, Winchester Press, Johannesburg.

Cochran, W.W., 1980, 'Wildlife telemetry', in S.D. Schemnitz (ed.), *Wildlife management techniques manual*, 4th edn., pp. 507–520, Wildlife Society, Washington, DC.

Combrink, L. & Little, I.T. (eds.), 2012, *Review of the Blue Swallow international action plan and regional red list assessments: Summary of an international workshop 2012*, Endangered Wildlife Trust, Johannesburg.

Evans, S.W. & Barnes, K.N., 2000, 'Blue Swallow *Hirundo atrocaerulea*', in K.N. Barnes (ed.), *The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland*, pp. 32–34, BirdLife South Africa, Johannesburg.

Evans, S.W., Biggs, D., Van Zyl, C., Cohen, L., McNamara, M., McCartney, S. et al., (eds.), 2003, *Blue Swallow* (Hirundo atrocaerulea) *population and habitat viability assessment (PHVA). Draft Workshop Report.* [s.l.], Conservation Breeding Specialist Group (IUCN/SSC) Southern Africa, Endangered Wildlife Trust, Johannesburg.

Evans, S.W. & Bouwman, H., 2010, 'Habitat selection by blue swallows *Hirundo atrocaerulea* Sundevall, 1850 breeding in South Africa and its implications for conservation', *African Journal of Ecology* 8, 871–879. https://doi.org/10.1111/j.1365-2028.2009.01183.x

Evans, S.W., Cohen, L., Sande, E., Monadjem, A., Hoffmann, D., Mattison, H. et al. (eds.), 2002, *Blue Swallow (*Hirundo atrocaerulea*) International Action Plan*, Conservation Breeding Specialist Group, Johannesburg, South Africa.

Evans, S.W., Monadjem, A., Roxburgh, L., McKechnie, A.E., Baker, E.M., Kizingu, R.B. et al., 2015, 'Current conservation status of the Blue Swallow *Hirundo atrocaerulea* Sundevall 1850 in Africa', *Ostrich* 86, 195–211. https://doi.org/10.2989/00306525.2015.1047808

Frouz, J. & Paoletti, M.G., 2000, 'Spatial distribution of different life stages of one dipteran community along hedgerow and field margin', *Landscape and Urban Planning* 48, 19–29. https://doi.org/10.1016/S0169-2046(99)00074-2

Galatowitsch, S. & Richardson, D.M., 2005, 'Riparian scrub recovery after clearing of invasive alien trees in headwater streams of the Western Cape, South Africa', *Biological Conservation* 122, 509–521. https://doi.org/10.1016/j.biocon.2004.09.008

Gijsbertsen, B., 2017, Cartographic Unit, Discipline of Geography, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal.

Gijsbertsen, B. & Hill, T., 2017, Cartographic Unit, Discipline of Geography, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal.

Ginn, P.J., Mcllleron, W.G. & Milstein, P. le S., 1989, *The complete book of Southern African birds*, Struik, Cape Town.

Gonzalez, A. & Chaneton, E.J., 2002, 'Heterotroph species extinction, abundance and biomass in an experimentally fragmented microecosystem', *Journal of Animal Ecology* 71, 594–602. https://doi.org/10.1046/j.1365-2656.2002.00625.x

Hanula, J.L. & Wade, D.D., 2003, 'Influence of long-term dormant season burning and fire exclusion on ground dwelling arthropod populations in long leaf pine flatwoods ecosystems', *Forest Ecology and Management* 175, 163–184. https://doi.org/10.1016/S0378-1127(02)00130-5

Holland, J.M., 2004, 'The environmental consequences of adopting conservation tillage in Europe: Reviewing the evidence', *Agriculture, Ecosystems and Environment* 103, 1–25. https://doi.org/10.1016/j.agee.2003.12.018

Kareiva, P. & Wennergren, U., 1995, 'Connecting landscape patterns to ecosystem and population processes', *Nature* 373, 299–302. https://doi.org/10.1038/373299a0

Keith, S., Urban, E.K. & Fry, C.H. (eds.), 1992, *Birds of Africa*, vol. 4., Academic Press, London.

Kenward, R.E., 2001, *A manual for wildlife radio tagging*, Academic Press, London.

Macdonald, I.A.W., Van Wijk, K. & Boyd, L., 1993, *Conservation priorities in South Africa: Results of a questionnaire survey carried out during 1992; a report of the Southern African Nature Foundation and the Green Trust, WWF*, Southern African Nature Foundation, Stellenbosch.

Matterson, H., 2001, *Blue Swallow working group newsletter*, Blue Swallow working group, Ixopo.

Mucina, L. & Rutherford, M.C. (eds.), 2011, *The vegetation of South Africa, Lesotho and Swaziland*, South African National Biodiversity Institute, Pretoria.

O' Connor, T., 2002, *Breeding success of Blue Swallows in KwaZulu-Natal: Influence of habitat and grassland condition*, Endangered Wildlife Trust- Blue Swallow Working Group, Johannesburg.

Rolstad, J., 1991, 'Consequences of forest fragmentation for the dynamics of bird populations: Conceptual issues and the evidence', *Biological Journal of the Linnean Society* 42, 149–163. https://doi.org/10.1111/j.1095-8312.1991.tb00557.x

Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R. et al., 2000, 'Global biodiversity scenarios for the year 2100', *Science* 287, 1770–1774. https://doi.org/10.1126/science.287.5459.1770

Scott-Shaw, R., 1999, *Rare and threatened plants of KwaZulu-Natal and neighbouring regions*, KwaZulu-Nature Conservation Services, Biodiversity Division, Pietermaritzburg.

Spottiswoode, C.N., 2005, 'Blue Swallow, *Hirundo atrocaerulea*', in P.A.R. Hockey, W.R.J. Dean & P.G. Ryan (eds.), *Roberts Birds of Southern Africa*, VIIth edn., pp. 752–754, Trustees of the John Voelcker Bird Book Fund, Cape Town.

Temple, S.A., 1986, 'The problem of avian extinctions', *Current Ornithology* 3, 453–485. https://doi.org/10.1007/978-1-4615-6784-4_11

Turner, A.K., 2004, 'Family Hirundinidae (swallows and martins)', in J. del Hoyo, A. Elliott & D.A. Christie (eds.), *Handbook of the birds of the world, vol. 9: Cotingas to pipits and wagtails*, pp. 602–640, Lynx Edicions, Barcelona.

Wakelin, J., 2004, 'Diminishing returns: Critical times for South Africa's Blue Swallows', *Africa- Birds & Birding* 9, 42–46.

Wakelin, J., 2006, 'An investigation to determine the critical habitat requirements of the breeding Blue Swallow *Hirundo atrocaerulea* Sundevall', MSc thesis, University of KwaZulu-Natal, South Africa.

Wakelin, J. & Hill, T.R., 2007, 'The impact of land transformation on breeding Blue Swallows *Hirundo atrocaerulea* Sundevall, in KwaZulu-Natal, South Africa', *Journal of Nature Conservation* 15, 245–255. https://doi.org/10.1016/j.jnc.2007.05.003

Weyer, V.D., Granger, J.E., Hill, T.R. & O'Connor, T.G., 2015, 'Land transformation and its implication for biodiversity integrity and hydrological functioning from 1944 to 1999, Karkloof catchment, South Africa', *Bothalia*: *African Biodiversity and Conservation* 45, 1–13.

Wilcove, D.S., Rothstein, D., Dubow, J., Phillips, A. & Losos, E., 1998, 'Quantifying threats to imperilled species in the United States', *Bioscience* 48, 607–615. https://doi.org/10.2307/1313420

Yahner, R.H., 1997, 'Habitat fragmentation and habitat loss', *Wildlife Society Bulletin* 24, 592.