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Habitats used by Lesser Spotted Eagles (*Aquila pomarina*) during migration and wintering as revealed by Satellite tracking and remote sensing

Habitatnutzung des Schreiadlers (Aquila pomarina) *während des Zuges und der Überwinterung – Ergebnisse der Satellitentelemetrie und Fernerkundung*

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1. Introduction

Satellite telemetry (ST) provides detailed information on the routes taken by migrating wildlife, the location of their stopover sites and the stopover durations. Comprehensive satellite tracking of Lesser Spotted Eagles (*Aquila pomarina*) since 1992 to the present day, has brought to light previously unknown details on the migration and wintering patterns as well a other aspects (e.g. habitat use and territoriality in the breeding grounds) in the life history of these birds (Meyburg & Meyburg 2009a, b, Meyburg et al. 1993, 1995, 2000, 2001, 2004b, 2006, 2007a, b, 2008).

The Lesser Spotted Eagle is one of Germany's critically endangered species and the decline in its population is unquestionably due to a great extent to habitat loss in the breeding areas (Matthes & Neubauer 1989; Meyburg et al. 2004a). Conditions prevailing during migration (Meyburg 2005) and in the wintering areas (Kemp 2000, Meyburg et al. 2001) may also play a role, but few such data have been collected (Meyburg et al. 2004, 2008). The reason for this is the difficulty to study this long-distance migrant during migration and wintering. This has only been improved since ST is applicable to this species since ring recoveries (Danko et al. 1996, Meyburg et al. 2005) and direct observation in the field help hardly to improve our knowledge.

The precise locations of Lesser Spotted Eagles during stopover phases and wintering, as determined by satellite tracking, allow for combined usage with satellite images to answer questions about habitat use, or other factors influencing the course of migration and wintering. This method was tested on White Storks *Ciconia ciconia* fitted with satellite transmitters (PTTs). The outcome for the African continent corresponded closely with previously published information (Gerkmann 2007). This study led to the development of new methods for evaluating stopover and migration data. The combination of satellite and Geographical Information System (GIS) data serves as an instrument for habitat analysis, to an extent impossible with field studies alone. The comparative wealth of information available for the White Stork permitted comparison with results achieved via satellites, and thereby a validation of the methods employed.

Here also extensive use of PTTs provided information on the course of migration. As little is known of the habitat requirements of the Lesser Spotted Eagle in its African passage and wintering areas (Meyburg et al. 1995, 2004b), these initial analyses using ST information supplied important new facts. In addition, with the help of daily updated vegetation index cards (NDVI), it can be determined to what extent the choice of stopover sites is influenced by the prevailing state of the vegetation.

Little is known on habitats used by Lesser Spotted Eagles in Africa (Meyburg et al. 1995, 2004b), although initial analyses using Satellite Telemetry information supplied important new facts. The tracking data used here have been analysed before by Meyburg & Meyburg (2009c) in relation to temporal and geographic migration patterns, as well as flight distances and speeds. The present study concentrates on a standardised analysis of tracking data in combination with geographical data. This involves the selection of precise fixes, and the definition of stopover and migration data using a newly developed index. In addition, with the help of the daily updated Normalized Difference Vegetation Index (NDVI), we try to determine to what extent the choice of stopover sites is influenced by the prevailing state of the vegetation.

2. Methods

2.1 The selection of telemetry data during stopovers

In order to gather information on habitat use in eastern, central and southern Africa the tracking data from a pair of Lesser Spotted Eagles were combined with satellite-supported information on vegetation cover (Global Landcover 2000, Mayaux & Bartholomé 2003) using GIS (ArcMap 9.1). The two eagles were trapped on 6 July 1997 by B.-U. Meyburg and J. Matthes and the male retrapped on 18 July 1998. Solar-powered PTTs, providing fixes based on the Doppler effect, were deployed within the scope of a long-term project of the World Working Group on Birds of Prey and Owls (WWGBP) (Meyburg & Meyburg 2009c). The telemetry periods of the male covers the time-frames 6 July 1997 – 30 December 1997 and 18 July 1998 – 14 November 1999, that of the female the period 6 July 1997 – 27 January 1999 (see Meyburg & Meyburg 2009c). The data set for this study is restricted to the migration routes and wintering areas.

PTT fixes were examined before selecting those for analyses. The filtering and data validation procedures established criteria based on animal movement capabilities and behaviour (e.g. maximum speed, local versus migration movement). Argos data were inspected for time and distance relationships among location estimates. LC 0, LC A, and LC B class points were discarded, but also LC 1, LC 2, and even LC 3 class points.

Using a separate interface the data are visually presented using GIS (ArcMap 9.1). A total of 1,156 locations were used, still including imprecise fixes and a different number of fixes per day. By comparing satellite telemetry Doppler/Argos data with GPS fixes we were able to demonstrate that, contrary to information from Argos (1996), deviations in the Doppler telemetry fixes could be as much as several kilometres which was confirmed by Kaatz (2004), Hays & Akesson (2001) and Pfeiffer & Meyburg (2009). Meyburg & Fuller (2007) emphasise that the accuracy of the each Doppler/Argos fix must be checked. A newly developed procedure allows the determination of the actual deviation and a selection of the most accurate fixes (Gerkmann et al. 2008). As habitat use during stopovers is of particular interest, a pre-selection of satellite telemetry data was undertaken. The most precise fixes for each day were selected (deviation < 5 km), where possible in the early morning or evening, in order to eliminate fixes made during flight Gerkmann (2007).

In order to study habitat use during stopovers, a newly-developed distance index (I_{dist}) was used to distinguish between stopover and migration phases. The index describes the relationship of three consecutive fixes between distance flown and distance actually covered. If these are same, it is considered a direct movement (migration). If the distance flown far exceeds the actual distance covered it is considered to be an indirect movement, which can be defined as flight movement within a stopover site (Gerkmann 2005, 2007).

2.2 Combination with satellite data

The Global Landcover Map GLC 2000 was used for habitat analysis (Mayaux & Bartholomé 2003). For the year 2000, it presents land vegetation coverage in 27 different classes, with a resolution of 1 km^2, and covers the whole of Africa. During a field trip to Botswana and South Africa in 2005, land vegetation coverage was collected at 348 coordinates in order to conduct a ground truthing of the GLC map. The land vegetation coverage was classified into six different groups with 15 sub-classes (Gerkmann 2007) and compared to the respective ground vegetation coverage classes of the GLC map.

As wetlands are inadequately depicted in the GLC map, we also refer to the Global Lakes and Wetlands Database (GLWD) for Africa, available in a resolution of 1 km^2 and showing 12 wetland types (Lehner & Döll 2004a, b).

In addition to habitat use, NDVI data from the NOAA-AVHRR satellite platform were used to discover whether regional vegetation conditions and their seasonal changes influence the choice of stopovers. The NDVI is a dimensionless index between 1 and -1 that depicts the proportion of green vegetation by using the different absorption rates of chlorophyll in red (Xred) and infrared (Xnir) bands of light. High NDVI values signify a high proportion of green vegetation. The NDVI data cover a spatial resolution of 8 x 8 km and are available in 10-day blocks. For each 10-day period a mean value per pixel is calculated in order to eliminate cloud coverage (Tucker et al. 2005).

Our telemetry dataset is overlaid in ArcMap with the GLC and GLWD maps to attach a habitat type to each dataset. As the resolution of both datasets is higher than the possibly incorrect telemetry fix deviation, the points for the evaluation are buffered (radius of 5 km) and the proportional area per habitat is calculated. Although this results in a mixed habitat use for every fix, this method prevents false results arising from imprecise telemetry fixes. Nonetheless, the method only provides an approximation of actual habitat use.

The merging of telemetry data with NDVI is done by splitting the former into months and overlaying them with the three relevant NDVI 10-day period maps. Because the NDVI data are of lower resolution, buffering was not necessary and the respective NDVI value was allocated to the precise point in time of the telemetry fix.

2.3 Comparison of the data with random points

In order to achieve reliable results on actual preferences for certain habitat types or vegetation conditions, a random dataset is generated, which corresponds to the scale of the telemetry data used and their spatial distribution (94 random points, corresponding to the number of the relevant stopover data according to I_{dist}). These randomly generated points were then also overlaid with the remote reconnaissance datasets. The results of the telemetry and randomly generated points were then studied for significant differences using the Man-Whitney U test.

2.4 Overlap with nature reserves

The stopover area data obtained by I_{dist} were checked for overlap with nature reserves, using a GIS template with national and international reserves in the United Nations Environmental Programme World Conservation Monitoring Centre (UNEP WCMC).

3. Results

3.1 Location of the most important stopover sites

The selection of fixes with less faulty deviation, and reduction to one dataset per day, resulted in a total of 152 fixes for the final analysis. These fixes were the basis for the classification of the stopover and migration data according to the distance index I_{dist}.

Altogether 119 of the 152 datasets could be classified (78 %), of which 27 were allocated to the migration dataset (direct flight) and 92 to stopover data (indirect flight). The dominance of stopover data is due to the selection of the time frame from which data were used.

3.1.1 Stopover areas of the male Lesser Spotted Eagle with PTTs 28000 and 6970

Stopover sites were identified in the following regions:

1. Western Tanzania: In the Mpanda Line Forest Reserve, some 100 km to the east of Lake Tanganyika, the bird rested from 31.10 to 04.11.1997 (Fig 1). The fixes on 3 and 4 November cannot positively be classified as stopover, but are however included as the bird only left the area on 5 November. All fixes lie within an area of less than 20 km in diameter.
2. Lukanga Swamp: The Lesser Spotted Eagle stayed in the Lukanga Swamp in Central Zambia from 15 to 19.11.1997 (Fig. 2).
3. Kabwe: After leaving the Lukanga Swamp the Lesser Spotted Eagle next rested some 139 km to the southeast in a Forest Reserve of some 250 km^2 between the cities of Kabwe and Lusaka. The eagle sought out this area in three consecutive years, albeit with only a single longer stay from 22.11 - 02.12.1997. Two further fixes from the area on 10.12.1998 and 02.03.1999 were not classified as stopovers.

Fig. 1: Stopover sites of the Lesser Spotted Eagles in Eastern Africa. *Rastgebiete der Schreiadler im östlichen Afrika.*

4. Kafue Flats: The eagle made a prolonged stay near the Kafue Depression in Zambia from 04.12 - 30.12.1997 and three further visits on 14.12.1998, 12.01.1999 and 07.02.1999 (Fig. 2). The eagle possibly remained in the same area for the whole period from 14.12 to 07.02, perhaps even extending to 26 February 1999 if fixes with a larger faulty deviance for 17 December 1998, 1 and 27 January 1999 and 26 February 1999 are included. This area had been defined as a wintering area in Meyburg & Meyburg (2009c). The area is listed an important wetlands site of high biodiversity under the Ramsar Convention (Ramsar Convention on Wetlands 2000).

3.1.2 Stopover areas of the female Lesser Spotted Eagle with PTT 27999:

1. Gezira: The Lesser Spotted Eagle stayed in the fertile region between the White and Blue Nile in Sudan at least from 18 to 21.11.1998 (Fig. 1). Its range was restricted to an area of some 120 km^2.
2. Luangwa: The eagle rested in the north of the South Luangwa National Park from 25.11 to 22.12.1997 (or perhaps to 27.12.1997) (Fig. 2), designated an *Important Bird Area* (Leonard 2001) . The

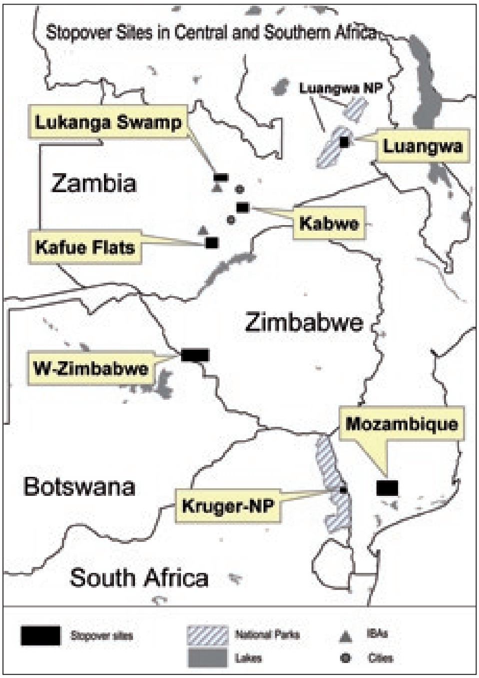

Fig. 2. Stopover sites of the Lesser Spotted Eagles in Central and Southern Africa. *Rastgebiete der Schreiadler im zentralen und südlichen Afrika.*

fixes between 22.12 and 27.12 have a high fault deviation, but nevertheless lie in the same stopover area. The Luangwa valley therefore served as a stopover area for over a month.

3. Western Zimbabwe: This stopover area, the Hwange National Park along the Zimbabwe-Botswana border, was visited twice (Fig. 2). In 1998 the bird stayed from 05.01 to 08.01, then left the area and returned 5 days later on 13.01, to leave again the following day. At the end of the year the bird stayed here from 23.12.1998 to 01.01.1999.
4. Kruger National Park: The eagle rested in the Kruger National Park in South Africa (Fig. 2) from 12.02 - 20.02.1998. On 21.02 the bird started its homeward migration, but rested several times on the way (see below).
5. Gonarezhou: This small stopover area (some 18 km^2) lies on the eagle's homeward migration route and was used from 25.02 - 03.03.1998 (Fig. 2).
6. Mozambique: This stopover area lies some 100 km east of the Kruger National Park. Female No. 27999 rested here from 12.01 - 26.01.1999 (Fig. 2).

3.2 Habitat use and preferences

The stopover and migration data calculated using the distance index give the following percentages of habitat use for the Lesser Spotted Eagle (Fig. 3):

Essentially three different habitat types are frequented. The most preferred habitat is *croplands* at 28.8 %, followed by natural habitats such as *deciduous woodland* (26.6 %) and *deciduous shrubland with sparse trees* (24.7 %). Lesser proportions are made up by *open shrubland* (around 10 %) and *closed deciduous forest* (4.4 %). Other habitat use is of minor significance (*closed grassland* with 0.97 %, *croplands with open woody vegetation with* 2.98 % and *water bodies* with 1.5 %).

The preferred stopover areas are above all *croplands* and *deciduous shrubland with*

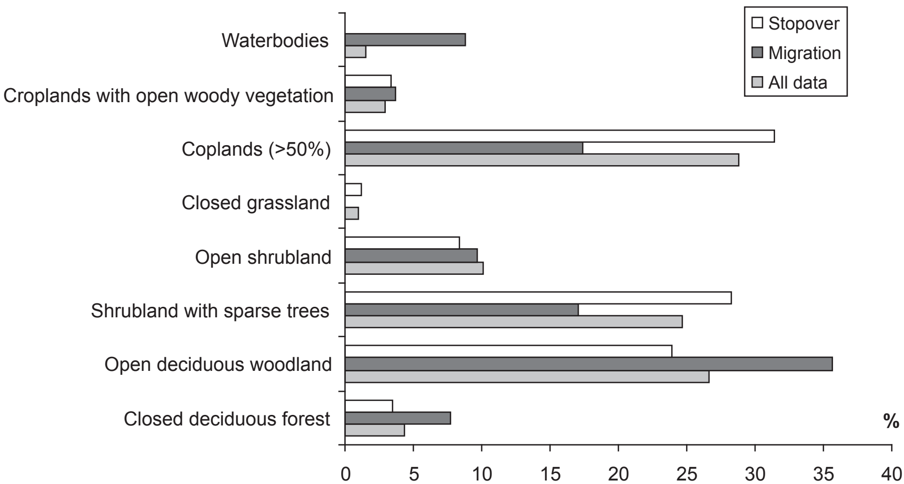

Fig. 3: Habitat selection of the Lesser Spotted Eagles in Africa according to the Global Landcover Map GLC 2000. *Habitatnutzung des Schreiadlers in Afrika entsprechend der GLC 2000-Karte.*

Table 1: Habitat preferences and avoidance in comparison to randomly selected points. *Habitatpräferenzen und -meidung im Vergleich zu zufallsverteilten Punkten.*

	Stopover area data		Migration data	
Habitat	Preference/ avoidance	Level of significance	Preference/ avoidance	Level of significance
Closed evergreen lowland forest	–	***	–	Tendency
Mosaic Forest/croplands	–	*	no significant difference	
Mosaic Forest/savannah	–	**	no significant difference	
Deciduous woodland	no significant difference		+	*
Deciduous shrubland with sparse trees	+	***	+	*
Croplands	+	***	no significant difference	
Water	–	*	no significant difference	

sparse trees, whereby during migration the eagle rested mainly in *deciduous woodland*.

Randomly distributed data (Tab. 1) in comparison showed a preference for *croplands* and *deciduous shrubland with sparse trees* during stopover periods (Man-Whitney U test, $p < 0.001$). During migration the habitat types *deciduous woodland* and also *deciduous shrubland with sparse trees* were preferred (Man- Whitney U test, $p < 0.05$).

These results are also supported when the make up of the previously defined stopover regions are considered. Fig. 4 shows the respective habitat types according to region. The size and outline of the region is restricted to the area used by the Lesser Spotted Eagle. Altogether only a few different habitats are involved. These however are very different in make up, dependent on their location. Even neighbouring areas such as Kabwe and the Kafue Flats in Zambia consist of the same types of habitat, albeit in very different proportions. Only three regions (Gezira, Kafue Flats and the Kruger

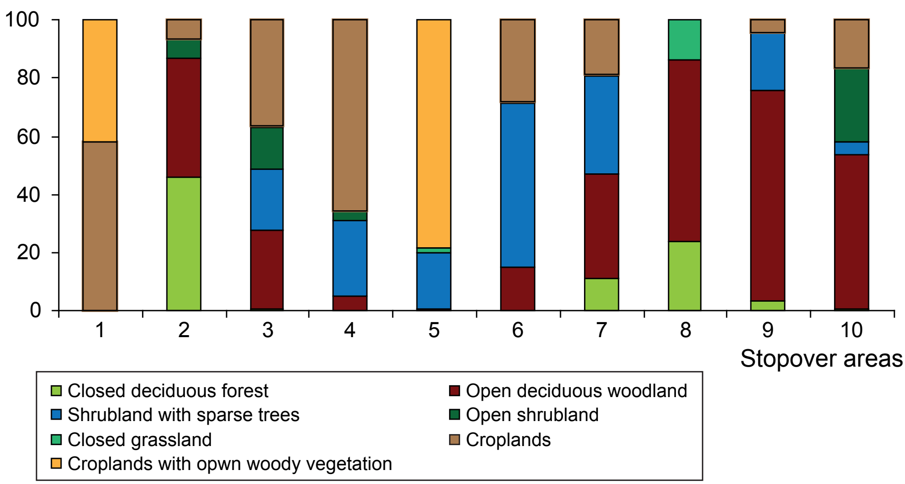

Fig. 4: Habitat composition of the Lesser Spotted Eagles in African stopover areas according to the Global Landcover Map GLC 2000. *Habitatzusammensetzung der Schreiadler-Rastgebiete entsprechend der GLC 2000-Karte.*

National Park) have a large proportion of cultivated land (> 50 %); the Gezira region is used exclusively for agricultural purposes. In the remaining areas there is a more or less large proportion of *croplands*, although other habitats dominate. In four regions this consists of *deciduous woodland* (41 % in Gonarezhou, 62 % in Mozambique, 73 % in West Tanzania and 53 % in West Zimbabwe). In the Luangwa region of Zambia the *shrubland with sparse trees* habitat also has a high proportion of 57 %. Open natural habitat such as *grassland* is scarcely represented here. Only the Mozambique region has some 14 % of closed grassland, but is otherwise dominated by bush and woodland habitats. If one compares the habitat make up of the areas of both Lesser Spotted Eagles separately, there is no essential difference or habitat preference by one or other bird. The high percentage of cultivated areas in the Kruger National Park is in contradiction to the expectation that the area is a national park. This is perhaps an artefact of the GLC 2000 map. In Fishpool & Evans (2001) cultivated areas outside the perimeter of the park only are mentioned, in particular the western catchment area of the rivers in the park. It is also reported in this context that, because of severe persecution of birds of prey, the park and the neighbouring farmland provides an important sanctuary for this species. Nevertheless it has also been observed in recent years that birds of prey from the park once again settle in the neighbouring farmland.

3.3 Influence of vegetation density on stopover behaviour

Indications of the influence of vegetation density on stopover patterns of the Lesser Spotted Eagle can be evaluated when the telemetry data are merged with the 10 day period (decade) NDVI maps. This is particularly evident when the mean NDVI values for Lesser Spotted Eagle stopover data are compared with randomly distributed data. The stopover data of the mean NDVI value for the first decade lie around 0.55 as compared to 0.48 for the randomly distributed points. In the second and third decades, the mean NDVI values for both stopover period fixes as well as random points are even higher (rainy season in the area studied): 0.55 (2nd decade) and 0.56 (3rd decade) for the stopover data and 0.40 (2nd decade) or 0,50 (3rd decade) for the randomly distributed points. These differences in all decades are significant according to the Man-Whitney U test ($p = 0.05$). It can therefore be concluded that the Lesser Spotted Eagle seeks out preferred areas where it has rained shortly beforehand.

3.4 Lesser Spotted Eagles and nature reserves

Altogether 38 of the 92 identified stopover fixes were located in nature protection reserves, amounting to 41.3 % of stopover data and 25 % of all Lesser Spotted Eagle telemetry data. Correspondingly five of the nine important stopover areas described above were within or bordering nature reserves.

Stopovers were made in the following nature protection reserves:

- Mpanda Line Forest Reserve (Tanzania)

Lesser Spotted Eagle 28000 stayed here from 31.10. - 04.11.1997 (with stopover locations from 31.10 - 02.11.97)

- South Luangwa National Park (Zambia)

Lesser Spotted Eagle 27999 stayed in the Luangwa valley for almost a month (25.11. -

27.12.1997 with sgtopover fixes until 22.12.1997)

- Forest Reserve (Kabwe) in Zambia

Lesser Spotted Eagle 28000 stayed from 24.11. to 01.12.1997 in the Forest Reserve, but spent the whole period 22.11. to 10.12.97 in the reserve or its immediate vicinity.

- Hwange National Park (Zimbabwe)

Lesser Spotted Eagle 27999 stayed only on 05/06.01.1998 in the southern part of the National Park; but stayed from 05.01 to 14.01.1998 in its immediate vicinity. On migration at the end of next year the bird returned to the area but did not stay within the nature reserve.

- Gonarezhou National Park (Zimbabwe)

Lesser Spotted Eagle 27999 stayed here in the period 25.02. - 03.03.1998 with stopover locations until 28.02.1998.

- Kruger National Park (Republic of South Africa)

Lesser Spotted Eagle 27999 stayed in the Kruger National Park from 12.02. to 20.02.1998 (with stopover fixes until 17.02.1998).

4. Discussion

For this study a new instrument for automatic identification of stopover periods and migration data was used for the first time. Meyburg & Meyburg (2009c) had already evaluated the telemetry data of this pair of Lesser Spotted Eagles in respect of the course of migration and stopover behaviour, and defined the southernmost location as the wintering area. Areas further to the north where the birds did not migrate for some time were defined as stopover sites. Meyburg & Meyburg (2009c) point out however that the stopover durations are in some cases longer than the stay in the (defined) wintering areas.

In other studies the migration, stopover and wintering are only defined in terms of distances above and below 50 km. Kaatz (2004) and van den Bossche et al. (2002) defined the end of autumn migration of the White Stork as occurring when the 18^{th} Parallel had been crossed and, on five consecutive days, a flight distance of less than 5 km was flown. Correspondingly, the start of (autumn) migration was defined when a daily flight distance of over 50 km was covered. These definitions allow a clear distinction to be made between migration - wintering - migration. On the other hand, stopover and migration periods in between were not taken into account.

As both the White Stork and the Lesser Spotted Eagle take longer or shorter stopover periods during migration, the present study does not explicitly differentiate between migration and wintering, but rather between stopover and migration periods. The difference between the two is determined using a newly developed index (I_{dist}), which as well as calculating the daily flight distance covered also measures the 'directness' of three consecutive fixes. Fuller et al. (1998) used a similar approach to assist in determining the directness of movement and thereby to differentiate between stopover and migration periods of the Peregrine Falcon (*Falco peregrinus*) and Swainson's Hawk (*Buteo swainsoni*) fitted with transmitters. Their study also compared the sum of the distances of several stretches of flight during migration with the direct line between start and end of migration. Shamoun-Baranes et al. (2003) also employed this 'directness' approach in order to differentiate between migration and stopover periods of White Stork fitted with transmitters. The new index used in the present study is a logical extension of these studies and enables automatic calculation of flight directness for consecutive fixes, and also differentiates between migration and stopover data by the inclusion of certain distance criteria. This methods allows the determination of short stopover periods during migration, which are then also included in the evaluation of habitat use.

The Kruger National Park and Mozambique areas defined above correspond to those Lesser Spotted Eagle wintering areas defined in Meyburg & Meyburg (2009c). The other stopover areas identified in the present study were only briefly mentioned there, as the study concentrates on the wintering areas.

The stopover areas determined by this method are based on the data of only two Lesser Spotted Eagles, so it is questionable as to how relevant these areas are for the Lesser Spotted Eagle population as a whole. Most information on stopover areas came from earlier telemetry studies by Meyburg et al. (1995, 2000, 2008). Some important Lesser Spotted Eagle passage areas were also mentioned by Zalles & Bildstein (2000). The majority of these areas lie in Israel, Zambia, Zimbabwe and South Africa. The areas in Israel belong to those identified by BirdLife International as important areas for migrant birds („*Raptor Migration Sites*", Zalles & Bildstein 2000) with very high numbers of migrating Lesser Spotted Eagles present on passage. Meyburg et al. (1995, 2000) only mention one area in West Sudan. Christensen & Sorensen (1989) also mention a number of records of Lesser Spotted Eagles in Sudan (marked on the map); however the overall relevance of the areas north of the equator are considered to be of minor importance whereas Meyburg et al. (2008) recorded the complete wintering of a juvenile Lesser Spotted Eagle in Sudan and neighbouring countries by means of 1,748 GPS fixes. Zalles & Bildstein (2000) mention a further Lesser Spotted Eagle (passage) area in Uganda, which is relatively close (50 km) to a stopover area cited by Meyburg (2001). The rest sites in Zimbabwe cited by Meyburg et al. (2004) are the result of the analysis of the movements of a Lesser Spotted Eagle fitted with a transmitter in Slovakia. These stopover areas lie in North and Central Zimbabwe and do not overlap with those areas identified here. The numerous stopovers in Zambia are only partly confirmed in the relevant literature. Only Meyburg et al. (1995, 2000) mention a stopover site near Lusaka in Western Zambia, Zalles & Bildstein (2000) two areas in Eastern Zambia with, in parts, large numbers of Lesser Spotted Eagles. There are also several records of resting Lesser Spotted Eagles in the Mozambique/South Africa border area. These records all stem from the evaluation in Meyburg et al. (2004) and overlap with the wintering area of Lesser Spotted Eagle Trans. No. 27999 in the Kruger National Park.

How do the results of the habitat evaluation correspond to existing knowledge on habitat preferences of the Lesser Spotted Eagle? Habitat analysis based on the African Global Land Cover map embraces a few inaccuracies, as the map on the one hand depicts the status in 2000 and, on the other hand, as a continental-wide map, also contains over and under estimates of certain land vegetation coverage classes. In a comparison between the GLC map and their own classification based on MODIS data, Giri et al. (2005) discovered discrepancies, in particular for the Sahel region. Here the proportion of savannah and grassland should be higher, with a corresponding reduction in the proportion of cultivated land. Our observations in Botswana and South Africa showed an agreement of only 60 % between our own vegetation classification and that of the GLC map, and a further 12 % of unreliable agreement due to mixed habitats. Nonetheless, the results achieved are very comparable with the information available in the relevant literature. Nuttall (1995) observed Lesser Spotted Eagles in Southern Africa and described their habitat as open bushland, often in close vicinity to wetlands. Observations in Kenya show that the Lesser Spotted Eagle frequents open plains and farmland, and also the vicinity of waterholes (Pearson & Meadows 1979). The references in the relevant literature on the use of wetland habitats can also be confirmed by evaluation of the telemetry data in conjunction with a wetlands map of Africa. Some 10 % of the stopover area data were recorded in wetland habitats (especially freshwater marshes and riverine woodland) (Fig. 5).

As we have concluded the Lesser Spotted Eagle seeks out areas where it has rained shortly beforehand. The more lush vegetation probably offers the birds more dietary resources (insects). In their studies, Dingle & Khamala (1972) and Sinclair (1978) showed a positive correlation between precipitation in the African savannah (Serengeti) or grassland, and the abundance of insects. Liversidge (1989) and Thiollay (1989) also concerned themselves with diet availability in Africa, in particular for birds of prey. According to them, semi-arid areas in the wet summer months provide very good conditions with a surplus of food. After rain, the numbers of termites, locusts and small vertebrates increase, as their life cycle is adapted to these fluctuating conditions (Liversidge 1989).

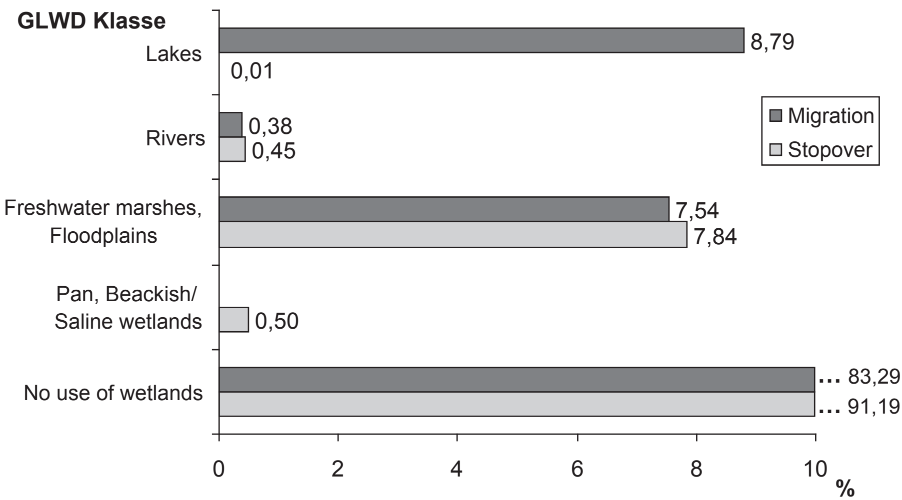

Fig. 5: The use wetlands in Africa by the Lesser Spotted Eagles according to the Global Lakes and Wetlands Database (GLWD) for Africa. *Die Nutzung von Feuchtgebietsflächen durch den Schreiadler in Afrika entsprechend GLWD (Global Lakes and Wetlands Database).*

Meyburg et al. (2004) also studied the relationship between vegetation (NDVI) and the presence of the Lesser Spotted Eagle and, in the case of a wintering area in Namibia, demonstrated that the species prefers to stay in regions richer in vegetation. If the duration of stay in a region is applied to its mean NDVI value, a tendency to longer stays in areas with higher NDVI is also evident. A study using a larger dataset could show whether or not a statistically reliable relationship exists in this instance. A study conducted in a similar way using White Stork telemetry data was based on a larger data base (60 individuals with transmitters over a 10 year period). Here a significant relationship between duration of stay and the mean NDVI value of the stopover site could be proved (Gerkmann 2007, 2008).

5. Summary

Few data have been collected to date on the ecological conditions in the passage and wintering areas of the Lesser Spotted Eagle. A new instrument for automatic identification of stopover and migration satellite tracking data was used to gather information on habitat use in Africa during migration, stopovers and wintering. Satellite telemetry data from a German pair of Lesser Spotted Eagles was combined with satellite-supported information on land vegetation cover and other features.

Lesser Spotted Eagle make stopovers of various duration during migration. The present study differentiates stopovers from migration periods by calculating the daily flight distance covered and the distances flown and actually covered for three consecutive fixes.

Essentially three habitat types were frequented, i.e. croplands (29 %), deciduous woodland (27 %) and deciduous shrubland with sparse trees (25 %).

In addition to habitat use, a study was also made to discover whether regional vegetation conditions and their seasonal changes influence the choice of stopover area. For this, NDVI data from the NOAA-AVHRR satellite platform were used. The Lesser Spotted Eagles seeked out areas where it had rained shortly beforehand. The more lush vegetation probably offers the birds more dietary resources (insects, amphibiens). Five of the nine important stopover areas were within or bordering nature reserves.

This study serves as a pilot project and is intended to encourage evaluation in this way of further satellite telemetry Doppler/Argos locations. New data based on GPS systems are of particular interest as the time-consuming validation of data is unnecessary and therefore the fixes can be incorporated without further revision.

Zusammenfassung

Entscheidend für das Überleben des Schreiadlers (Aquila pomarina) sind nicht nur die Bedingungen im Brutgebiet, sondern auch in den Durchzugs- und Überwinterungsgebieten, über die bislang kaum Daten gesammelt wurden. Da durch die Satellitentelemetrie (ST) relativ genaue Positionen (Doppler-Ortungen) von Schreiadlern bekannt werden, können diese mit Satellitenbildern überlagert werden. So lassen sich

Fragen zur Habitatnutzung oder zu beeinflussenden Faktoren auf das Zuggeschehen und die Überwinterung beantworten. Die hier verwendeten Telemetriedaten eines Schreiadlerpaares wurden bereits durch Meyburg & Meyburg (2009c) hinsichtlich des zeitlichen und geografischen Zugverlaufs, Flugdistanzen und Fluggeschwindigkeiten ausgewertet.

Neben der Habitatnutzung wurde auch getestet, ob regionale Vegetationsverhältnisse und ihre saisonalen Veränderungen Einfluss auf die Wahl der Rastgebiete haben. Hierzu wurden NDVI-Daten der NOAA-AVHRR-Satellitenplattform verwendet. Der „Normalized Differenciated Vegetation Index (NDVI)“ ist ein dimensionsloser Index zwischen 1 und -1, welcher den Anteil grüner Vegetation darstellt. Dabei werden die unterschiedlichen Absorptionsraten des Chlorophylls im roten (Xred) und Infrarot-Bereich (Xnir) des Lichts genutzt. Hohe NDVI-Werte weisen auf einen hohen Anteil grüner Vegetation hin. Die NDVI-Daten liegen in einer räumlichen Auflösung von 8 x 8 km vor und sind als 10 Tages-Kompositen verfügbar. Alle 10 Tage wurde ein Mittelwert je Pixel errechnet, so dass Wolkenbedeckung ausgeschlossen werden konnte (Tucker & Pinzon 2005).

Da es beim Schreiadler während des Zuges zu mehr oder weniger längeren Rastaufenthalten kommt, wird in der vorliegenden Arbeit nicht explizit zwischen Zug und Überwinterung unterschieden, sondern lediglich von Rast und Zug gesprochen. Deren Unterscheidung erfolgte mittels eines neu entwickelten Index (I_{dist}), welcher neben der geflogenen Tagesstrecke auch die „Gerichtetheit“ für jeweils drei aufeinanderfolgende Positionen einer Flugbewegung beurteilt.

Für die nach dem Distanzen-Index bestimmten Rast- und Zugdaten ergibt sich folgende Habitatnutzung der Schreiadler (Abb. 3): Im Wesentlichen wurden drei unterschiedliche Habitate aufgesucht: Kulturflächen bilden mit rund 28,8 % den größten Anteil, gefolgt von natürlichen Habitaten wie offenem Laubwald (26,6 %) und Buschland mit einzelnen Laubbäumen (24,7 %). Zu einem geringeren Anteil wurden auch offenes Buschland (rund 10 %) und geschlossener Laubwald (4,4 %) als Habitate genutzt. Geringfügige Nutzung wiesen die Habitate geschlossenes Grasland mit 0,97 %, Kulturflächen mit offenem Baumbestand mit 2,98 % und Gewässern mit 1,5 % auf. Gerastet wurde vor allem in Kulturflächen und laubwerfendes Buschland mit vereinzelten Bäumen, während des Zuges hielten die Schreiadler sich hingegen vor allem im Laubwald auf.

Ein Vergleich mit zufallsverteilten Daten (Tabelle 1) zeigte eine Präferenz für Kulturflächen und laubwerfende Buschland mit vereinzelten Bäumen während der Rast (Mann-Whitney U Test, $p < 0,001$). Während des Zuges wurden die Habitate Laubwald und ebenfalls laubwerfende Buschland mit vereinzelten Bäumen preferiert (Man-Whitney U Test, $p < 0,05$).

Ein Verschnitt der Telemetriedaten mit dekadischen NDVI-Karten lieferte Hinweise auf den Einfluss der Vegetationsdichte auf das Rastverhalten. Dies zeigte insbesondere ein Vergleich des mittleren NDVI bei Schreiadler-Rastdaten mit zufallsverteilten Daten. Daraus lässt sich schließen, dass die Schreiadler bevorzugt Regionen aufsuchen, in denen es zuvor geregnet hat. Die üppigere Vegetation bietet den Schreiadlern wahrscheinlich mehr Nahrungsressourcen (Insekten, Amphibien). Diese Studie fungiert dabei als Pilotprojekt und soll dazu ermuntern, weitere, bereits erhobene

Telemetriedaten auf diese Weise auszuwerten. Hierbei sind insbesondere neuere GPS-Daten von Interesse (Meyburg et al. 2006), da hier die aufwendige Datenvalidierung entfällt und die Positionen ohne weitere Bearbeitung übernommen werden können.

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